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Towards Smart User Models for Open Environments

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1 Introduction

Information Technology in recent years has moved rapidly from single use, centralized systems to distributed, multi purpose systems which are now increasingly embedded in a fully interconnected world. Advances in both development and deployment are being made through machine readable content (Semantic Web), massively parallel distributed computing (GRID computing), novel system-to-system interaction models (Peer-to-Peer computing), dynamic discovery and description of web enabled software applications (Web Services), XML based business process infrastructures (rosettaNET, ebXML), web development environments (Microsoft .NET and Sun ONE) and powerful visualization tools (DigitalCities) **[Willmott, et al.; 2002]**

Advances in all of these areas are converging in the next generation of information systems in which the integration of computers and networks render a multitude of services and applications accessible through easy-to-use human interfaces (see **[IST-FP6; 2003-2004], [Castells, 2003]**). This vision of 'Ambient Intelligence' places the user, the individual, at the centre of future developments for an inclusive, knowledge-based society. In this context, personalised and adaptive human-system interfaces have become a key requirement in understanding user requirements **[Luck, et al.; 2003a]**, **[Murray; 2002]**. As G. Fischer says: *The challenge in an information-rich world is not only to make information available to people at any time, at any place, and in any form, but specifically to say the right thing at the right time in the right way*.

Personalisation of systems and services can be achieved through an internal system representation. In general, the two main ways of keeping information about users have been *user profiles* and *user modelling*. User profiles represent the information needs and preferences of the user. User modelling is a broader discipline, which is generally concerned with how information about users can be acquired by automated systems and with how that information can be used to improve system performance.

Our work is concerned with user modelling in open environments. On one hand, User Modelling has its roots in Philosophy and Artificial Intelligence. The initial research on user models appears in the field of natural-language dialog systems **[Kobsa and Wahlster; 1989]**. However, User Modelling has made more progress in non-natural language systems and interfaces. For example, it has been successful in various recommending systems. Other fields of interest include adaptive interfaces, information retrieval, intelligent tutoring, help and guidance systems, and expert systems **[Kobsa; 1993]**. On the other hand, Agent Technology is being provided useful for dealing with open environments. Advances in this research area are provided through the increment of workshops, conferences and journals along last years.

Our proposal then is the line of contributions to the advances on user modelling in open environments thanks so the Agent Technology, in what has been called *Smart User Model.* Our research contains a holistic study of User Modelling in several research areas related to users. We have developed a conceptualization of User Modelling by means of examples from a broad range of research areas with the aim of improving our understanding of user modelling and its role in the next generation of open and distributed service environments.

This report is organized as follow: In chapter 1 we introduce our motivation and objectives. Then in chapters 2, 3, 4 and 5 we provide the state-of-the-art on user modelling. In chapter 2, we give the main definitions of elements described in the report. In chapter 3, we present an historical perspective on user models. In chapter 4 we provide a review of user models from the perspective of different research areas, with special emphasis on the give-and-take relationship between Agent Technology and user modelling. In chapter 5, we describe the main challenges that, from our point of view, need to be tackled by researchers wanting to contribute to advances in user modelling. From the study of the state-of-the-art follows an exploratory work in chapter 6. We define a *SUM* and a methodology to deal with it. We also present some cases study in order to illustrate the methodology. Finally, we present the thesis proposal to continue the work, together with its corresponding work scheduling and temporalisation.

1.1 Motivation

The Agents Research Group, the group to which the author belongs, has a long research tradition in the development and analyzing of Artificial Intelligence techniques. The origin of the group is the application of Artificial Intelligence to control and supervision. In this direction, the group has participated in the Robocup from 1995, getting successful results in the development of physical agents. Such agents have specific properties provided that they have a body that interact with the environment and need to adapt their behaviour to the new circumstances they encounter.

The successful results obtained lead the group shift the particular properties of physical agents to personalised agents. In this new field, some interesting results have been obtained in learning mechanism **[Montaner, et al., 2002a]** and collaborative recommender agents **[Montaner, et al., 2002b]**.

However, new challenges arise. First of all, there was quite difficult, even not impossible, to re-use user models acquired from a domain to another one. For example, if it is learn that the user prefers comfortable restaurants, it is quite hard to take advantages of such information in order to recommend to the user comfortable cinemas.

Second, the influence that the context has in the user should be taken into account. The context is a multi-dimensional parameter that icludes time, place, weather and emotions. For example, a user can accept a different recommendation if today is Monday than if it is Friday (close to the weekend), if he/she is at the office or at home, if it raining or it is terrible hot, and if he/she feels good or bad.

Finally, we realise that most of the work performed on personalised agents are based on modelling user interactiveness without taken into account advances on other areas that has a traditional background on the study of user models.

All such challenges have posed to the research group a new perspective on the development of personal agents, addresing the research towards new directions on the development of *Smart User Models*.

1.2 Objectives

Our research focus in to the development of methodologies for non-intrusive Generic User Models, which take advantages of the existent applications to extrapolate its knowledge of the user to new unknown domain. In addition, the *Smart User Model* should be able to capture any type of explicit or implicit information of the user in several domains to aggregate in a incremental way more knowledge of the user preferences and interests. These requirements of the *Smart User Model* can be summarized as follows:

- The *Smart User Model* must be generic in order to be used it in several domains, in open environments as Internet.

- The *Smart User Model* does not have to be annoying for the user: it must do the minimum amount of questions to the user.

- The *Smart User Model* should be take advantages of known information about the user in existing applications.

- The *Smart User Model* must favor the user information flow from ane domain to another one.

- The *Smart User Model* should be context-aware, especially regarding the Human Factor.

To achieve such requirements the following specific objectives are provided:

1. To develop a methodologies to build a *Smart User Model* for open environments.

2. To allow the reusability of user models in different applications.

3. To train the user model through machine learning techniques, methods and strategies to allow the flexibility and adaptivity to the domains.

4. To exploit the portability of new technological platforms in order to allow to the dynamic adaptation of information to personal preferences

5. To integrate the emotional factors in the user models to build *Smart User Models*.

6. To allow to the portability of users' emotional sensitivity to several domains.

2 What is a user and what is a user model?

In this section we provide the main definitions of users and user models in order to contextualise the different disciplines that have emerged to model users.

2.1 User: Features and behaviours

A user can be defined as someone who is doing "real work" with the computer, i.e., using it as a means rather than an end. Any person, who uses a program or system, however skilfully, without getting into the internals of the program, is considered a user **[FOLDOC; 2003]**.

Other definitions of the *user* are also possible. Thus, the Organization for the Advancement of Structured Information Standards **[OASIS; 2002]** defines a user as a natural person who makes use of a system and its resources for any purpose. Users in the system represent real human beings working in the context of the system. According to the World Wide Web Consortium Recommendation **[W3C; 2002]** a user is an individual (or group of individuals acting as a single entity) on whose behalf a service is accessed and for which personal data exists. A user has a certain background, works or requires a service in a certain context and most importantly, a user has a *mission* to perform within that context in the system.

A user can be seen as a compound of different elements, which we can call features and behaviours. Features are the peculiarities and distinctive aspects that differentiate one user from another. Behaviours are the actions or reactions of the user in response to external or internal stimuli. Both features and behaviours can be analyzed in different dimensions:

a. *Features: relating to experience, background, attitudes and capabilities*. **Experience** is the apprehension of an object, thought, or emotion through the senses or mind. It is the accumulation of knowledge or skill that results from direct participation in events or activities. The effect upon the judgement or feelings produced by any event, whether witnessed or participated in.[1] **Background** relates the demographic data that includes recorded data (name, address, phone number, etc.), geographical data (area code, city, state, country), and user characteristics (age, sex, education, disposable income, etc.). **Attitudes** are states of mind or feelings. They can be interpreted as disposition toward something or someone. **Capabilities** indicate the user skills and effectiveness in doing something. When a user has an advanced degree of competence, as in an art, vocation, profession, or branch of learning, it is said, that he/she is proficient.

b. *Behaviours:*

- *Behaviours relating to knowledge, beliefs, desires, intentions, goals, plans*. Assumptions about users' **knowledge** (or more generally, beliefs) concerning concepts, the relationships between concepts, facts and rules with regard to the domain of the application system have always been among the most important sources for personalisation **[Kobsa, et al.; 2001a]**. **Beliefs** correspond to the information that the user has about the world. They are the local knowledge base. **Desires** represent states of affairs that the user would (in an ideal world) wish to be brought about. Desires answer the question: What does the user want? **Intentions** represent desires that the user is *committed* to achieving; it is a course of action that the user intends to follow. Personal **goals** are what the user hopes to achieve by performing a particular activity (see **[Bandura; 1986]**). Personal goals serve as the mother of behaviour: they "organize, guide, and sustain" the individual's activity. **Plans** are the sequence of actions required to achieve an objective.

- Behaviours relating to preferences, interests. **Preferences** refer to psychographic data (e.g., data which describes lifestyle), customer qualifying data (frequency of product/service usage, etc.), registration for information offers, participation in prize draws, etc. In a general way, preferences are a group of options *controlled* by the user to satisfy their

[1] The American Heritage® Dictionary of the English Language, Fourth Edition

individual needs. **Interests** can be defined as a state of attraction and curiosity about someone or something. The main difference between preferences and interests is that the preferences are more conscious than the interests. An interest is the preliminary stage of a preference. The interest becomes a preference when it has been confirmed that there is a positive satisfaction of needs in the user.

- Behaviours relating to personality, traits. **Personality** relates to biological and psychological entities. **Traits** are particular features that describe the personality and the character of a user. For instance, a sense of humour and arrogance are two examples of traits.

- Behaviours relating to emotions, expectations, moods. **Emotions** are fundamental elements of human beings. They involve biological and cognitive phenomena. At the cognitive level, mood and personality are the most important. **Expectation** is the feeling that an action is about to happen. **Moods** are affective states, characterized by the fact that they are typically global and highly variable over time.

It is plain to see that there are many dimensions to users; this has led to the development of several disciplines.

2.2 What is a user model?

Models are representations of knowledge about the real world. A model is the first step in developing theories that produce deductions, explanations, predictive capabilities and behaviours. Consistently, a user model can be defined as a basic description and encapsulation of user characteristics, based on a complex network of associations, knowledge, and understanding that defines who the user is and what the user knows.

However, in the same way as there is no unique definition of a user, as we noted above, neither is there a unique definition of user model. There follows several definitions deriving from different disciplines:

- Natural Language

  Elaine Rich produced a pioneering approach to user models with her system called GRUNDY **[Rich; 1989]**. Her idea of user model was based on the idea of *stereotypes: sets of characteristics shared by many users.* J. Kay provides an alternative definition: *The user model is a set of beliefs about the user* **[Kay; 1995]**.
- Human-Computer Interaction

  According to the handbook of User Interfaces, *user models are representations of the user which are maintained by the system*. **[Benyon; 1993]**. Alternatively, Fischer defines u*ser models as models that systems have of users that reside inside a computational environment.* **[Fischer; 2000]**. Another interesting definition is the one provided by Kobsa: *User Models are collections of information and assumptions about individual users (as well as user groups), which are needed in the adaptation process of systems to individual actions of users* **[Kobsa; 1995]**.
- Recommendation Systems

  In recommender systems, the *user model keeps all the information needed to personalize the interactions with the user* **[Bueno, et al.; 2001]**.
- Adaptive Hypermedia

  In the User Model conference, *a User Model is an explicit representation of properties of individual users or user classes. It allows the system to adapt its performance to user needs and preferences* **[UM; 2003]**. Wahlster and Kobsa define *a user model as a knowledge source in natural-language dialog system which contains explicit assumptions on all aspects of the user that may be relevant for the behaviour of a system* **[Wahlster and Kobsa; 1986]**.

From these definitions, we identify the following key points:

1. The information about the user that should be kept in a user model is: beliefs, stereotypes, characteristics.
2. A user model is not static but should be updated according to user features.
3. There should be a system in charge of creating and maintaining a user model.

4. User models allow personalisation of the system.

We think that the following definition captures all these key points in a single sentence:

> *A User Model is the knowledge of a real user contained in a system which uses it to improve its interaction with that user.*

So if a user can have several features and beliefs according to the dimensions analysed in section 2.1, the user model tries to represent partially those features and beliefs. It may contain the representation of abilities, experiences, motivations, goals, assumptions about the user's knowledge, background, plans, tasks and individual traits that the system can maintain adaptively. Moreover, the user model includes the historical preferences of the user, with which his/her interests are defined in the different contexts in which they have been manifested.

2.3 Differences between a user model and a user profile

At this point, we think it will be of interest to distinguish between the concepts of user model and user profile.

Some authors understand the term *user profile* to mean all the information about a user, extracted from the information collected when he/she logs on to a web site or other system, in order to take into account his or her needs, wishes and interests. Roughly, a user profile is a structured and static representation of the user's needs, through which a retrieval system should act upon one or more goals based on that profile in order to autonomously pursue the goals posed by the user **[Amato and Straccia; 1999]**.

According to research carried out in British Telecom by Crabtree, Soltysiak and Thint **[Crabtree, et al.; 1998]** we can construct user profiles by general questionnaires, ratings of representative sample data and detailed and lengthy surveys. For instance, *Cupcakes* **[i33; 2003]**, introduced by the i33 Technology Corporation, offered the ability to customise content, sales offers and advertising messages for each user based on his/her "Cupcake", an editable profile that resides on his/her computer.

User Profiling is a business concept from marketing and credit risk assessment **[Bothé, et al.; 2000]** with the aim of building *databases* that contain the preferences, activities and characteristics of clients and customers. It is a term for many techniques that group people together and assign a label to them. Grouping is often on the basis of basic social-economic data, e.g. gender, age, income, education, zip code. It is a practice that has long been part of the commercial sector, but which has developed significantly with the growth of e-commerce and the Internet. It is quite common for the profiling databases to hold references to millions of web clients. The goal of profiling is to have the most complete mapping of the consumer.

User modelling can be defined as the ***effort*** involved in creating a profile of the user's interests and habits. User Modelling systems differ to User Profile in the way they acquire, use and represent a profile, that is to say, it is dynamic.

Building a user model involves defining the "who", i.e., the degree of specialisation in defining who is modelled, and what the user history is; the "what", i.e., the goals, plans, attitudes, capabilities, knowledge, and beliefs of the user; the "how", i.e. in what way the model is to be acquired and maintained; and the "why", including when to elicit information from the user, to give assistance to the user, to provide feedback to the user, or to interpret user behaviour.

A user model must contain other additional properties **[Fink and Kobsa; 2002]** that differentiate it from a user profile. User models must be able to:

- learn the interests and preferences of users based on their usage of the application.
- predict interests and preferences of individual users based on those of similar users, and on assumptions about homogeneous user subgroups (so-called "stereotypes").
- infer additional interests and preferences using domain knowledge.
- store, update and delete explicitly provided information and implicitly acquired assumptions.

- care for the consistency and privacy of the user model contents.
- supply authorised applications with current information about the user.
- support long-term user modelling - which implies that the lifetime of individual user models in an application must extend beyond a single user session.
- take into account security and privacy and related technical implications.

In short, user profiling is a particular case of user modelling. User profiling is driven to exploit the user model in a specific domain, sometimes independently of the objectives of the user. It is application-centred. In contrast, user modelling is user-centred and uses the objectives of the user to adapt the application.

2.4 Benefits of user modelling

Because human beings have different knowledge, preferences and goals, there are many situations where individualised treatment of the user, based on information in the user model, should offer advantages. Among them, it is possible to distinguish the following:

a) Improving the interpretation of user actions and understanding the user better.
b) Anticipating behaviour and user actions. **[IntelliOne; 2002]**
c) Adapting the interface presented to the user.
d) Improving the actions of a system that operates on behalf of the user.
e) Steering the adaptation of intelligent adaptive systems to the behaviour of individual users.
f) Improving the accuracy of intelligent adaptive systems.
g) Enabling user variability to be measured.
h) Helping to collect details of past interactions with the system and to make inferences on a variety of parameters, such as learning style, knowledge acquisition, expertise and preferences.
i) Identifying user variations over time.
j) Increasing the speed of the execution of tasks and reducing lost time.
k) Presenting suitable information.
l) Recommending products or services.

m) Supporting collaboration between users.

[Kass and Finin; 1988] summarise all these advantages as follows:

1. Supporting the task (i.e. plans and goals) of recognising and interpreting the information seeking behaviour of a user.
2. Providing the user with tailored help and advice.
3. Eliciting information, getting input, and resolving ambiguity.
4. Providing output.

[Kobsa; 1990a] recognises the following properties in user modelling:

- Taking into account the user's behaviour to deliver additional relevant information.
- Recognising the degree of expertise of the user in particular situations.
- Discovering wrong beliefs and misconceptions of the user and informing the user about them.

Another approach is taken by **[Sparck Jones; 1990]**, who lists the following benefits of employing a user model:

- **Effectiveness**. The prime object of the user model is that the system reaches the correct decision. A correct user model is thought to help the system achieve this.
- **Efficiency**. A user model can also serve to reach the correct decision in an economical way.
- **Acceptability**. The system may use a user model to support its decision-making in a comprehensible and agreeable way.

The benefits of User Modelling have been demonstrated through applications in businesses, such as live help systems for e-commerce web sites. There are several potential benefits of user modelling in this context:

a) Human assistants can use the personal information in the user models to provide the users with efficient support tailored to their personal needs.
b) Assistants can be more comfortable in their supporting role.

c) Consultation resources can be saved, and thus, financial savings can be made for the e-commerce company.

In general, user models can help to improve performance. Usually the computational complexity in systems is huge and real-time responses are required in most cases. If the system knows the user well in advance, it only has to search the data concerning the user's interest rather than the whole repository. This will improve both accuracy and efficiency.

2.5 Techniques and methods for building user models

There are three main ways of classifying the techniques applied in building user models, according to different criteria:

1. Manual vs. Automatic
2. Knowledge-based vs. Behaviour-based
3. Explicit-based vs. Implicit-based

Manual vs. Automatic is probably the most traditional classification. Two main schools are identified in **[Brown, et al.; 1997a]**. The first uses "hand-coded" user models, which are typically static. Once they are designed, they not change. The second method uses "machine-coded" user models, which are dynamic, that is, the structure changes over time.

The *Knowledge-based vs. Behaviour-based* classification emphasises the kind of features kept in the user model. Knowledge-based approaches engineer static models of users and dynamically match users to the closest model. Behaviour-based approaches use the users' behaviour itself as a model, often using machine-learning techniques to discover useful patterns of behaviour.

Finally, the *Explicit-based vs. Implicit-based* classification is concerned with "explicit" user models which are "constructed explicitly by the user" and "implicit" user models which are "abstracted by the system on the basis of the user's behaviour" **[Rich; 1979]**. Explicit user modelling techniques use survey, dialog and other methods to obtain the user knowledge directly (User-programmed). That is, the system designer determines how to model the users **[Bothé, et al.; 2000]**, **[Jameson, et al; 1997]** in the following ways:

- By user interviews and questionnaires.
- By “knowledge engineers" using user stereotypes.
- Rule-based profiles, where the users specify their own rules in the profile, rules that control the behaviour of the model.

Implicit user modelling techniques are based on observing the user’s behaviour or inferring user information from domain knowledge or other user information. That is, a user model is constructed by the system as it “learns” more about the user. Machine learning techniques, such as induction and classification, where the modeller tries to identify certain patterns in the user's behaviour, are typical techniques for this purpose. Here the user actions are observed in order to try to make sense of them.

3 Historical Perspective

History plays a fundamental role in education and research. A neophyte who is under the impression that the state of knowledge is unchanging is often surprised to learn of significant gaps in knowledge, as well as continuous modifications being made to what appears to be definitive knowledge. An historical perspective makes all this clear **[Bernstein and Bushnell, 2002]**. This is what we attempt to provide in this section: we include a short historical review of user modelling, in which we have distinguished three main stages of development: the early stages (up to 1990), the academic stage (early1990s) and a commercial stage (late1990s to the present day).

3.1 Early stages

According to **[Kobsa; 2001a]** user modelling is usually traced back to the works of Allen, Cohen and Perrault in 1978 and 1979 and Elaine Rich in 1979. For a ten-year period following this seminal research, numerous application systems were developed that collected different types of information about, and exhibited different kinds of adaptations to, their current users. In this early work, the user modelling was performed by application system, and often no clear distinction could be made between system purposes components that served user modelling and components that performed other tasks. From the mid-eighties onwards, such a separation was increasingly made, but no efforts are reported on rendering the user modelling component reusable for the development of future user adaptive systems.

[Kobsa; 1990b] seems to be the first author who used the term *"User Modelling Shell System"* for such kinds of software tools, in which both system and user purposes were supported. The term "shell system", or "shell" for short, was thereby borrowed from the field of Expert Systems. The first advances in this type of user models were made in the medical expert system MYCIN **[Shortliffe, 1976]**. The shell systems predominated in the seventies and early eighties. Towards the mid-eighties the developers began to generate simple stereotype hierarchies based on rules and facts in user-adaptive applications.

3.2 Academic stage: user modelling shells

After the first experiences in the early stage, towards the early nineties, there was initially a great deal of effort put into building user modelling shell systems incorporating the basic structures needed to develop user-adaptive applications systems. This work was exploratory and based on the experiences of the researchers and developers in this field.

Several requirements at this stage were considered by **[Kobsa; 2001b]** and are summarised as follows:

***a*) Generality, including domain independence**

Domain independence requires a degree of generality so shell systems could be used in multiple and multi-purpose tasks. The main application field was student-adaptive tutoring systems. The application of these shell systems outside the educational domain was not successful.

***b*) Expressiveness**

This capability, expected from the shell systems, required not only that these were able to serve as a means for expressing hypothesis about the users, but also its self-reflexive assumptions incorporating uncertainty.

***c*) Strong Inferential Capabilities**

The user modelling shell systems required many techniques of Artificial Intelligence and formal logic for reasoning; for example, reasoning in a first-order predicate logic, reasoning with uncertainty, plausible reasoning and conflicts resolution. The reason for this is to do with their application in domains such as natural-language dialog and intelligent tutoring systems, where the complexity of the tasks and assumptions about the users were necessary.

Towards the middle of the nineties, the application shift from the user-adaptive system to other domains such as learning environments and personalised hypermedia, created a need for other kinds of techniques for reasoning (see **[Kobsa, et al.; 2001b]).**

3.2.1 Example systems

Some of the most important shell systems developed during the academic stage are shown in Table 1. Following, in chronological order, there is a brief description of each of them.

Cascade [VanLehn; 1993]

Cascade is a model of cognitive skill acquisition. This is generally used to account for the psychological results of the self-explanation effect. Several investigations have shown that in the acquisition of sophisticated skills, such as physics problem solving, or Lisp coding, students who explain examples to themselves show improved learning and use analogies more efficiently in their problem solving. *Cascade* enables us to reproduce the self-explanation effect in its learning mechanisms.

UMT [Brajnik and Tasso; 1994]

UMT allows the user model developer the definition of hierarchically ordered user stereotypes, and of rules for user model inferences as well as contradiction detection. Information about the user that is received from the application can be classified as invariable premises or (later still, retractable) assumptions. After the firing of all applicable inference rules and the activation of all applicable stereotypes, contradictions between assumptions are sought and various resolution strategies applied (`truth maintenance').

BGP-MS [Kobsa and Pohl; 1995]

BGP-MS (Belief, Goal and Plan Maintenance System) allows assumptions about the user and stereotypical assumptions about user groups to be represented in a first-order predicate logic. A subset of these assumptions is stored in a terminological logic. Inferences across different assumption types (i.e., types of modals) could be defined in a first-order modal logic. The system can be used as a network server with multi-user and multi-application capabilities.

DOPPELGÄNGER [Orwant; 1995]

This is also a user modelling server that accepts information about the user from hardware and software sensors. Techniques for generalising and extrapolating data from the sensors (such as beta distributions, linear prediction, Markov models, and unsupervised clustering for stereotype formation) are put at the disposal of user model developers. The users can inspect and edit their user models.

TAGUS [Paiva and Self; 1995]

TAGUS represents assumptions about the user in first-order formulas, with meta-operators expressing the assumption types. The system allows for the definition of a stereotype hierarchy and contains an inference mechanism, a truth maintenance system, and a diagnostic subsystem that includes a library of misconceptions. It also supports the simulation of the user through forward-directed inferences on the basis of the user model, and the diagnosis of unexpected user behaviour.

UM [Kay; 1995]

From the point of view of the application system, UM was more a library of user modelling functions than an independent user modelling component. It therefore is not a user modelling shell in the strict sense. Rather, it is a toolkit for user modelling that represents assumptions about the user's knowledge, beliefs, preferences and other user characteristics in attribute-value pairs. Each piece of information is accompanied by a list of evidence for its truth and its falsehood. The source of each piece of evidence, the kind of evidence it is (observation, stereotype activation, rule invocation, user input, told to the user) and a time stamp are also recorded.

OLAE [Martin and VanLehn; 1995a] [Martin and VanLehn; 1995b]

OLAE (Online Assessment of Expertise) is a tool to help assessors determine what a student knows, as compared to most student assessments that determine how much a student knows. This tool is being used in introductory college physics. It uses Bayesian nets to observe student behaviour and compute the probabilities that the student knows and uses each of the rules in a given knowledge domain.

The student model (i.e. user module) consists of a rule-based program that reflects the way the student computes answers to actual problems, both correctly and incorrectly. Bayesian networks are used to address the uncertainty of the rules. This uncertainty is produced by such situations as typing errors or a student guessing the solution to a problem and getting it correct.

ATS [Gürer, et al.; 1995]

The Adaptive Training System (ATS) uses the ML-Modeller as its student modelling component. The purpose of the ATS is to represent a student's knowledge state and the transition to an expert state, and thereby provide specialised tutoring adapted to the student's learning style. By using machine-learning techniques to emulate the novice to expert transition, the system dynamically models the student's learning progress.

POLA [Conati and VanLehn; 1996]

POLA (Probabilistic Online Assessment) is also used with introductory physics. It is a student modelling framework that carries out a probabilistic online assessment of student problem solving. OLAE uses knowledge tracing in its student modelling. POLA is able to turn this tracing into a system of probabilistic reasoning, which generates predictions about the solution the student is following. The end result of this is an assessment of the student's mastery of the knowledge involved in the solution.

Interbook [Brusilovsky; 1999]; [Brusilovsky and Schwarz; 1997]

Interbook has been designed to work upon a WWW application. It traces what the users have seen, rather than what they have done, and learns information about the user from the traces.

This analysis covers the more representative shell systems at this stage; however this classification is not extensive; it is a sample of the evolution of shell systems towards the more complex user models developed in the next stage of this historical perspective: the commercial stage.

Table 1. User models of the Academic Stage

System Name [Author, year]	*Techniques*	*Applications /Domain*
Cascade [VanLehn, K., 1993]	Inference rules	Intelligent Tutoring Systems/ Cognitive skill acquisition.
UMT [Brajnik and Tasso, 1994]	Stereotypes / inference rules	Natural-Language Interface /Tourist advisor
BGP-MS [Kobsa and Pohl, 1995]	Stereotypes/ Implicit inference rules as first-order modal logic.	Natural Language System/ Dietary advice in pregnancy; ergonomic kitchen layout; simulation of citizen action committees and hypertext.
DOPPELGÄNGER [Orwant, 1995]	Linear predictions, Markov models, Unsupervised clustering, sensors collecting information about the user	Personalised Newspaper
TAGUS [Paiva and Self, 1995]	Inference methods, simulated reasoning / Stereotypes	Learning Modelling
UM [Kay, 1995]	Stereotypes, rule-base of constraints, inference rules (Hybrids)	Natural-Language Dialog System / Hypermedia newspaper / Coaching system/ Movie advisor
OLAE [Martin, J. and VanLehn, K.;1995]	Bayesian Networks	Student Modelling
ATS [Gürer, D., et al. 1995]	Case-based reasoning/ Fuzzy methods	Student Modelling /
POLA [Cristina Conati and Kurt VanLehn, 1996]	Bayesian networks	Student Modelling / Solving problem in physics
Interbook [Brusilovsky, P., and Schwarz, E., 1997]; [Brusilovsky, P., 1999]	Annotation-based Adaptive Navigation Support	Student Modelling/ Adaptive Hypertext and Hypermedia

3.3 Commercial stage: stand-alone user models

Until this stage, the user modelling shell systems were embedded in applications. At this new stage, user modelling systems are not functionally integrated (embedded) into the application but communicate with the application through inter-process communication and can serve more than one user/client application at the same time. They are called generic user models and we would describe them as stand-alone user models. Generic User Modelling systems, in to some degree, opened the commercial stage on user models.

According **[Fink and Kobsa; 2000a]** the main feature that differentiates the most current commercial systems from user modelling shell systems is their client-server (centralised) architecture.

Some of the advantages provided by this architecture in comparison with embedded user modelling components are:

- Centralised information about the user: Maintained in a repository that can be accessed by several applications simultaneously.
- Reciprocity in the utilisation of the user information: two applications can acquire and use information about the user reciprocally.
- Reduction of redundancy of user information: consistency is achieved more easily.
- Accuracy in the information about user groups, for example, stereotypes and user group models can be maintained with low redundancy.
- Techniques and security policies for protecting user modelling servers can be more practical in terms of identification, authentication, access control and encryption.
- Additional and relevant information about the users can be integrated more easily in the user model repository, for instance, transactional histories, demographic data, qualification of risk credit, etc.

Despite these advantages, there are some potential weaknesses that must also be considered, such as the availability of networks and bandwidth for transmission of large amounts of data. These limitations have a negative affect on the performance of the applications that have to consult the user modelling database.

Commercial user modelling servers include some additional services that were unavailable in academic user modelling shell systems. Examples of such new user modelling services include:

- **Examining similarities and differences between users.** The applications incorporated techniques to measure the degree of similarity in particular domains in which such hazy concepts as users' tastes, lifestyles and personality were more difficult to predict with isolated techniques. (See **[Breese et al., 1998a]**, **[Herlocker et al., 1999a]**).
- **Connectivity between different databases systems.** External information related with the user is mandatory in enterprise applications. Open database connectivity is necessary in these kinds of user modelling systems.
- **Privacy and security policies incorporated.** Users must be informed of the basic elements gathered by the system so that they can put more trust in commercial user modelling systems. Some of these elements are: what information is collected by the system; how the system uses the information and for what purpose; how the system secures, shares, rents, sells and in general, disseminates the information; and finally, how much personal information about a user can be stored, grouped and commercially collected. It is important to emphasise that privacy involves not only the confidentiality of personal data, but also that behaviour remains private.
- **Relatively quick adaptation.** This capability is considered one of the most important in achieving user acceptance when he/she interacts with the application. Satisfactory interaction depends on it and leads to user loyalty.
- **Robust extensibility in the acquisition methods.** At present, some enterprises require combined methods for acquisition and personalisation of user information, by means of application program interfaces (APIs).
- **Load Distribution of processes and communications.** Balancing the load distribution is especially important for applications in networks where it is difficult

to predict the number of requests that will be issued to a user modelling server system.

- **Failure tolerance strategies.** Centralised architectures need to provide substitute mechanisms in case of a breakdown.
- **Transactional Consistency.** Parallel read/write on the user model and abnormal process termination can lead to inconsistencies that must be avoided by carefully selected transaction management strategies.

A list of systems belonging to this stage, together with a short description is provided below.

3.3.1 Example systems

Electronic commerce promoted increasing personalisation of the web towards the end of the 1990s and so the systems corresponding to this stage emphasise the role of user models for personalisation. Web personalisation technology actively tailors content to each individual visitor, making the online experience efficient and satisfying. From a more general perspective, personalisation allows the relationship with customers on the Internet to go from anonymous mass marketing and sales to 'one-to-one' marketing **[Peppers and Rogers; 1993]**. User models were mainly used, then, to capture customer interests.

The main user model tool systems for web personalisation at present are shown in Table 2, and described below.

AVANTI [Fink, et al.; 1996], [Fink, et al.; 1997]

AVANTI is a hypermedia information system for a metropolitan area (e.g. public services, transportation, buildings) for a variety of users with different needs (e.g., tourists, residents, elderly people, blind persons, wheelchair-bound people and users with slight forms of dystrophy). It uses an initial interview to create the initial primary assumptions (i.e., user profile), draws inferences to generate additional assumptions, and uses stereotypes for certain subgroups of users (e.g. tourists, blind users). It then customises the web pages presented to the user. For example, wheelchair users are presented with information about access facilities when viewing relevant web pages.

P-TIMS [Strachan, et al.; 1997]

A commercial financial management system which was updated with an adaptive and adaptable interface using a simple user model and rule set. As the user spends more time using the system and uses more complex functions, the system reveals a more extensive interface. The user model is explicitly exposed by providing a "preferences" dialog box, which the user can adjust at any time. Empirical evaluation showed that it improved a subjective measure of user satisfaction.

ORIMUHS [Encarnação; 1997]

ORIMUHS is an adaptive hypermedia help system that supports context-sensitive and user-adaptive presentation of hypermedia help, providing user-controlled help adaptation and agent-based retrieval of additional information. It incorporates a sophisticated user model with stereotypes (levels of expertise), as well as agent-based retrieval of help information. ORIMUHS has been implemented in medical imaging and CAD systems.

Lumière [Horvitz, et al.; 1998]

Uses a Bayesian user model to infer a user's needs based on the user's background, actions and queries. Lumière prototypes served as the basis for the *Office Assistant* (a.k.a. Clippy) in Microsoft Office '97, which provides guidance and tips to the user.

Group Lens [Breese et al., 1998]

Net Perceptions[2], employs various collaborative filtering algorithms **[Breese et al., 1998b]**, **[Herlocker et al., 1999b]** for predicting users' interests. Predictions are based on ratings explicitly provided by users (e.g., in on-line forms), implicit ratings derived from navigational data (e.g., products that the online customer viewed and products that have been put into the shopping cart), and data from transaction history (e.g., products purchased in the past).

[2] http://www.netperceptions.com/

HyperAudio [Petrelli, et al.; 1999]

HyperAudio is an adaptive and portable electronic guide for museum visitors. As users walk through the museum, their physical location is used to implicitly navigate a virtual network of exhibit information. Audio, text and graphic information is then presented on the palmtop computer. Users are initially categorised (stereotyped) by attributes entered by an attendant at the start of the visit. It forms the basis of a larger project that explores the combination of physical and virtual spaces **[Specht and Oppermann; 1999]**.

LikeMinds™

Andromedia, is similar to GroupLens. The main differences include a more modular architecture, better load distribution, ODBC support, and slightly different input types (namely purchase data, navigational data, explicitly stated user preferences and pre-defined product similarities).

Personalization Server™

ATG[3] allows rules to be designed that assign individual users to one or more user groups based on their demographic data (e.g., gender and age), information about the user's system usage and information about the user's software, hardware and network environments. Rules can also be defined for inferring individual assumptions about the user from his or her navigation behaviour and for personalising the content of web pages. Personalization Server operations are therefore in line with the 'stereotype approach' from classical user modelling research (Rich, 1979b; 1989).

Learn Sesame [Bowne; 2003]

Allows for the definition of a domain model consisting of objects, object attributes, and event types. It accepts information about the user from an application, categorises this information based on the domain model and tries to detect recurrent patterns, correlations and similarities through incremental clustering. It uses a post-neural algorithm to generate user profiles from the clickstream data. Interesting observations are then reported back to the application.

[3] Art Technology Group, ATG Dynamo Personalization Server. http://www.atg.com/

Frontmind™

Manna[4] provides a rule-based development, management and simulation environment for personalised information and personalised services on the web. It is different from other rule-based products like Personalization Server in that it uses Bayesian networks for modelling user behaviour integrated into its personalisation framework.

Personis [Kay, et al.; 2002]

Personis is a user model server developed in an adaptive hypertext system using an application of personalised Jazz music. The goal of the Personis project is to explore ways to support powerful and flexible user modelling and at the same time to design it, from its foundations, so that it can support user scrutiny and control **[Kay; 2000]**.

Other recent commercial user modelling systems are discussed in **[Fink and Kobsa; 2000b]**. In addition, there exist a number of comprehensive commercial e-commerce environments and corporate applications with built-in, user-modelling components which cannot, however, be separated from the rest of the system (e.g., in BroadVision One-To-One Enterprise **[BroadVision; 2003]**).

[4] Manna, Inc. is a company focussed on the Internet Relationship Management market for online business. http://portfolio.isaka.net/manna/

Table 2. User models from the Commercial Stage

System Name [Author, year]	*Techniques*	*Applications /Domain*
AVANTI [Fink, J., Kobsa, A., and Nill, A., 1996]· [Fink, Joseph, Alfred Kobsa, and Andreas Nill, 1997]	Initial interviews and stereotypes	Hypermedia information system/ Metropolitan area information system in a city
P-TIMS [Strachan, L., et al., 1997]	Stereotypes	/ Commercial financial management system
ORIMUHS [Encarnação, L. Miguel, 1997]	Stereotypes and agent-based information retrieval	Adaptive Hypermedia Help System/Medical imaging and CAD systems
Lumière [Horvitz, Eric., et al., 1998]	Bayesian Networks	Guidance assistant
Group Lens [Breese, et al., 1998]	Collaborative Filtering/ Explicit and Implicit rating (navigation data)	Recommender System; One-to-One Marketing; Multi-Channel sales / Movies, Music; Industrial Markets
HyperAudio [Petrelli, D., 1999]	Stereotypes	Adaptive electronic guide/ tourism
LikeMinds™ [Andromedia]	Collaborative Filtering, explicit preferences	e-marketing/
Personalization Server [ATG]	Stereotypes and demographic data/ Rule-based	On line marketing and sales/Financial services, manufacturing, government, media, entertainment and retail,
Learn Sesame [Bowne Internet Solutions, 2000]	Clustering algorithms/ Click Stream data	Recommender system; Personalisation of web content and User Interface for each visitor / Entertainment
Frontmind™ [Manna, 1997]	Bayesian networks/ Rule-based	Internet Relationship Management / e-Commerce; marketing; education; retail; tourism.
Personis [Kay, J., et al., 2002]	Internal inferences, hybrid.	/Entertainment Jazz Music
BroadVision One-to-One Enterprise [BroadVision, 2003]	Rule-based	One-to-One Marketing/ Personalisation

3.4 Conclusions

This historical perspective has attempted to show how attempts to model users who interact with information systems have developed. The first stage consisted of shell systems which tried to capture the user features, followed by stand-alone systems which tried to provide information about the user. Now, as the computing landscape shifts from the individual stand-alone computer systems to a networking system, where distributed, open and dynamic systems interact, new computer models and, therefore, new approaches for building user models, are required. We will see in the following section how Agent Technology is playing an important role in this new generation of user models.

4 User models: an agent technology perspective

Agents are important elements of research into Distributed Artificial Intelligence (D.A.I.). According to **[Weiss, 1999],** Distributed Artificial Intelligence is *“the study, construction, and application of multiagent systems, that is, systems in which several interacting, intelligent agents pursue some set of goals or perform some set of tasks”*.

A software agent is defined by Wooldridge **[Wooldridge; 2002]** as: a computer system which is capable of *independent* action on behalf of its user or owner. Software Agents, sometimes called *softbots*, have been widely used in Internet applications. The important issue, then, is that agents represent the user and should therefore maintain information about them. Another interesting definition provided by IBM is the following: *"Intelligent agents are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals or desires”*.

The area of agents and multi-agent systems has grown and has become a promising technology in several application areas. There have been many novel methods, algorithms and theories formulated and investigated, that have made important contributions to classical software engineering and computer science; distributed systems and parallel computing; various fields of robotics; collaborative systems; internet services and technologies; grid computing; knowledge management; computer supported manufacturing; coalition formation and teamwork.

One of the technological agent challenges described in the roadmap of Agent Technology for the next decade **[Luck, et al. 2003b],** is to develop agent ability to understand user requirements. However, we will see throughout this study that agent technology is not so much concerned with how user models are built but rather with how they are used in various applications.

In fact, researchers in traditional areas of user modelling, with an awareness of the importance of agent technology in open environments, are already incorporating agent technology in their work.

This is the case of Adaptive Hypermedia, Educational Hypermedia, Human-Computer Interaction, Kansei Engineering, and others. The core of each discipline is to capture and represent the knowledge of the user. Each research area has contributed to some degree to user model understanding, as well as to developing different methods of acquiring, learning and adapting this understanding. We will now review the advances in each area, according to the classification provided by **[Brusilovsky; 2001a]** which we have updated and extended with additional fields. We emphasise the role of agents in each research area.

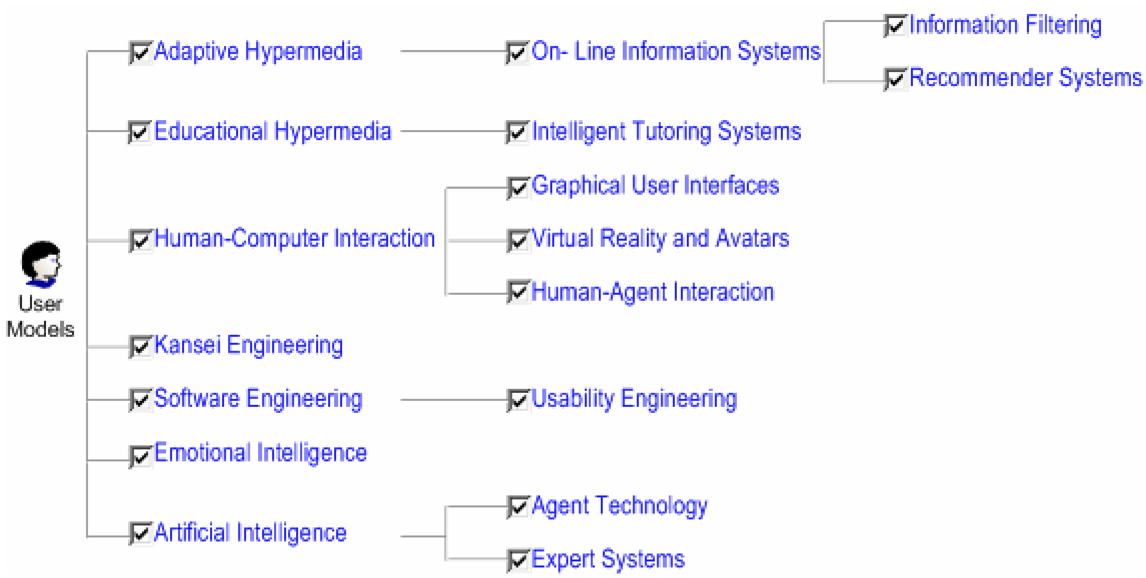


Figure 1.The incidence of Agent Technology in several research areas.

4.1 Adaptive Hypermedia

Adaptive hypermedia involves the research into understanding user traits using computer interfaces. It attempts to trace user knowledge and provide individual advice by creating an adaptive system with an interface management approach **[Brusilovsky; 2001b].**

Adaptive hypermedia systems make use of a user model to collect information about that user's knowledge, goals, experience, etc., in order to adapt the content and the navigational structure of hypertext. An example of these types of user models is the AHAM system described in **[Wu, et al.; 2001]**.

Kass and Finin in 1988 seem to be among the pioneers in using agents for user modelling in adaptive hypermedia. For them, a user model is as a subclass of agent model. An *agent model* is a model of any entity, regardless of its relation to the system doing the modelling; hence, a *user model* is the model of the user currently interacting with the system, and is eventually made up of more than one agent.

Kass and Finin provide the following classification of user models, from the agent perspective:

- **Specialisation**: The user model may be *generic* or *individual*. A typical model may act as a "bridge" between a generic and an individual model.
- **Modifiability**: If the user model is modified during the course of an interaction, it is *dynamic*. Otherwise, it is *static*. User models that track user goals and user plans are dynamic.
- **Temporal extent**: The dimension of temporal extent is defined on a short-term–long-term scale. At the extreme of short-term models, the user model is discarded as soon as the interaction ends. On the other hand, static models (as well as individual models) need to be long-term.
- **Method of use**: User models may be descriptive (i.e. described in a simple data base which can be queried), or prescriptive (where the system simulates the user to check the user's interpretation of the response).
- **Number of agents**: Some systems are not limited to a one-to-one relationship between user and system. There might be several agents involved in the interaction, such as in a medical diagnosis system where there is one doctor interacting with the system as well as one patient. Both the doctor and the patient may be modelled by separate agent models. The system could also have a model of itself.
- **Number of models**: For each given agent, it is possible to have several models. Separate models for an individual agent correspond to real-life situations where

humans can “wear different hats” depending on whether they are acting as a private person, or represent a company etc. Kass and Finin claim that there has to be a central model responsible for deciding which sub-model to employ in any given situation.

One particular case of Adaptive Hypermedia is the On-Line Information Systems, which aim is to help users in the tasks they need to carry out regarding Internet Services. Particular techniques of On-Line Information Systems are: Information Filtering and Recommender systems.

4.1.1 Information Filtering

Information filtering systems are designed to examine a stream of dynamically generated documents and display only those which are relevant to a user's interests. Recently, user modelling techniques have become more and more popular since they proved to be a useful means of user-centred information filtering and presentation.

[Maes; 1994a] was the pioneer in introducing agent technology in the field of information filtering. There are many examples of these intelligent agents, but we shall limit ourselves to explaining the more relevant ones concerned with user preferences and user behaviours. For instance, Maxims, **[Maes; 1994b]**, describes an electronic mail filtering agent. The agent determines, with some degree of certainty, the user’s typical priorities and activities in their e-mail application (delete, forward, sort, and archive mail messages) on behalf of the user. In addition, it makes suggestions to the user about what to do.

Maes also developed *Newt* **[Maes; 1994c]**, an intelligent agent that is trained by feedback of examples of a user’s preferences and interests to maintain a single user model in the news domain.

Later on **[Billsus, et al.; 2000]**, recognised that the problem of *information overload* could be solved by incorporating user models in the context of intelligent information agents. *“Agents locate and retrieve information with respect to users’ individual preferences. As* *intelligent information agents aim to automatically adapt to individual users, the development of appropriate user modelling techniques is of central importance".* For profiling and information purposes, these agent models are characterised by the following notions and potentials:

- A user's preferences are incorporated in one or multiple agents acting on behalf of the user as the actual information filter.

- Information can be acquired from a multitude of sources, either by direct inquiry on search engines, or by delegating a request for information to agents specialised in information retrieval.

- In more extended systems, ecologies of agents may be created: i.e., sets of user agents interacting with sets of information retrieval agents.

- Learning in such systems may be incorporated by machine learning algorithms, such as reinforcement learning **[Seo and Zhang, 2000]**, or by techniques such as evolutionary algorithms.

An example of a multi-agent system that filters and discovers information from user models is *Amalthea* **[Moukas and Maes; 1997a]**, **[Moukas and Zacharia, 1997]**. An example of ecologies of agents is **[Moukas; 1996]**; this system can subsequently enhance its effectiveness by using economic models for assigning credit to (un)successful operations, thus "learning" which interactions produce sufficient pay-off.

Finally, *Profile* **[Simons; 1997]**, a project of the Nijmegen University, deals with information filtering on a dynamic archive. Queries are refined and extended with respect to the user model and domain structure is represented in a hand-crafted *ontology*[5].

[5] A Ontology defines the terms and basic relations for the understanding of an area, as well as the rules for combining the terms employed in defining the extensions of the vocabulary [Neches, 1991]

4.1.2 Recommender Systems

The purpose of a Recommender System is to advise the user about some product or item. Recommender Systems are based on user profiles which are a part of a user model, as stated in section 2.3. In general, two main techniques are most often used: An item-to-item correlation and people-to-people correlations **[Schafer, et al.; 1999]**. For item-to-item correlation (also called content-to-content), an attempt is made to classify items based on their content or type of product and then recommend similar items to a customer. People-to-people correlations work on a principle similar to recommendations by word-of-mouth. The software creates profiles based on users' interests, and identifies groups of other individuals with similar profiles. It then makes its recommendations to individual users based on what other users, with similar profiles, have found interesting.

The main differences between Information Filtering and Recommender systems is that the latter are able to deal with

- Serendipity content: documents which users would not necessarily have found by themselves, but which has been searched for and/or viewed by similar users. This type of content enables the user to be among the 'first to know';
- Topical content: documents which are being viewed by lots of users right now. This type of content prevents users from being among 'the last to know';
- Relevant content: documents (or products) which have been rated most highly (or purchased) by other similar users.

User feedback allows the system to refine user profiles and allows groups of similar users to benefit from each other's experience, enabling the development of virtual communities.

Some of the most popular Recommender systems are the WebWatcher **[Joachims, et al.; 1997]**, Syskill & Webert **[Pazzani, et al.; 1996]**, Letizia **[Lieberman, 1995a]** and IRES **[Montaner, et al., 2003]**. Applied Psychology Research **[APR; 2002]** has developed software components that intelligently match items to items, items to people and people to people. Another approach in Recommender systems has been developed in VacationCoach

Inc.[6] by means of Me-Print™ Technology, in which recommendations are based on a user profile obtained by explicitly asking the user for information **[Ricci, 2002]**. TripMatcher™ is another innovative approach used by Orbitz, Eurovacations, Ski Europe, Luxelife, Travelot and Preferred Traveler. TripMatcher combines hybrid techniques such as content filtering, collaborative filtering and click stream analysis.

With regard to the use of agent technology in recommender systems, Proto-Agent™ collector[7] **[de la Rosa et al.; 2003]** is a noteworthy system. Put simply, it is a bare agent that contains the model of behaviour of a person in a specific subject of negotiation. This agent can obtain interactions of transactions via four different inputs: the historic (basic state of user model), the contextual information (by mean click stream and response to contextual offers to update the user model), the response to limited offers from a company (another update of the user model by mean click stream) and suggestions from other persons (again by mean click stream). Proto-Agent tries to model how a human behaves in contracting or obtaining goods and services. Its main function is to **filter any incoming information** and excitation (input) to the person, according to that person's individual and subjective tastes, which are contained in the model.

4.2 Educational Hypermedia

Educational Hypermedia concerns the systems that use Hypermedia for educational purposes. User modelling in this research area is focused on the learning abilities of the user regarding certain domain knowledge. In this sense, the term *student modelling* is used as an alternative to user model, and the systems that make use of such models are called *intelligent tutoring systems*.

Student modelling provides an intelligent tutoring system with the capability of individualising its interactions with a student. Student modelling, as a model of a learner, represents the computer system's belief about that learner's knowledge. It is generally used

[6] http://www.vacationcoachinc.com

[7] Proto-Agent™ is a prototype developed by Agents Inspired Technologies S.A., a spin-off company of the University of Girona. Spain. http://www.agentsinspired.com

in connection with applications in computer-based instructional systems. A student model is used to adapt the display characteristics of the interface to the needs of the learner.

One interesting system in this area and particularly in the field of Open Distance Learning is the project MAS-PLANG[8]. MAS-PLANG is a Multi-Agent System designed to transform the educational virtual environment, in an adaptive hypermedia system which takes different learning styles into consideration, utilizing an Index of Learning Styles (ILS) Questionnaire **[Soloman and Felder; 1993]**. The ILS is an instrument used to assess preferences in four dimensions (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) of a learning style model formulated by Richard M. Felder and Linda K. Silverman **[Felder and Silverman; 1988]**.

In the MAS-PLANG system, the adaptation techniques are addressed to the personalised selection of the didactic materials, the tools of navigation and the strategies of navigation of the educational environment according to the student's learning style. In the model of student Artificial Intelligence, techniques such as, Case-Base Reasoning and Fuzzy Logic have been used. The system is able to classify students according to their ability to process, to perceive, to receive, to organise and to understand the information. MAS-PLANG has been developed under the central concept of a known, intelligent agent which acts in representation and benefit of the student **[Aguilar, et al.; 2002]**. The student has been modelled by means of a tool for personalisation used in marketing campaigns **[Peña, et al.; 2002]**.

Other interesting tutoring systems are Web-EasyMath **[Tsiriga and Virvou; 2002]** and ELM-ART **[Weber and Specht; 1997]**. The former uses a student model which employs stereotypes, while the latter has been designed to teach LISP on the World Wide Web. It includes an educational LISP interactive interpreter, intelligent problem analysis, intelligent suggestion of examples and an episodic learner model.

[8] PLAN-G: Design and Implementation of a New Generation Telematics Platform to Support Open and Distance Learning.

4.3 Human-Computer Interaction

Human-Computer Interaction is focused on the design, evaluation, implementation and study of interactive computing systems that are easy, quick and productive for humans to use. Human-Computer Interaction is a wide discipline, in which user models play a different role depending on their application. In this sense, we have distinguished their use in the field of Graphical User Interfaces, Avatars and Human-Agent Interaction.

4.3.1 Graphical User Interfaces

Research on Graphical User Interfaces involves the interactions between users and computers or information systems using pictures, generally windowing systems that exploit the use of metaphors, icons, buttons, dialog boxes, etc. more than just words to represent the input and output of the system.

With the explosion of devices, computing platforms and contextual conditions, user interfaces need to become more adapted to multiple configurations of the context of use. In the past, many techniques were developed to perform a task analysis for obtaining a single user interface that was adapted to a single context. As this user interface may become unusable for another context of use, there emerges a need for modelling tasks which can be supported in multiple user contexts, which consider multiple combinations of the contextual conditions. Of course, the main contextual condition is the user who is interacting with the system and here the user models plays a central role.

More recently, research on collaborative interface agents has shown how an explicit task model can be used to control the behaviour of a software agent that helps a user to perform tasks using a GUI. One example, of such interface agents has been developed in the COLLAGEN project **[Eisenstein and Rich; 2002]**.

4.3.2 Virtual reality and avatars

In terms of user modelling, avatars are images that show believable gestures (laugh, preoccupation, confusion, surprise, etc) to the user, in an attempt to provide non-verbal communication. Avatars allow users to very quickly identify and change their subconscious conclusions, decisions, and/or agreements about those actions that are shaping their lives.

A first step towards the generation of believable characters in virtual environments was the *Oz project* at Carnegie Mellon University. This project combined technology with art to help artists create high quality interactive drama, based in part on Artificial Intelligence. Soon called agents, these characters integrated a set of intelligent agent capabilities such as goal-directed reactive behaviour, emotional state and behaviour, social knowledge and behaviour and certain natural language abilities in broad and shallow architectures **[Bates, et al.; 1991]**. In addition, these characters had built-in personality and emotion models. In two of the four components that made up the Oz project, the concept of user model is studied through a user interface and a planner concerned with the long term structure of users' experiences in the virtual world.

More recently, Krenn *et al* have applied the concepts of agents and user model in avatars, implementing Net Environments **[Krenn, et al.; 2002]**. They have built a multi-user application for internet where the users are represented by avatars which are situated in a virtual location. The user can design her/his avatar which then becomes autonomous after creation. Creating these avatars involves user modelling, with details of personality and emotions.

Similar works on social responses to avatars and virtual agents with differing levels of realism in virtual environments were studied within the EQUATOR project[9]. This involves not only designing and building physically believable, virtual humanoids, but also embodying them with behaviour traits to enable them to interact with other users in virtual environments **[Garau, et al.; 2003]**. Some of the conclusions from this project recommend continuing to work towards optimising users' experience in avatar-mediated communication with intelligent agents.

[9] The Equator project aims to develop innovative technologies, theories, methods and applications by focusing on the convergence of traditional and digital media and by bringing together people from Computing Science, Psychology, Sociology, Art and Design. http://www.equator.ac.uk/partners/index.htm

A particular use of avatars is found in the field of entertainment, in which laboratories and companies are developing new features for avatars. For instance, Massive Ltd. (a company which developed stand-alone software which was used in the movie "Lord of the Rings".

In the VIP-Advisor project **[Hernández and García, 2003]**, capabilities of natural language processing, speech recognition and on-line translation are developed in a intelligent virtual assistant with 3D avatars in a agent-based architecture.

Finally, Johnson and their colleagues **[Johnson et al.; 2000]** have compiled a broad, state-of-art in avatars applied in web-based learning. In their work, they include subfields called animated pedagogical agents or guidebots. For instance, the *Adele*[10] and *Steve*[11] guidebots are based on a user model of a learner which involves thoughts and emotions for improving empathy with the learner, as well as increasing his or her enthusiasm.

4.3.3 Human-Agent Interaction

Agents are computer systems and so they require functionalities and interfaces for managing dialogs with users. At higher level of operations, they support personalisation of human-agent interaction and other agent behaviours.

FIPA, an international organization for agents' standardisation, has a reference interface model. They propose generalizing user interface as a functionality called a UDMS (User Dialog Management Service) in the FIPA98 Specifications. A UDMS covers different types of software components involved in interaction with the user, such as, graphic user interfaces, natural language and speech recognizers, etc. Specifically, a UDMS provides two interfaces:

– User interface for the human user
– Agent interface: Agent Communication Language interface

[10] Agent for Distance Education - Light Edition.
[11] Soar Training Expert for Virtual Environments.

Agents can interact with users using a UDMS. It is a gateway between the human world and agent world. However, a UDMS defines boundaries of human interaction with agents, but provides no internal details.

One example of this interaction between humans and agents has been developed in *Conversive AnswerAgent*™.

4.4 Kansei Engineering

Kansei is a Japanese term having to do with the psychological image of a product. Sometimes known as "Sensory Engineering" or "Emotional Usability", it has been used in the design of software systems and various consumer products.

KANSEI Information Processing has been proposed as the third target of information technology, according to a classification proposed by Hashimoto **[Hashimoto, 1997]** (see Table 3). He considers that a system has to understand not only the user's intentions, but also other sensing ability. Therefore, Kansei Engineering seeks to correlate sensory perceptions, brainwave patterns and stimulus dimensions in order to optimize physiological and psychological environments and ultimately, tailor products directly to the preference of the consumer.

Table 3. Classification of Information Technology [Hashimoto, 1997]

Category	*Evaluation*	*Domains Examples*
Physical Signal Processing	Measurement	Sound, light, force
Semantic Symbol Processing (Language)	Recognition	Symbolic knowledge, logic
Emotional Information Processing (Kansei)	Appreciation	Feelings, intuition, sympathy.

Kansei Engineering is a technology that attempts to quantify cognition and product image in such a way as to influence the product development process (see Figure 2). The first step in Kansei Engineering consists of determining the Kansei words suitable for the product or service to be designed. Designers then create different concepts based on these words. In the next step, these concepts are prompted to the user who rates the product with the same Kansei words. The rating test contains scales from 1 to 5 with antonym Kansei words on both e nds. This is the *Semantic Differential Method* used in Advertising and Marketing to solve the problem of quantifying subjective data. The process may continue to cycle until the people involved in the development are satisfied with the results.

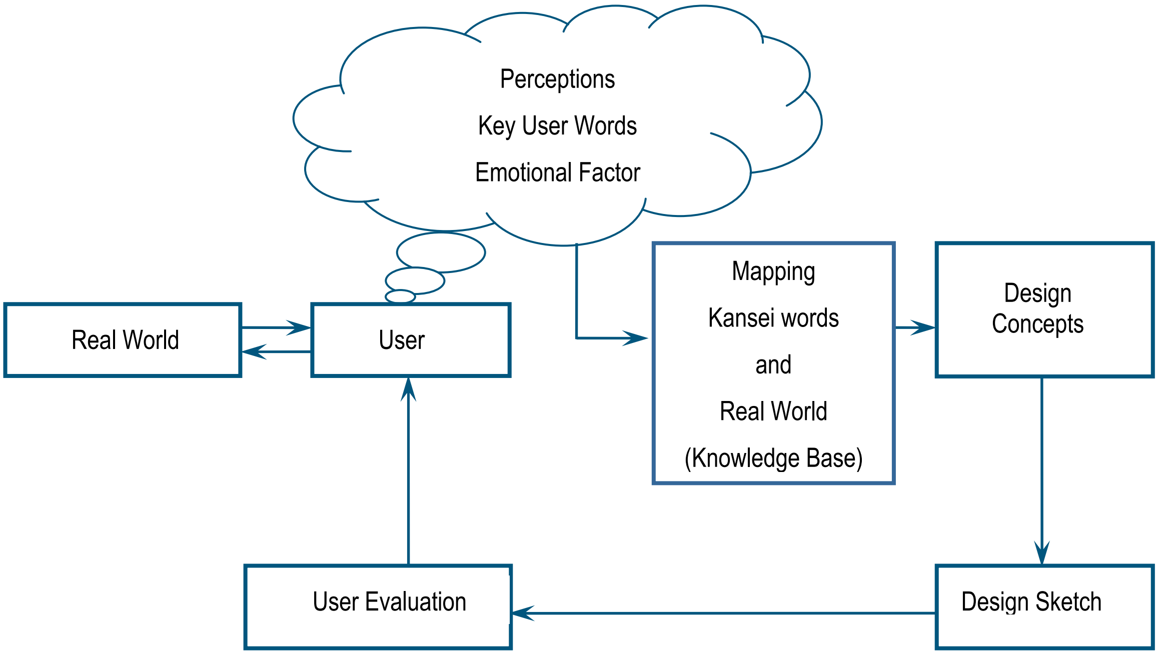


Figure 2. General Process of Kansei Engineering [**Nagamachi, 1997]**

User models in Kansei Engineering can be used with the aim of including subjective aspects of the users in the querying criteria. While many techniques have been proposed in user modelling, little attention has been spent on analyzing the amount of information involved in this modelling process and the multi-interpretation of such information.

Image retrieval by subjective content has been recently addressed by the Kansei Engineering community in Japan **[Tomofumi, et al.; 2002]**. One of the most relevant works is the Textile Design Image Database System, which is based on Kansei retrieval method using user models. This method provides easy and flexible access to a Design Image Database by specifying certain "Kansei words" to make the user satisfied in his/her perceptual retrieval **[Fukuda, et al.; 1994]**.

A good example of applying agent technology using Kansei Engineering is the work done by Ichida and Akiyoshi **[Ichida and Akiyoshi; 1998]**. They suggest the possibility of collaborative work in constructing 3D virtual-reality world with agents. They propose a way of decreasing the human burden by utilizing some supporting agents, which are virtual collaborators. In this study, a "KANSEI agent" predicts the user's KANSEI and proposes a new design; a "Conception agent" generates new ideas; an "Advice agent" analyzes the user's KANSEI and suggests a tendency and a "Random agent" makes new content randomly in order to gather new points of view.

4.5 Software Engineering

Software Engineering concerns the study of techniques and methods for developing and maintaining software that provides high quality solutions to problems. The importance of the user in the overall development of software has required a user-centred approach from the very beginning.

As Fleming and Cohen **[Fleming and Cohen, 1999]** observe, a user-centred approach requires an understanding of the reality: who will use the system, where, how, and to do what? Then, the system is designed in order to iterate a design-implementation evaluation cycle. In this way it is possible to avoid serious mistakes and to save re-implementation time since the first design is based on empirical knowledge of user behaviour. Such knowledge can be acquired through many different techniques, among them, direct observation, interviews and questionnaires.

Direct Observation is the most reliable and precise method, especially valuable for identifying user classes and related tasks. Moreover, it enables the identification of critical factors, such as social pressure, which can have a major effect on user behaviour when the system is used in the field. Unfortunately, direct observation is very expensive, because it requires experimenters to observe each user individually. For this reason, it is useful when a reduced number of observations are enough to generalize behavioural predictions or when hypotheses have to be tested rather than generated.

Interviews collect self-reported experience, opinion, and behavioural motivations. They are essential for finding out procedural knowledge as well as problems with currently used tools. Interviews cost a bit less than direct observations, because they can be shorter and easier to code. However, they still require skilled experimenters to be effective. By contrast, self-administered *questionnaires* can be handed out and collected by untrained personnel so that a huge quantity can be gathered. They allow for statistical analyses and stronger generalizations than interviews. Questionnaires provide an overview of the current situation, as well as specific answers. Which combination of these methods is worth applying depends both on requirements and budget.

[Shubin, 1999] designed *PrintWizard* for Digital Equipment Corporation. In this application, interview techniques were used to allow system administrators to manage printers on a network. The application is based on the information provided by user models to optimize typical tasks carried out by the user. However, the users group here is more cohesive: system administrators, who all share a reasonable understanding of the task. Other examples are Rezz[12] and Boston[13] which were developed Usability Engineering techniques (see below).

Wooldridge and Jennings **[Wooldridge and Jennings; 1999]** present us ADEPT, a multiagent application that can be instantiated for various business application domains. The system was developed as part of the project, Advanced Design Environment for Process Tasks (ADEPT). They attempt to reaffirm the main arguments favouring the view that intelligent agents and multiagent systems can potentially play a significant role in complex and distributed-systems engineering. They offer methodologies and frameworks to developers to address the pragmatic concerns of software engineers responsible for the development of agent-based systems.

Recently, part of the Software Engineering community has specialised in what is known as *Usability Engineering*.

[12] Rezz, a hotel reservation system, works as a sub-site associated with web sites for conferences and other events.

[13] Boston.com is an On-line magazine that provides information about Boston.

4.5.1 Usability Engineering

In the software engineering community the term usability has been more narrowly associated with user interface design. ISO/IEC 9126, developed separately as a software engineering standard, defined usability as one relatively independent contribution to software quality associated with the design and evaluation of the user interface and interaction **[Serco Ltd; 2002]**. Hence, usability and user modelling have a two-way relationship. On the one hand, usability evaluation has long been recognized as an indispensable part of the development of user models. On the other hand, user modelling has been found to enhance the effectiveness and/or usability of software systems in a wide variety of situations.

Usability is defined colloquially as "***ease of use***", of a system that interacts with a user. Usability is an abstract concept, that includes both usefulness for some given purpose or task, and ease of use, and includes the following aspects: *effectiveness* and *efficiency* with respect to the task, as well as *learnability*, *memorability* and *operability* of the system's controls, and an overall judgement of *user satisfaction.*

Regarding quality of use, the ISO norm **[ISO; 2000]** says that usability is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

An example of usability is BASAR (Building Agents Supporting Adaptive Retrieval). BASAR assists the user to improve its WWW usability and usefulness. BASAR builds a model of the user (preferences, interests, and tasks) using both explicit (asking the user) and implicit (observing the user) modelling techniques **[Fischer, et al.; 1985]**, **[Krogsæter, et al.; 1994]**. BASAR is based on agent technology.

Card sorting is a particular usability technique which consists of discovering the users' mental models of the information space, that is to say, how the users envision the organization of information. Card sorting is particularly useful for defining web site structures. Designers will use feedback from the users to help them design the way the information to be displayed is structured. Card sorting was applied in the redesign of the website of Sun Microsystems in 1995 and is capable of mapping the content of a website to the users' expectations.

4.6 Emotional Intelligence

Emotional intelligence *"is a type of social intelligence that involves the ability to monitor one's own and others' emotions, to discriminate among them, and to use the information to guide one's thinking and actions"* **[Mayer and Salovey, 1993]**. There are a huge number of parameters with which emotional intelligence can be measured, ranging from feelings of boredom to feelings of happiness and euphoria, from hostility to fondness, etc. All of them should be taken into account when building a user model since there is an obvious link between personality traits and user preferences - both being indications of default tendencies in behaviour. However, personality provides a high-level representation of user tendencies that interact with other factors to provide complex sets of preferences and behaviours.

There are several approaches to computational models of emotions. Each one focuses its research according to its application in particular domains; some of them are described in **[Seif, et al.; 1998], [Seif, et al.; 1999]**. *Event appraisal models* proposed by **[Roseman, et al., 1990]** identify events with emotions. The OCC[14] model **[Ortony, et al.; 1988]** provides a taxonomy which labels general emotions based on a valence for the reaction to events and objects. Another example is the "Six Basic Emotions" model proposed by **[Ekman, 1982]** which is based on research into universal facial expressions. Other models are based on physiological simulation of emotions, where each emotion is defined in terms of the physiological reaction to it **[Picard 1997]**.

The DFKI (German Research Centre for Artificial Intelligence) group began three projects in 1998 concerned with emotions and personality in human lifelike characters. The Puppet project promotes the idea of a virtual puppet theatre as an interactive learning environment to support the development of a child's emotional intelligence skills. The second project features an Inhabited Market Place in which personality traits are used to modify the characters' roles as virtual actors in sales presentations. Finally, the Presence project uses an internal model of the actor's (and possibly the user's) affective state to guide the conversational dialogue between actor and user. All projects implicitly involve a study of user modelling of personality traits and emotions in cognitive science.

[Koepeck, 2001] has defined a user model based on the personality and emotions, describing it as dialogue automata with properties of information systems. This work is supported by another study by **[Green, et al., 2001]** on neuronal biophysics and computation that tackles the matter of how to obtain the description of the behaviour of a system and how it can be modified by generating a series of interactions between the inputs and outputs, while the internal state of system is changing.

In the field of entertainment, an interesting example is the AIBO™ [15] robot. It is able to express its emotional factors. Different configurations permit it to communicate happiness, sadness, anger, surprise, fear and dislike. The robot is fully autonomous and mobile with more than a thousand behaviours, co-ordinated through a complex behaviour-based motivational system **[Fujita and Kitano, 1988]**.

Agent Technology poses additional challenges to emotional intelligence in the sense that agents act on behalf of the user, and should therefore be emotionally consistent. Work in the domains of education and entertainment stresses the importance of social qualities in an agent, in order to maintain a consistent and believable interaction. These qualities include:

- Personality
- Emotions
- Social relationships
- Emotional Intelligence

[14] Ortony, Clore, and Collins.

[15] The name AIBO is coined from the words: " AI (Artificial Intelligence)" " eye" and " robot" . In Japanese the word " aibu" means " partner" or " pal"

The effect of these elements on interaction is still at the phenomenological level but important findings relating objective and subjective user responses to these factors have been identified. Research in this area is only just beginning and further studies are needed to investigate user models that represent the underlying personality of users. Models should be coherent and independent while reflecting the subsequent changes in the user **[González, et al.; 2002]**.

Closely related to the field of emotional intelligence, is the research on avatars (see section 4.3.2). For example, **[Imbert, et al.; 2000]** uses avatars to model user features such as personality, traits, moods and emotions. They conclude that some tasks delegated by users can be realized by intelligent agents attached to avatars. But, the main trouble is that users perceive these psychological features from their own subjective point of view.

4.7 Artificial Intelligence

Artificial Intelligence attempts to understand intelligent entities. But unlike philosophy and psychology, which are also concerned with intelligence, Artificial Intelligence strives to *build* intelligent entities as well as understand them **[Rusell and Norvig, 1995]**. There are several fields in Artificial Intelligence related to user modelling among which we have underlined Expert Systems and Agent Technology.

Other fields of Artificial Intelligence, such as Machine Learning or Reasoning, have provided techniques to model the user in other disciplines, mainly for adaptation purposes. For the sake of length, we shall not describe them in this work.

4.7.1 Expert Systems

One of the research results in the area of artificial intelligence has been the development of techniques which allow the modelling of information at higher levels of abstraction. These techniques are embodied in languages or tools which allow programs to be built that closely resemble human logic in their implementation and are therefore easier to develop and maintain. These programs, which emulate human expertise in well-defined problem domains, are called expert systems. **[Norvig and Russell; 1995]**

The role of user models in expert systems relies on the fact that the explanation of the system should be adequate to the knowledge level of the user in the domain. For instance, a user modelling system is described in GESIA **[Brown, et al.; 1997b]** in which it is intended to dynamically capture and model user behaviour within an expert system. The GESIA system provides a unique user model for each user, as well as for classes of users, and uses a Bayesian type network to represent both the user model and an uncertainty in its decision process.

4.7.2 Agent Technology

Agent Technology highlights the importance of developing open-distributed and fully scalable systems on intelligent environments that will interact in a collaborative way in multiple domains, on behalf of multiple users.

Some studies on user models in agent technology appeared in 1993 written by Kozierok and Maes **[Kozierok and Maes; 1993]**. They developed a Calendar Interface Agent that manages requests for meetings on behalf of the user. It can learn, in a certain time, the preferences and the considerations of its user, storing them in the memory where they can be reinforced by the user. In 1995, Letizia appeared, **[Lieberman; 1995],** an agent which assists users in navigating the World Wide Web. The user must explicitly indicate his/her interests when using the traditional search engines such as WebCrawler or Lycos. The agent infers the intentions of the users, deducing his/her behaviour when they surf on the WWW.

In 1994, Etzioni and Weld **[Etzioni and Weld; 1994]** proposed defining the goals and beliefs about the preferences of a user based on the behaviour (interaction) of the agent within the environment. Specifically, a user model is based on explicit conversations with a software agent, such as an Intelligent Personal Agent. From the dialogue; the agent must be able to learn the user's interests and preferences autonomously (with minimal feedback from the user) and adapt to the changing needs of the user over time through a user model **[Nwana and Ndumu, 1999]**. The user model can have a mixture of explicit interactions with an agent and interactions with the web itself **[Armstrong, et al.; 1995]**, **[Thomas and Fischer; 1996].**

As a consequence of the use of agent technology, new research fields have arisen, some of which may end up embedded in other disciplines in the near future. They are *e-contracting* and *e-negotiation agents*, *Coalition agents* and *Context Aware agents*.

4.7.2.1 E-Contracting and e-Negotiation Agents

Agent technology is leading to the possibility of creating large scale electronic markets on the Internet. Current systems will be extended to allow users to delegate trading on the Internet to intelligent agents which will alert the user when a given price is available for a given product, or even to complete the sale on the user's behalf.

The user models in e-Markets allow the system to determine the kind of preferences and behaviours that the user is willing to adopt in negotiation processes.

4.7.2.2 Coalition of Agents

By extrapolation of the coalition concept in **[Jiang and Dasgupta; 2001],** a coalition is a collection of intelligent agents that collaborate for some major purpose or goal by cooperating, exchanging information, sharing resources and pooling capabilities. Resources and capabilities may include information, assets, computing infrastructures and co-ordination in military strategies.

Within software agent technology, user modelling could be used as support for the automated exchange of information, the maintenance of process models and, in particular, for the specification of joint-working plans and for resolving conflicting goals during development. The idea is to delegate some of the organisational tasks to the agents; the agents are able to handle the tasks because they will have acquired the competence from user models of the people involved.

4.7.2.3 Context-Aware Agents and Nomadic User Models

Recent advances in technology, especially in wireless communication, are increasing the use of Mobile, Wearable and Pervasive Computing **[Intille; 2002]** in order to enable new forms of user adaptive applications. Today, intelligent devices can interact with each other anytime and anywhere in the world. According to Byun **[Byun and Cheverst; 2001]**, the exploitation of user modelling techniques within the domain of context-aware computing is a relatively unexploited research area.

A context-aware system can adapt its behaviour according to the user’s personal or environmental context. In this way, context-aware applications capture and analyse information about the current context of a user, such as his current physical location, his past navigation, his technological equipment, other users in his environment, and so forth. The system then provides the user with information and functionality that is best suited to his current situation. This includes information that is adapted to the user's location, the user's interaction history, and other types of relevant information, but also information and functionality that provides a shared context among geographically dispersed users to facilitate group interaction. In order to adapt the information and functionality to the current context and the current user, a mapping between a user model and the potential contexts of use has to be identified **[UM; 2001]**.

MyCampus **[Sadeh, et al.; 2002]** is a semantic web environment for context-aware services, developed on campus at Carnegie Mellon University. The environment revolves around a growing collection of customizable agents, capable of (semi-)automatically discovering and accessing Intranet and Internet services, as they assist their users in carrying out different tasks (e.g. planning an evening, organizing a study group, looking for a place to eat, filtering incoming messages). In this way, a set of ontologies describes contextual attributes, user preferences and web services, making it possible to easily accommodate new task-specific agents and new web services.

The CoolAgent Recommendation System (CoolAgent RS), **[Chen and Tovrin; 2001],** was developed in 2001, by HP Laboratories. It is a context-aware, software agent system which has the ability to allow contextual information to be freely distributed among agents so that the meaning of that information can be shared and understood. It provides a flexible infrastructure for agents to capture heterogeneous contextual information in the physical world, and represent it, uniformly, for machine processes. It also allows agents to negotiate with other agents in the vicinity for contextual information that is not directly accessible through sensing. The concept of User Modelling is being used in a web-based editor and constrained to the domain of professional mobility and meeting arranger **[Griss, et al.; 2002]**.

Another similar project was COMRIS (Co-Habited Mixed Reality Information Spaces) **[Van de Velde; 1997]**, in which information agents gather relevant information, based on a model of specific interests of a user in a Conference Centre. The idea is to improve the information received by people attending the conference **[Arcos and Plaza; 2001]**.

Nomadic Information Systems are a particular case of context-aware systems. Here *nomadicity* means the capability of people to move easily from place to place, while retaining access to information and a set of services **[NII; 2002]**. End-users are usually real people, professionals in areas other than computers, with no fixed place for their daily activities. Users of nomadic information systems either have permanently connected devices with them all the time, or can use arbitrary stationary devices to access a nomadic system personalized to their needs, while they are moving. In most cases the user model acquisition is driven by monitoring the activities of users in the information space or by an analysis of their connection and device characteristics. Additionally, nomadic information systems can make use of localisation technologies (GPS, DGPS, Infrared, and digital compass) to adapt to a richer context model of the user’s current situation.

4.8 Conclusions

User models have been a matter of study in several disciplines, each of which focuses on a particular aspect of the user. Table 4 shows a collection of systems with representative user models in each discipline.
Thus:

- Adaptive Hypermedia: Stresses ***interest*** and ***preferences*** of users.
- Educational Hypermedia: Underlines the user learning ***abilities*** and ***cognition*** skills.
- Human-Computer Interaction: Highlights the effective ***communication*** between the user and the computers
- Kansei Engineering: Tries to find the ***perception*** of the user in preferences of user models.
- Software Engineering: Tries to achieve user-centred ***satisfaction*** in order to improve the effectiveness and the use of the system.
- Emotional Intelligence: Uses emotions to make user interactions more ***realistic***.
- Artificial Intelligence: builds ***autonomous*** and ***flexible*** intelligent user models.

All the disciplines have a common challenge in the near future: modelling a user in a network in which heterogeneous systems interact. Most of them have already started to work in this direction and are using agent technology as a way to developing their computational user models on the Internet. Agent Technology has several positive consequences:

- Agents can interact with the user models and delegate complex tasks of learning, reasoning, training and maintenance allowing to the agents to be more efficient.
- User models can be based on the collaborative incremental interactions between more than one agent in order to improve progressive understanding of the users.
- User models can be available to more than one agent, which avert the redundancy of information about the users in benefit of themselves.

These advantages have resulted in Agent Technology being used in all the disciplines as a transversal platform in which a distributed user model can be developed.

- Adaptive Hypermedia: *Agents representing* interest and preferences of the user to help users to locate personally meaningful information more easily.
- Educational Hypermedia: User models are deployed in ***agents responsible for capturing*** abilities and cognitive skills.
- Human-Computer Interaction: User models are ***agents*** developed as ***assistants*** to facilitate effective communication between user and computers.
- Kansei Engineering: ***Agents*** are ***sensory*** components of the systems which capture the perceptions of the users.
- Software Engineering: Increases usability and efficiency through ***coordination, composition and co-operation*** of ***agents*** to satisfy the user.
- Emotional Intelligence: ***Agents*** are addressed in ***smart*** fields integrating rational and emotional capabilities, being aware of the context and situations.
- Artificial Intelligence: Intelligent Agents are developed in such a way as to have the properties of ideal agents in order to model the users and to act on their behalf.

Table 4. Systems that have developed user models in the different research areas

System name [Author]	*Research areas*
AHAM [Wu, et al. 2001] Vignette V6 Content Suite [Vignette]	Adaptive Hypermedia
Ringo [Shardanand, U. and Maes, P., 1994] FireFly [Maes, P. et al. 1994] Maxims [Maes, 1994] Newt [Maes, 1994] Amalthea [Moukas, 1996] Profile [Nijmegen University, 1997]	Adaptive Hypermedia / Information Filtering
WebWatcher [T. Joachims et al., 1997] Syskill & Webert [Pazzani M. & Billsus D., 1996] Letizia [Lieberman, H.] Profile-based Alerts [APR Solutions] IRES [ARLab, 2003]	Adaptive Hypermedia/ Recommender Systems

TripMatcher [TripleHop Technologies] Me-Print™ Technology [VacationCoach Inc.] Amazon [Amazon.com] Activebuyersguide [activebuyersguide.com] Proto-Agent™ [Agents Inspired Technologies]	
MAS-PLANG [Peña, C., et al., 2002] ELM-ART II [Weber, G. and Specht, M. 1997]	Educational Hypermedia / Intelligent Tutoring System
Web-EasyMath [Tsiriga, V., Virvou, M., 2002]	Educational Hypermedia/ Intelligent Tutoring Systems/ Student Modelling
Oz Project [CMU] EQUATOR project [Eight UK Universities] Massive [Massive Ltd.] Adele [Johnson and Rickell] Steve[Johnson and Rickell] VIP-Advisor [IST Project 32440]	Human Computer Interaction/ Virtual Reality and Avatars
PbD [Cypher, 1993] Graphics editors NewsWeeder [Lang, 1995]	Human Computer Interaction/ Human Agent Interaction
Textile Design Image Database System (TDIDS) [Bianchi, Berthouze L. Tako]	Kansei Engineering
PrintWizard [Digital Equipment Corp.]	Software Engineering
Rezz Boston.com BASAR [Fischer G., Lemke, A.C. and Schwab, Th., 1985]	Software Engineering/ Usability Engineering
EMIR [I. & A. Research Inc.] Puppet project [DFKI, 1998] Inhabited Market Place [DFKI, 1998]	Emotional Intelligence

Presence project [DFKI, 1998] PETEEI [El-Nars et al.; 1999] AIBO [Fujita & Kitano, 1998]	
GESIA [Brown, et al.; 1997]	Artificial Intelligence/ Expert Systems
Fare Watcher [Travelocity.com]	Artificial Intelligence/ Agent Technology / e-Contracting and e-Negotiation
KIMSAC project [Yarafa, Y., 1999]	Artificial Intelligence/ Agent Technology /Coalition of Agents
My Campus [CMU] CoolAgent RS [HP Labs, 2001] COMRIS [Van de Velde, W. 1997]	Artificial Intelligence/ Agent Technology / Context-aware Agents

The main contribution of Agent Technology is, therefore, the ability to deploy user models in a distributed environment, populated with heterogeneous services and applications. We need, however, to think about this the other way around, that is, what is the contribution of the traditional disciplines of user modelling on Agent Technologies?

It is interesting to note that Agent Technology is using user models without paying to much attention to previous works from other disciplines in the building these models. We believe that, in order to meet the challenges described in the roadmap **[Luck, et al. 2003]** regarding the ability of agents to understand user requirements in distributed systems, researchers in Agent Technology should be aware of the advances in other disciplines, such as those discussed in this work. The synergy generated from mutually beneficial cooperation in research in all these areas (from Agent technology to User Modelling, and from User Modelling to Agent Technology), would surely bring meaningful, successful achievements.

5 CHALLENGES IN USER MODELLING

In a clear vision of how Information Technology will develop in the next ten years, **[Roush, 2002]** and **[Borriello, 2002]** say that the *smart devices* around us will allow easy access to relevant information and will maintain current and correct information about their locations, their contexts of use and maintain the right information in the right moment about the users. However, the principal message is that the users will always have priority over the devices. The technologies will have to adapt to the user and not vice versa. In this sense, we consider that personalisation will be a key issue in the future, where all systems will want to know more about the user.

A good question related to this vision of Agent Technology is in **[iNET; 2002]**: *How will users interact with healthcare, life sciences, e-Government, e-Learning, environmental services, dynamic supply-chains, financial services, and community/social support systems?* In answering their own question, the authors describe the near future (the next 10 years) where on-line environments and open networks are distributed everywhere and, at anytime; the users (organizations and/or individual persons) can achieve their own goals on behalf of themselves. In addition, the interactions between the users have to be flexible enough to handle changes in the user context and the availability of resources. It is a complex problem which has to be carried out by parts and involves multidisciplinary knowledge areas. Having studied recent advances in different disciplines, we have identified some of the main challenges in this field of research that might be analyzed. Some of them are:

- Ubiquitous user models
- Portability and mobility
- Privacy and security
- Standards tools and best practices
- Smart user modes for quality of life

5.1 Ubiquitous user models

The idea that 'proprietary' user models should be developed for each application system is still present today. The need to build a distributed user model is a challenge that has not been yet successfully solved.

It is important to bear in mind that user modelling is a wide research area and applications are also multi-varied. Hence, the utilization of user models as independent and self-manageable is the next approach to user models.

A ubiquitous user model can be considered as a gateway that allows the user to interface with several systems without pre-setting each application. To maintain the independency of the user model from any system, the user model should be able to operate by itself according to the behaviour of user, anytime, anywhere.

5.2 Portability and mobility

A first challenge in the short term is the portability of user models through multiple on-line and off-line platforms. This technological challenge is being developed early on in some distributed systems. Nowadays, computing is increasingly becoming mobile, but in the near future, the reliability of mobile networks (with factors like bandwidth, quality of service, security, interoperability and device capabilities) will still fall short of the demands imposed by the client-server architecture for user modelling systems, which requires permanent connectivity. Although ubiquitous and pervasive computing does not seem to be fully developed in the present real-world, portable user models have to be considered immediately since these will allow mobile user models to be developed, with an agent perspective, taking advantage of advances in research fields such as mobile agents. Several approaches (client-server for replication of user models, distributed user models, portable user models and mobile user models) may be improved to achieve user models that "reside" permanently with the users and which work like ideal agents. In this area of research, we can classify three main efforts in building these user models:

- **Context aware user models**

When services are ubiquitous, users can access them from *everywhere* and *continuously in time*, moving physically in different environments. This means managing different strategies for locating and accessing information about the user. As a consequence, we need new techniques to obtain user information, with the minimum of interactions, by blending the data from several sources in the context. User modelling would benefit from research into *semantic interoperability*[16], not only at the mobile level but at the fixed level. This requires the coherent integration of technologies from traditional knowledge representation, databases, semantic models, ontologies (e.g. Semantic Web), Agent Communication Languages (e.g. FIPA-ACL, KQML), increasingly prevalent web syntaxes (such as XML and RDF) and protocol formalisms.

- **Completeness and Functional Consistency**

Completeness and consistency are two complementary fields. The first refers to rules that govern the information of the user so that it is reliable and safe. The second refers to the principle that maintains the information of the user without logical failures. If the user may interact with more than one environment at a time; then, it is necessary to develop a strategy for keeping and maintaining individual user information consistent and not redundant. The problem nowadays is that each system builds a monolithic solution of its user model suited only to its own particular needs for its applications. For this reason, we consider it necessary to improve the development of reusable and standardized mechanisms on data structures in user modelling in order to promote flexibility in these dynamic contexts.

- **Availability**

[16] The difficulty in integrating resources that were developed using different vocabularies and different perspectives on the data

This factor can be considered as the “opportunity” to have the user model at our disposal whenever and in whatever form it is required. Availability is a measure of how much the user model suffers degradation or interruption in its service. In principle, the users will expect to be able to use their user models at anytime and anywhere: their home, their workplaces, their vacations places, etc. To a very large degree, this factor is limited by access to internet and of device capabilities. The effect on user models is that they will have to become more able to adjust readily to different network operating conditions, and, at the same time, they will have to become auto-manageable to prevent possible failures at the communication and application level, without disturbing interaction with the users.

5.3 Privacy and security

One of the major challenges in the near future for user modelling is guaranteeing the privacy and security of user information. A key element, in terms of social acceptability, is respect for user privacy in agent-based systems **[Dickinson et al. 2003]**. While *privacy* refers to keeping user information confidential and hidden from others; *security* aims to develop strategies and mechanisms that guarantee that the user's information has an acceptable degree of integrity and authentication **[Gosh; 2002]**. In the middle of the At the heart of privacy and security is the problem of how users can find relevant information without revealing more than they want to about their own data or behaviour. The relationship between privacy and security is natural: security mechanisms are necessary to preserve the user's privacy.

However, the true challenge lies in obtaining and building relationships of trust with the users in the next generation of open and distributed platforms of services. This trust is needed to integrate mechanisms and technological resources that allow users part control of their data, maintaining a balance between their privacy and their security at the instant they have put this information "on the air” across the networks and data repositories. This trust can be exploited in different ways by applying techniques used in agent technology, such as reputation, social rules in open systems, self-enforcing protocols - itself a guarantee of fairness - and consensus, in order to allow the users to find relevant information without having to lose the balance between their security and privacy.

5.4 Standards, tools and best practices

Best practices should be considered in order to speed up improvements in the comprehension of ad-hoc methodologies used in the development of user models. The combined experience of a critical mass of researchers and companies needing results from research in User Modelling might be a possible solution that would contribute to finding the best way to benefit from results of all the disciplines involved and achieve improvements in design, development, implantation and operation.

The available non-commercial and commercial tools (e.g. UML, AUML, GAIA, etc) are used in developing software components in general and of agents in particular, in order to build better methodologies and to improve our understanding of best practices in industrial and commercial applications of user modelling. This effort will extend the development of important topics, such as the following:

- Formalization: In the mid term, the formalization of logical approaches to user models could have benefits in the orientation towards a clear concept of implementation in multiple domains.

- Open interoperability and scalability: User Modelling Systems might implement mechanisms that allow open interoperability and scalability and improve integration with new and emerging technologies at the representation level and the inference level.

- One user model for multiple domains: The adaptability of user models ought to be reasonably efficient and is necessary to integrate complementary machine learning techniques, benefiting from multi-agent based domains. Advanced techniques of machine learning incorporated into multi-agent systems could predict user behaviours in several domains using ontologies for user models. For instance, the current version of *The Platform for Privacy Preferences* (P3P) specifications **[Reagle and Cranor; 1999]** does not permit user information to be shared with another domain, even though the same company operates in several domains with the same web sites. As far as we can see, this subject has not yet been investigated by researchers. However, in the private sector, extensive experience exists of implementing P3P on sites that share significant amount of content. This experience could be put to use to identify potential solutions to the problems of different companies sharing the same user model, with the consent of the user. On the other hand, the induction of user models in old applications should also be considered through the *agent wrappers*.

- Transparency for future applications: User models in the future will have to be *easily understood* by the applications. They will need to represent the users clearly, understandably and in a feasible way without the need for changing their structures and mechanisms of acquisition and learning. This will provide the user modelling system the capability of being used in other devices or applications without modification.

Finally, the use of standard technologies is a major requirement due to the variety of platforms in which the user model can be implanted and the increasing needs for in-depth, B2B (business-to-business) component interactions.

5.5 Smart user models for quality of life

Eliciting user preferences and desires is a broad and complex challenge that the User Modelling community research has attempted to take on with several techniques: *knowledge acquisition* by means of learning interests and personalisation, *marketing theory* by means of Customer Relationship Management and *uncertainty in A.I.* through probabilistic networks. The complexity of the problem makes it a matter for permanent research by several groups around the world. At present, there are no user models, in the strict sense of the word, in appliances and services such as intelligent keys, cars, watches and smartcards.

In the future, all the disciplines analyzed in this paper will need to work in synergy if we are to build appliances according to the vision of Ambient Intelligence which describes the likely prospect of an environment with numerous devices (embedded and mobile) that will improve the quality of life.

6 Towards Smart User Models

From the study carried out in drawing up this report, we can conclude that the foundation of future advances rests on the use of Agent Technology across the board. Moreover, in our opinion, advances in Emotional Intelligence, Kansei Engineering and Artificial Intelligence will be highly important in meeting the challenges that will allow systems to include the human factor linked to sensitive states of the users and their interactions with the system by means of *user models agents.*

In this line we have performed an exploratory work based on creating an adaptive user model, which captures the evolution of the user regarding his/her emotions: a *Smart User Model (SUM)*. Emotional Intelligence has been described as an important part of human decision making **[Goleman, 1995]**. It has been proved that, at a neurological level, emotions play a definitive role in the cognitive process **[Joseph, 2001]**. From our point of view, then, a user model based on a set of objective and subjective characteristics, quantitatively and qualitatively measurable, is not enough to build systems aimed at supporting human decision-making. According to the definition of user model presented in Chapter 2 we adding the emotional factors to the user model to define a *Smart User Model*.

In order to constraint such research, we focus on user models for recommender systems. The current scenario in recommender systems is given by the interaction of one user model to one recommender system. This means, that the user has several user models according to the number of applications which he/she interacts (see Figure 3). In this scenario, the user must provide his/her information whenever he/she needs a service in different recommender system. In addition, the user models do not share a common structure and vocabulary about the user with other recommender systems. These limitations do not allow still the portability of the user model and the possibility of sharing it in different domains.

The next generation of recommender systems will have a user model moderately portable, which will interact with several open, distributed and heterogeneous environments of services throught the use of ontologies in order to communicate the user preferences in several domains (see Figure 4).

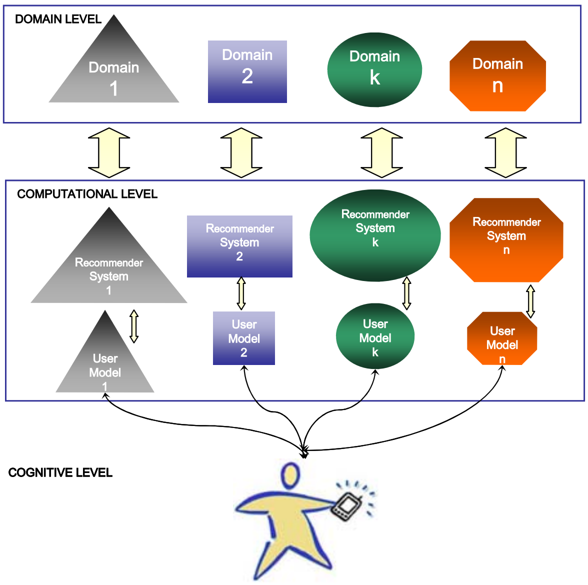


Figure 3. The current scenario in Recommender Systems.

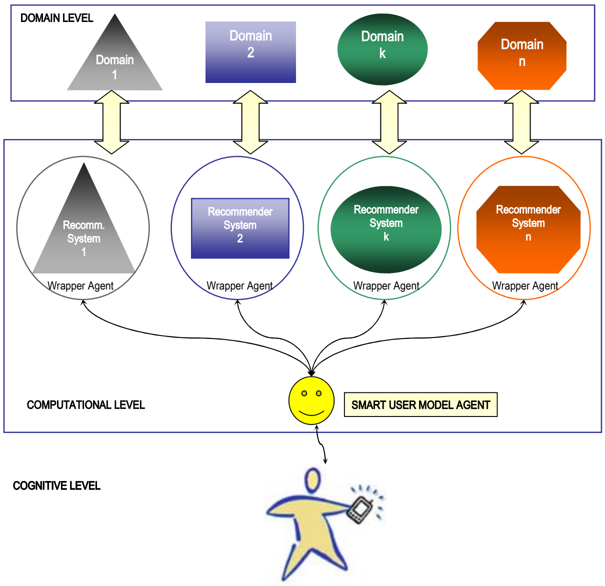


Figure 4. The Next Generation of Recommender Systems

In order to achieve such *Smart User Model* we propose a methodology that allows the knowledge transfer from one domain to the other. Such methodology is explained in this chapter.

This chapter is organized as follow; first, we introduce the different representational levels of the user information, in which we provide a possible *SUM* definition. In section 2, we propose a methodology and its stages to deal with the *SUM* through formal representations. In section 3, we illustrate the technique proposed with an example. Finally, we introduce a multi-agent architecture in which a *SUM* can be interpreted to existing applications in open environments.

6.1 Representational Levels

In order to provide a formal definition of *Smart User Models* we distinguish three representational levels: the Cognitive level, the Computational level and the Domain level (see Table 5).

Table 5. Representational levels in the Smart User Models.

Cognitive Level (Human beings)	**Computational Level (Machine)**	**Domain Level (Entity / Service)**
Mental States	**Programs / Agents**	**Composition**
Mental representations (Features, thinking, understanding, knowing, attitudes, predispositions, emotions, feelings)	Data Structures / Ontologies (Classes, Instances, Attributes, Relations / Terms and Definitions, Axioms, Relationships)	Characteristics (Objects, properties)
+	+	+
Algorithms (Behaviours, Volition)	Computational Procedures (Methods/Communicative Acts, Interaction Protocols, Content Languages)	Organization (Operation)
= Cognition of objective, subjective and emotional features and behaviours of a user	= Running Programs / Agents acting in behalf of user	= Available Items, objects / Services in a domains with attributes

The cognitive level relates the capability of perceiving, individual learning and developing through individual or social interaction with the environment. At this level the user perceives, stores, processes, and retrieves information. In terms of human personality, **[Miller, 1991]** propose three dimensions for the cognitive level:

a. Cognition : Thinking (knowing, understanding);
b. Affect : Emotion (attitudes, predispositions, emotions, feelings) and
c. Conation : Volition (intentions to act, reasons for doing).

This cognitive model recognizes that the mind receives information and manifests action through the body. Body can be considered in terms of biological or genetic influences, bodily functioning and overt behaviour or output. The model also recognizes there is a feedback loop between overt responses (or behaviour) and resulting stimuli from the environment. In summary, the cognitive level can be defined as *"the act or process of knowing including both awareness and judgment"* **[Merriam Webster's Dictionary]**.

The aim is then is to achieve an artificial cognitive representation of the user. For doing it at the computational level these are the set of data structures, attributes, its relations, axioms, mathematical formulations and methods that allow representing the cognitive information of the user into readable and comprehensible meta-data for a software information system.

The domain level is the particular environment in the real world in which the user is modelled. It is marked by specific characteristics and organization according to design goes of the software applications.

Following some notation is given to represent formally the mental features of a user at the different levels.

6.1.1 Cognitive Level

Let be a user defined by his/her features and behaviours ***F***.

Let ***F*** be the ***space*** of **features** and **behaviours** of a user composed by three dimensions:

$$F = O \cup S \cup E$$

O is finite set of objective attributes of user. These can be provided by the user or acquired from any database. Relate the name, age and socio-demographic information of the user.

$$O = \{o_1, o_2, o_3, \ldots, o_i, \ldots, o_n\}$$

S is finite set of subjective attributes of user. These are the personal judgment that the user performs according to her/his impressions, feelings and opinions or an arbitrary expression of his/her private preferences. These features can only be acquired through user interaction with external environment and the system.

$$S = \{s_1, s_2, s_3, \ldots, s_j, \ldots, s_m\}$$

E relates psychological traits and personality, such as joy, surprise, sadness, anger, disgust, etc. Emotional traits can be acquired through Emotional Intelligence Test.

$$E = \{e_1, e_2, e_3, \ldots, e_k, \ldots, e_l\}$$

6.1.2 Computational Level

Let be ***L*** the ***set*** of ***attributes*** which represent the features and behaviours of a user, ***F***, at the computational level. ***O, S*** *and* ***E*** are then mapped at the computational level by the corresponding set of attributes:

$$A^O = \{a_1^O, a_2^O, a_3^O, \ldots, a_i^O, \ldots, a_n^O\}$$
$$A^S = \{a_1^S, a_2^S, a_3^S, \ldots, a_j^S, \ldots, a_m^S\}$$
$$A^E = \{a_1^E, a_2^E, a_3^E, \ldots, a_k^E, \ldots, a_\ell^E\}$$

Each attribute can take values in a given domain, using the following notation:

$$v_i^O = value(a_i^O)$$
$$v_j^S = value(a_j^S)$$
$$v_k^E = value(a_k^E)$$

The particular values for the perceptions over the interests of the user are normalized and labelled to the following set of values:

Table 6. Labels and values of the perceptions about of interests of the users.

Very Not	Not	A little bit Not	Normal	A little bit	Very	Very much
[0, 0.14)	(0.14, 0.28)	(0.28, 0.42)	(0.42, 0.57)	(0.57, 0.78)	(0.71, 0.85)	(0.85, 1]

With those set of attributes, it is possible to define a *Smart User Model* as follow:

Definition 1: We can define a *Smart User Model*, *SUM,* as the collection of attributes-value pairs that characterize at the user.

$$SUM = \left\langle \begin{array}{l} \left[\left(a_1^O, v_1^O\right), \left(a_2^O, v_2^O\right), \ldots, \left(a_i^O, v_i^O\right), \ldots, \left(a_n^O, v_n^O\right)\right], \left[\left(a_1^S, v_1^S\right), \left(a_2^S, v_2^S\right), \ldots, \left(a_j^S, v_j^S\right), \ldots, \left(a_m^S, v_m^S\right)\right], \\ \left[\left(a_1^E, v_1^E\right), \left(a_2^E, v_2^E\right), \ldots, \left(a_k^E, v_k^E\right), \ldots, \left(a_\ell^E, v_\ell^E\right)\right] \end{array} \right\rangle$$

If we distinguish,

$$\begin{aligned} U^O &= \left[\left(a_1^O, v_1^O\right), \left(a_2^O, v_2^O\right), \ldots, \left(a_i^O, v_i^O\right), \ldots, \left(a_n^O, v_n^O\right)\right] \\ U^S &= \left[\left(a_1^S, v_1^S\right), \left(a_2^S, v_2^S\right), \ldots, \left(a_j^S, v_j^S\right), \ldots, \left(a_m^S, v_m^S\right)\right] \qquad \textbf{(6.1)} \\ U^E &= \left[\left(a_1^E, v_1^E\right), \left(a_2^E, v_2^E\right), \ldots, \left(a_k^E, v_k^E\right), \ldots, \left(a_\ell^E, v_\ell^E\right)\right] \end{aligned}$$

Then, we get the following alternative definition:

$$SUM = \left\langle U^O, U^S, U^E \right\rangle \qquad \textbf{(6.2)}$$

6.1.3 Domain Level

Let be ***D*** a set of attributes that define a given domain.

$$D = \left\{a_1, a_2, \ldots, a_h, \ldots, a_p\right\}$$

Let be $A^D \subset D$ the ***set*** of characteristics, properties and organization or operation of an item (object or service) in a given domain *D*.

$$A^D = \left\{a_1^D, a_2^D, \ldots, a_h^D, \ldots, a_p^D\right\}$$

Let be $A^I \subset D$ a ***set*** of interests of a user in particular objects or services in a domain *D*.

$$A^I = \{a_1^I, a_2^I, ..., a_i^I, ..., a_p^I\}$$

Let be A^U the socio-demographic features of the user in the domain *D*, normally introduced in a "login" procedure.

$$A^U = \{a_1^U, a_2^U, ..., a_k^U, ..., a_r^U\}$$

6.2 Smart User Model management

From the *SUM* definition we propose in this section a methodology to both, learn user features from user information stored in recommender systems and deliver the user features to other recommender systems.

In this sense, we use the term known domain to specify domains in which the user has interacted with, and so the corresponding recommender system kepts information about the user interests and preferences. Conversely, we call "unknown domain" the ones to which the user has never interactd with.

Then, our methodology is based on the following steps:

1. **Acquisition-generalization method.**
   Such method allows the information shift from a known domain to the *SUM*.

2. **Acquisition-specialization method.**
   For information transfer from the *SUM* to an unknown domain.

3. **Update method.**
   We use this method to change the *SUM* according to the results obtained by the recommender systems. Results are assumed to be acquired as a feedback value ([0,1]).

The method can be applied once for every domain. So it can be incremental.

Generalization, specialization and update methods have been widely studied by machine learning researchers. Particularly, the combination of generalization and specialization has been proved useful in others domains (see **[Armengol, 1997]**, **[Armengol, 2000]**).

In the following sections all methods are provided according to the different attributes of the *SUM*: objective, subjective and emotional.

6.2.1 Acquisition-generalization method

In this section we propose a method to shift user information from existing applications to other ones, thank to the *SUM*.

6.2.1.1 Acquisition-generalization method for objective attributes

In order to acquire the *SUM* features from existing user information in a given domain. We propose the development of a ρ^O graph.

Table 7. Definition of mapping function for acquisition-generalization method

Domain Level	Computational Level	Mapping Function	Domain Level → Computational Level
A^U, A^D, A^I	A^O	ρ^O	$\rho^O : A^U \rightarrow A^O$

ρ^O is defined as a directed graph that relates the values of the socio-demographic attributes of the user, A^U, in the *Smart User Model (SUM).*

A directed graph is a tuple, *G = (V, E)* in which $V = \{v_1, v_2, \ldots, v_i, \ldots, v_n\}$ is a set of vertex or nodes; *E* is a set of edges or arcs, $E \subseteq V \times V$; so each $e_i \in E$ is $e_i(v_i, v_j)$ is the arc from v_i to v_j.

In the case of ρ^O, the vertex of graph are the attributes A^U and A^O, and the edges, $E \in A^U \times A^O$. So arcs define pairs that describe a binary relationship between the socio-demographic attributes and objective attributes from a user on a given domain, $(a_i^U \in A^U)$, to the ones at the *Smart User Model*, $(a_i^O \in A^O)$ (see Figure 5).

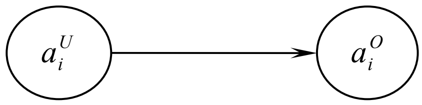


Figure 5. Graphical representation of the ρ^O graph.

6.2.1.2 Acquisition-generalization method for subjectives attributes

To shift the information contained in the *SUM* to a particular domain, we propose the use of a directed weighted graph, ρ^S.

A directed weigthed graph can be defined as a tuple *G = (V, E, W)* in which $V = \{v_1, v_2, ..., v_i, ..., v_n\}$ is a set of vertex or nodes; *E* is a set of weighted edges or arcs, $E \subseteq V \times V \times W$; so each $e_i \in E$ is $e_i(v_i, v_j, w_i)$ is the arc from v_i to v_j where its cost is $w_i \in W$. $W = \{w_1, w_2, ..., w_i, ..., w_n\}$ is a set of weights $w_i \in \Re$.

In the case of ρ^S the vertex are the attributes A^I and A^S, and the edges are defined in $A^I \times A^S$. So arcs define pairs that describe a binary relationship between the user interests-attributes and subjective attributes at the domain level, $(a_i^I \in A^I)$ and the ones at the *Smart User Model*, $(a_i^S \in A^S)$ (see Figure 6).

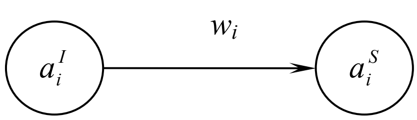


Figure 6. Graphical representation of the weighted graph ρ^S for acquisition-generalization method for subjective attributes.

Weigths are computing according to the value of the attribute at the domain level. So

$$w_i = value(a_i^I) \quad \in [0,1] \qquad \textbf{(6.3)}$$

6.2.2 Acquisition-specialization method

In this section, we introduce a methodology to obtain the information of the *SUM* and project it to unknown domains.

6.2.2.1 Acquisition-specialization method for objective attributes

In order to acquire objective attributes, we propose to develop a φ^O graph.

Table 8. Definition of mapping function for acquisition-specialization method

Domain Level	Computational Level	Mapping	Computational Level → Domain Level
A^U, A^D, A^I	A^O	φ^O	$\varphi^O : A^O \rightarrow A^U$

φ^O is defined also as a directed graph, *G = (V, E)*.

In this case the vertex of graph are the attributes A^O and A^U, and the edges, $E \in A^O \times A^U$. So, arcs define pairs that describe a binary relationship between the objective attributes and socio-demographic attributes of the *Smart User Model* and the socio-demographic attributes at the domain level.

6.2.2.2 Acquisition-specialization method for subjectives attributes

To shift preferences and interests of the user from the SUM to the domain level, a graph ρ^S is required.

ρ^S, is defined as a directed weighted graph (see Figure 7), in which each vertex is the subjective attributes in the *Smart User Model* (a_i^S) and the others vertex are the item-attributes of interest in the domain level with unknown values.

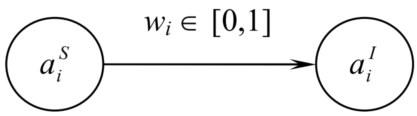


Figure 7. Graphical representation of the weighted graph ρ^S for acquisition-specialization method for subjective attributes.

Weigths are computing according to the value of the attribute at the domain level. So

$$w_i = value(a_i^I) \quad \in [0,1] \qquad \textbf{(6.4)}$$

6.2.3 Update method

In this section, we introduce a methodology for to update the information of the *SUM* accordingly to the user interaction in a given domain.

6.2.3.1 Update method for objective attributes

Objective attributes represent socio-demographic features that are measurable with a certain degree of certainty. So the only change expected from the system is due to new attributes values. In this case, the new values are then updated.

6.2.3.2 Update method for subjective attributes

The feedback of the system can be used to update the weight values of the graph involved in the recommendation process.

So, each weight of the corresponding relationship between interest-attributes (domain level) and subjective attributes (computational level) are rewarded or punished according to the following equation.

$$w_i = \varphi w_i + (1-\varphi) * Feedback \qquad \textbf{(6.5)}$$

Feedback is a value between [0,1] and φ is a parameter of the system evolution dynamics. We have experience in the use of this update method in trust environment **[Montaner, et al., 2002b]**.

6.2.4 Methods for emotional features

Dealing with emotional features of the user is something more complex than objective and subjective features. In this case, we have defined a methodology based on three stages: *initialization*, *update* and *advice* (see Figure 8).

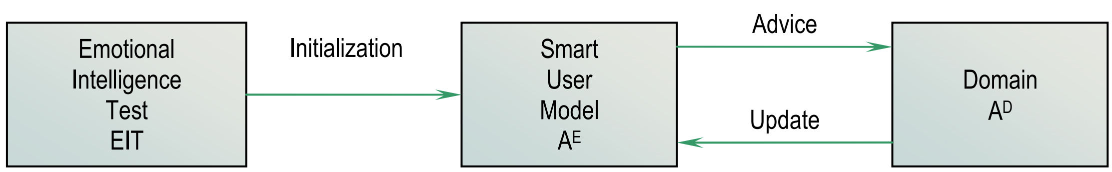


Figure 8. Initialization, advice and update stage of emotional features of the user into the Smart User Model

The *initialization stage* consists in the acquisition of emotional features of the user to compound the *Smart User Model*. This stage contains three steps, *parameter distribution, valence aggregation and labelling*.

The *update stage* consists in the keep informed the *Smart User Model* due to the emotional changes of the user according to the most recent interactions.

Finally, the *advice stage* proposes a method to help recommender systems to provide suggestions according to the emotional state of the user.

6.2.4.1 Initialization

The initialization of emotional features about the user can be acquired by means of the *Emotional Intelligence Test* (EIT) **[Quenndom; 2003]**. The emotional intelligence test provides a set of parameters from the user, which can be classified and labelled. Such parameters are five: *Self-conscience; Self-Control; Goal-Orientation and Motivation; Self-Expression and Social-ability; and Empathy.* Each parameter is defined in [0, 1] (See Figure 9).

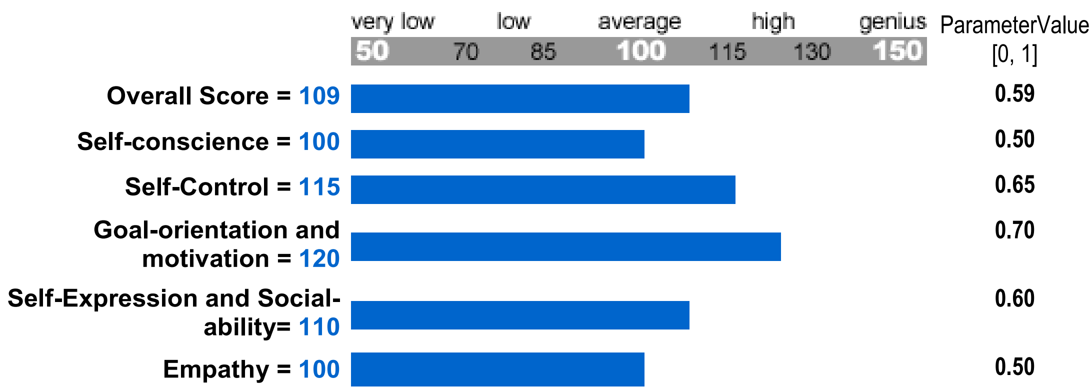


Figure 9. A sample of the results of the Emotional Intelligence Test [www.Queendom.com]

The parameters provide information about the user from which we wish to compute the current emotional state of the user. Parameters allows to know general range for emotions indicating whether an emoting individual is feeling *pleasant* versus *unpleasant*, *dominating* versus *vulnerable*, and *activated* versus *quiescent*. Such states can be classified in:

- Markedly Negative: This state includes the affective states or moods typically of a user with bad humour. As consequence, the suggestions of the recommender systems have to be carefully studied.
- More Negative: This range of affective states is a degree more flexible than the first one. In the same way includes moods with "high sensibility", that shoud be taken into account at the moment of the recommendations.
- Neutral: Users in these affective states are doubtful. They don't crack under pressure but they may still become anxious, depressed or very nervous when things become difficult. The users are more propensities to receive a wide range of recommendations than in the previous cases.
- More Positive: In this range of moods the user has a relative self-control. He/she is open to new, non-expected recommendations.
- Markedly Positive: At this state, any kind of excitation from the environment, including unexpected recommendations, are usually welcomed.

Such emotional states represent positive and negative emotions and the degree of *attraction* or *aversion* that the user feels toward a specific object or event.

In order to compute the emotional state, namely *markedly negative, more negative, neutral, more positive, markedly positive*, from the EIT, a three step procedure is proposed:

1. Parameter distribution
2. Valence aggregation
3. Labelling

Following each of these steps is detailed.

Step 1: Parameter distribution

The first step consists on spreading information of the parameters of the EIT according to related moods. Such moods (affective states) are provided by psychology studies made by **[Hillsdale, et al., 1988]**

Let be Par the set of parameters, namely:

Par = {Self-conscience, Self-Control, Goal-Orientation, Self-Expression, Empathy}.

Each parameter $\boldsymbol{p_i} \in$ Par has a value, VAL($\boldsymbol{p_i}$)

Let be *Mood* the set of the all possible user moods,

$$Mood = \{m_1, m_2, m_3, ..., m_k, ..., m_n\}$$

A set of moods is defined for each parameter,

$$\forall \text{ parameter } \boldsymbol{p_i} \in \text{Par}, \exists \text{ a set of moods } Mod(p_i) \subset Mood$$

At this step a value of mood m_{ij}, VAL(m_{ij}), is computed for each mood of each parameter, that is:

$\forall$ $\boldsymbol{p_i} \in$ Par

$\forall$ $m_{ij} \in Mod(p_i)$

$$\text{VAL}(m_{ij}) \Leftarrow \text{VAL}(\boldsymbol{p_i}) \qquad \textbf{(6.6)}$$

Be aware that VAL($\boldsymbol{p_i}$) $\in$ [0, 1], so VAL(m_{ij}) $\in$ [0, 1] too.

At the end of this step, each mood $m_{ij} \in Mood$ has a value.

Step 2: Valence Aggregation

Once the different moods are known, we need to compute the emotional valence ratings. This step is performed in two sub-steps:

-First, we compute the individual combination of each valence,
-Second, we compute the global value.

Step 2.1: Valence Computation

At this step, we compute the value of each valence.

Let be *Valence* the set of all values for the valences:

Valence = {(- -), (-), (- +), (+), (+ +)}

For each valence, ***valence**$_i$*, a set of moods, $Mod(valence_j)$ is defined,

$\forall$ valence ***valence**$_i$* $\in$ *Valence*, $\exists$ a set of moods $Mod(valence_i) \subset Mood$

Then, we compute the value of the valence, VAL($valence_j$) for each $valence_j \in Valence$ as follow:

$\forall\ valence_j$

$\forall\ m_{ij} \in\ Mod(valence_j)$

$$\text{VAL}\ (valence_j) = \frac{\sum_{j=1}^{j=n} VAL(m_{ij})}{Nm} \qquad \textbf{(6.7)}$$

Where Nm = Cardinality of $Mod(valence_j)$,

and VAL ($valence_j$) $\in$ [0,1]

Step 2.2 : Global mood of the user

At this step, we compute the final value of all the valences for the user, $GlobalMood_i$, as

$$GlobalMood_i = \frac{\sum_{j=1}^{j=Numval} VAL(valence_j)}{Numval} \qquad \textbf{(6.8)}$$

Where *Numval* = Number of valences

The result $GlobalMood_i$ is defined in [0, 1].

Step 3: Labelling

The Global mood is defined as a fuzzy variable that takes values according to the labels shown in the table 9. We divide these features in several categories according to the relatively temporary state of feelings in the user:

1. Those that describe a state of motivation markedly negative.
2. Those that describe a state of motivation slightly remarkable towards negative mood.

3. Those that describe a neutral state of motivation of the user and can motivate to him positively or negatively.
4. Those that describe a state of motivation slightly remarkable towards positive mood.
5. Those that describe a state of motivation markedly positive.

Table 9. Labels for the fuzzy sets of emotional attributes in the Smart User Model

Label	Markedly Negative	More Negative	Neutral	More Positive	Markedly Positive
x_i	[0, 0.2)	(0.2, 0.4)	(0.4, 0.6)	(0.6, 0.8)	(0.8, 1]

The emotional state is defined at [0, 1] interval.

Several membership functions are possible to define the fuzzy sets. As a start point of our research and taking into account the computational efficiency and the posterior discretization of the results we have chosen trapezoidal *membership functions (MFs).*

MFs are specified by four parameters *{a, b, c, d}* (with (a<b<c<d)) which determine the four corners of the trapezoidal membership functions.

$$trapezoid\ (x;\ a,\ b,\ c,\ d\} = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \dfrac{d-x}{d-c}, & c \le x \le d \\ 0, & d \le x \end{cases}$$

An alternative concise expression using min and max is the following:

$$trapezoid(x;a,b,c,d) = \max\left(\min\left(\frac{x-a}{b-a},1,\frac{d-x}{d-c}\right),0\right)$$

Figure 10 shows the fuzzy values proposed.

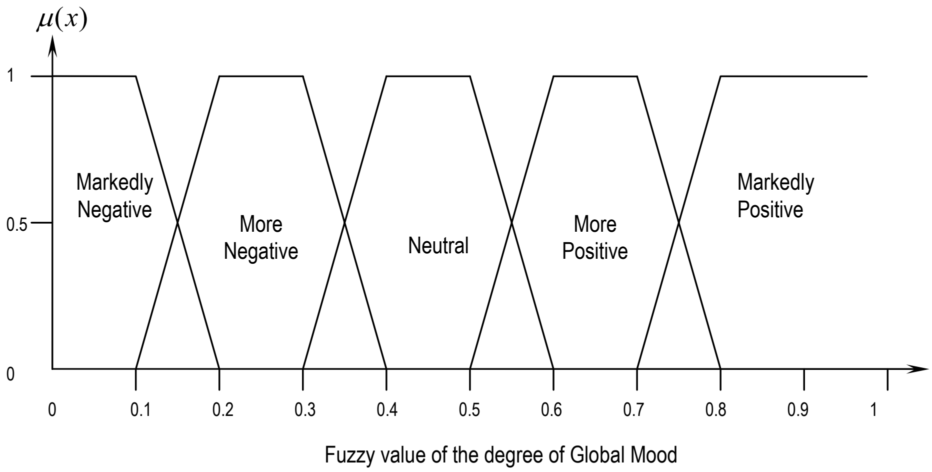


Figure 10. Membership functions for the degree of Global Mood

The following table summarizes the initialization steps.

Table 10. A possible table of relations between parameters and valences through the moods.

Valence / Parameter	(- -) [0, 0.2)	(-) (0.2, 0.4)	(- +) (0.4, 0.6)	(+) (0.6, 0.8)	(+ +) (0.8, 1]
Self-conscience	weak	Afraid Anguished Frightened Helpless Scared	Confident Courageous Cowardly	Lively Stimulated	happy
Self-control	Aggressive Desperate fed up Intolerant vengeful	Annoyed Discontented Disgruntled Disgusted Exasperated Furious Hopeless Impatient Tense Worried	Agitated Amazed Anxious Astonished Calm Curious Excited Nervous relaxed	Eager Jubilant Passionate Serene	Ecstatic Elated
Goal-orientation and motivation	Apathetic Dejected listless	Bored Confused Despondent Disappointed Discouraged Disdainful Dismayed Gloomy grief-stricken Hesitant Tired	Carefree Doubtful Resigned Stubborn	Hopeful Interested Satisfied	Contented
Self-expression and social-ability	Angry Depressed Sad unhappy	Ashamed Embarrassed Nostalgic	Indifferent Shy Surprised regret	at ease Fascinated Grateful Inspired Joyful sensual	Affectionate Cheerful
Empathy	Lonely Offended Outraged repelled	Distrustful Embittered Jealous Hostile	Compassionate Earnest Proud	Enthusiastic Humble Respectful Tender Warm-hearted	Amused Delighted

Moods

VAL ([0, 0.2))

Parameter Distribution

Global Mood

6.2.4.2 Advice

The goal of this stage is to take advantages of the information of the emotional state of the user, A^E of the *SUM,* in the domain level.

We propose to develop a mechanism based on attribute *activation* and *inhibition* to improve specific recommendations of the recommender systems. For each domain a set of attributes, E^D, will be activated or inhibited depending on the emotional user state. The attributes that allows relate the activations and the inhibitions with the Global Mood are called *excitatory attributes,* $E^D, E^D \subseteq \{A^D \cup A^I\}$, which represent emotional connections between the attributes and the emotional state. In each domain, a table that relates emotional states with excitatory attributes is defined (see Table 11).

Table 11. A possible table of activations and inhibitions for the excitatory attributes.

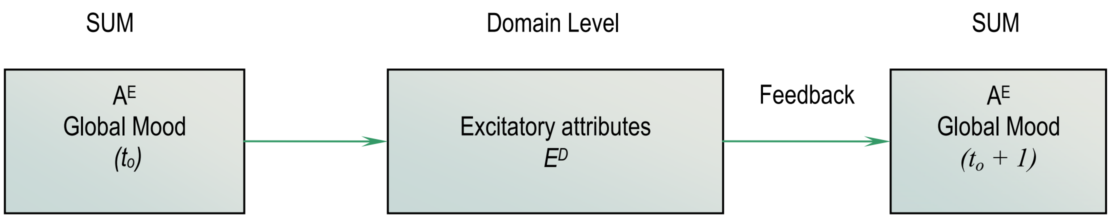
Excitatory attributes	**Markedly Negative**	**More Negative**	**Neutral**	**More Positive**	**Markedly Positive**
e_1^D	Inhibit	Inhibit	-	-	Activate
e_2^D	Inhibit	inhibit	Activate	-	Activate
.					
.					
.					
e_k^D	Inhibit	Activate	Inhibit	Activate	Activate

Activation means that the recommender system should take especially care of the attribute when doing the recommendation. Inhibition means that the recommender system can ignore recommendation.

6.2.4.3 Update

At this stage, emotional features A^E of the *SUM* are updated according to the feedback of the recommender system (see Figure 11).

Figure 11. Update emotional attributes of the Smart User Model



A feedback value is provided for each recommendation, this value is between [0,1] interval.

$$GlobalMood_{to+1} = \varphi GlobalMood_{to} + (1-\varphi) * Feedback \qquad \textbf{(6.9)}$$

Where φ is the factor of system evolution dynamics to ***reward*** or to ***punish*** the correspondent excitatory attribute according to the feedback recommendations.

6.3 Cases Study

In this section, we illustrate with an example the methodology proposed. We will assume that the user Juan Valdez®[17] has interacted with the recommender systems, restaurant and movies. We want to acquire a *SUM* and use it in another domain, namely the marketing domain. In this section, we present the cases study to illustrate how the formal definitions and methods can be used in order to develop a *Smart User Model*. We use an example applied on three domains: Restaurants, Movies and Marketing. For a better understanding of our example, we have distinguished three cases: Restaurants is One Single Known domain; Movies is also a Known domain and Marketing is an Unknown domain.

[17] Juan Valdez®, the Cafe de Colombia Logo, is a trademark of National Federation of Coffee Growers of Colombia

6.3.1 Objective Features

In this section, we will focus on the methods for objective features (see Figure 12).

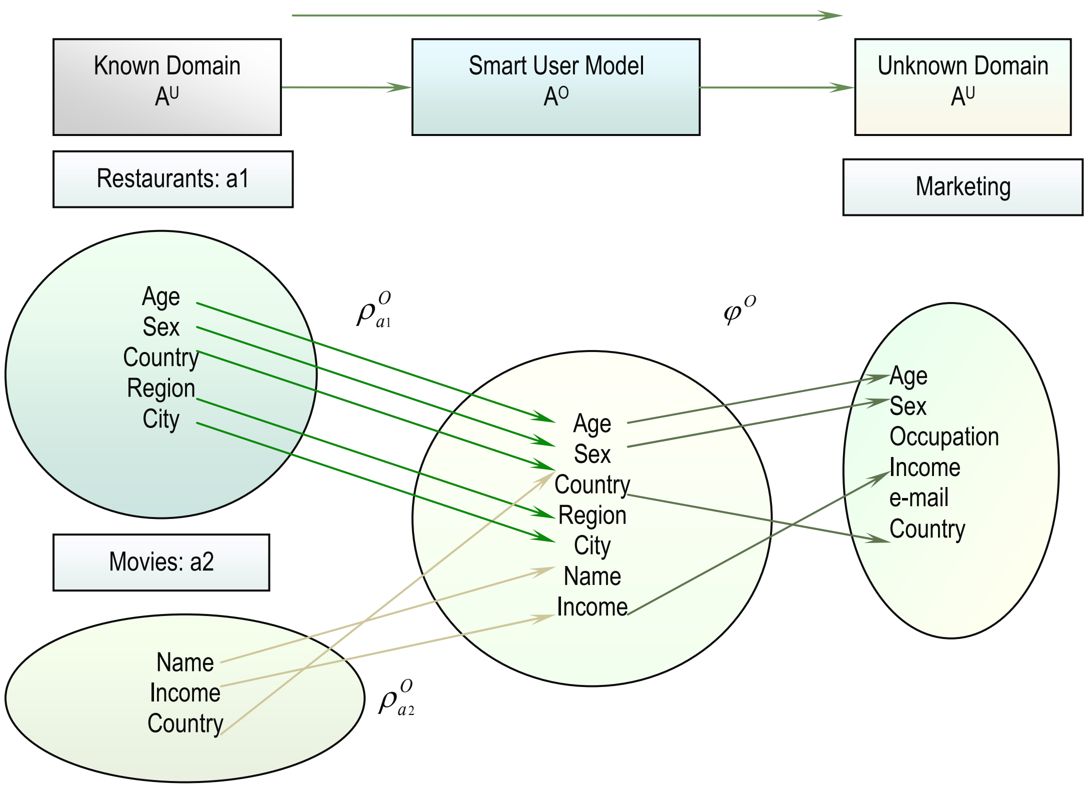


Figure 12. Graphical representation of the weighted graph ρ^O and φ^O for objectives attributes of the Smart User Model

Case a. Generalization from the restaurant domain

In the restaurant domain, the following socio-demographic features have been defined:

$$A^U = \{age, sex, country, region, city\}$$

Then, ρ^O_{a1} is defined from the restaurants domain to the *SUM* as follow:

$$\rho^O_{a1} = \{(\text{age, age}), (\text{sex, sex}), (\text{country, country}), (\text{region, region}), (\text{city, city})\}$$

Assume that, Juan Valdez (*JV*), has the following profile at the domain level:

value (age) = 57

value (sex) = male

value (country) = spain

value (region) = Catalonia

value (city) = Girona

We use A_{JV}^{U} to note all values of Juan Valdez:

A_{JV}^{U} = {57, male, Spain, Catalonia, Girona}

According to ρ_{a1}^{O} the *SUM* acquired from the domain level for Juan Valdez is then following:

$$U^{O} = [(age,57),(sex,male),(country,Spain),(region,Catalonia),(city,Girona)]$$

Case b. Specialization to the marketing domain.

Let's suppose that the unknown domain is the marketing one. In this domain the following socio-demographic features are considered:

$$A^{U} = (age, sex, occupation, income, e\text{-}mail, country)$$

At the *SUM*, the current information of the user, A^{O}, is the following:

$$A^{O} = \{age, sex, country, region, city\}$$

The corresponding graph φ^{O} is the following:

$$\varphi^{O} = \{(age, age), (sex, sex), (country, country)\}$$

In our example, Juan Valdez has the following values at the *SUM*:

$$A^{O}_{JV} = \{57, \text{male, Spain, Catalonia, Girona}\}$$

Since Juan Valdez has never interacted with the marketing domain, no values for each attributes are known for him.

After applying φ^{O} for Juan Valdez, we get the following values at the marketing domain.

value (age) = 57

value (sex) = male

value (occupation) = nil

value (income) = nil

value (e-mail) = nil

value (country) = Spain

Case c. Generalization from the restaurants and movies domain

In our example, we have two known domains (restaurants and movies) with the following user demographics attributes:

$$A^{U}_{a1} = \{age, sex, country, region, city\} \quad \text{(Restaurants domain)}$$

$$A^{U}_{a2} = \{name, income, country\} \text{ (Movies domain)}$$

Then, the final set of objective attributes at the *SUM* is:

$$A^{O} = \{name, age, sex, income, country, region, city\}$$

According to these sets of attributes A^{U}_{a1}, A^{U}_{a2} and A^{O}, the following graphs are defined:

$$\rho^{O}_{a_1} = \{\text{(age, age), (sex, sex), (country, country), (region, region,), (city, city,)}\}$$

$$\rho_{a2}^{O} = \{(\text{name, name}), (\text{income, income}), (\text{country, country})\}$$

In our example, Juan Valdez, has the following attributes in the two domains:

$$A_{JVa1}^{U} = \{57, \text{male, Spain, Catalonia, Girona}\}$$

$$A_{JVa2}^{U} = \{\text{Juan Valdez}, 36000, \text{Spain}\}$$

So, at the *SUM* we get:

$$U^{O} = \begin{bmatrix} (name, JuanValdez), (age, 57), (sex, male), (income, 36000), \\ (country, Spain), (region, Catalonia), (city, Girona) \end{bmatrix}$$

6.3.2 Subjective features

In this section, we apply the methodology for dealing with subjective features (see Figure 13).

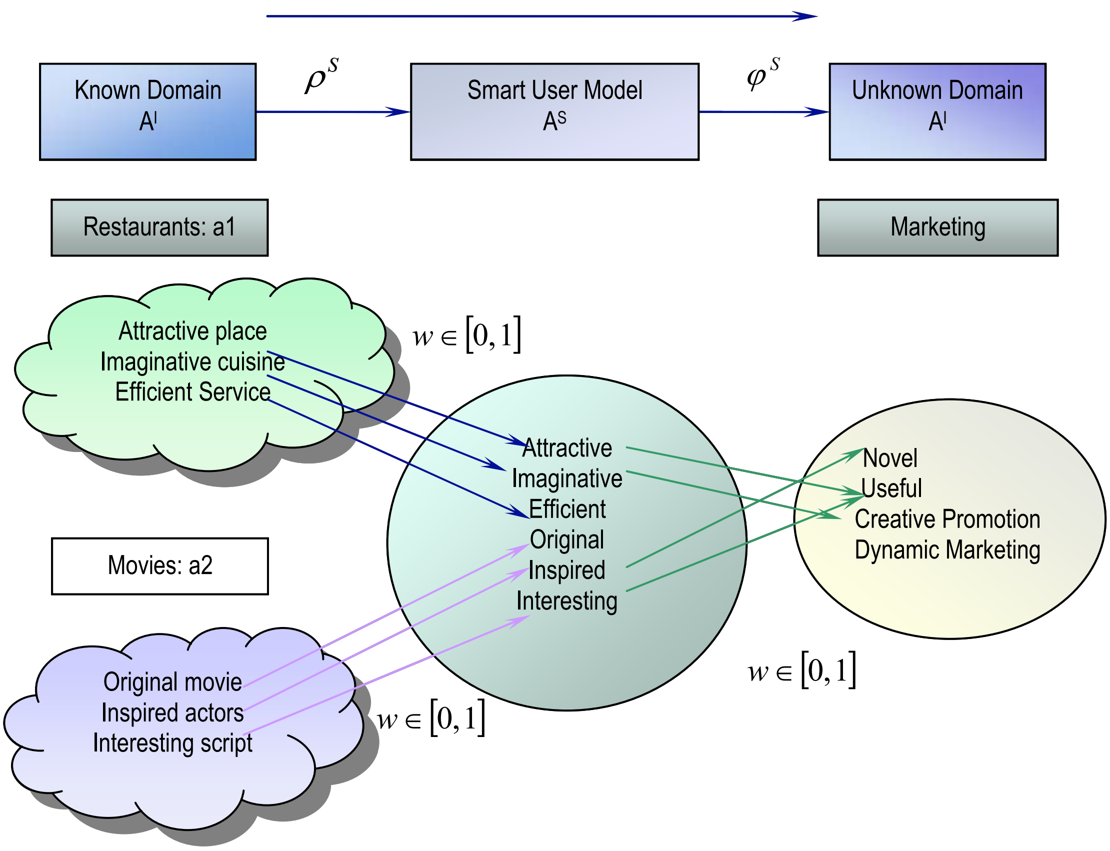


Figure 13. Graphical representation of the weighted graph ρ^{S} and φ^{S} for subjective attributes of the Smart User Model

Case a. Generalization from the restaurants domain

In our example, suppose that the restaurants recommender system has the following interests' attributes to capture user interests:

$$A^I = \{attractive\ place,\ imaginative\ cuisine,\ efficient\ service\}$$

The corresponding attributes at the *SUM* are $A^S = \{attractive,\ imaginative,\ efficient\}$

Our user, Juan Valdez, has been modelled according to these initials interests with the following values:
value (attractive-place) = 0.7
value (imaginative-cuisine) = 0.8
value (efficient-service) = 0.1

In a summarized form:

$$A^I_{JV} = \{0.7, 0.8, 0.1\}$$

Table 12. Values of subjective attributes of an item in Restaurants domain.

A^I	
Attributes	Values
Attractive place	0.7
Imaginative cuisine	0.8
Efficient service	0.1

The corresponding graph, ρ^S is the following:

ρ^S_{JV} = {(attractive place, attractive, 0.7), (imaginative cuisine, imaginative, 0.8), (efficient service, efficient, 0.1)}

Case b. Specialization to the marketing domain

Initially the characteristics of the *SUM*, A^S, are the following:

$$A^S = \{attractive,\ imaginative,\ efficient\}$$

At the domain level, the marketing recommender system expects information of the user regarding the following interests:

$$A^I = \{\text{novel product/service, useful, creative promotion, dynamic market}\}.$$

For the user Juan Valdez, these interests are unknown.

Table 13. Values of subjective attributes of an item in Marketing domain.

A_b^I	
Attributes	Values
novel product/service	Unknown
useful	Unknown
creative promotion	Unknown
dynamic market	Unknown

The graph corresponding to the shift of information from the *SUM* to the marketing domain according to ρ^S is the following:

ρ_{JV}^S = {(attractive, useful, **0,5**), (Imaginative, Creative, 0,7), (Inspired, Novel, 0,3), (Interesting, useful, **0,3**)}

$$A_{JV}^I = \{0.3, 0.5, 0.7, \text{nil}\}$$

Note that in case of having two possible values for the same attribute, we get the maxim.

Case c. Generalization from the restaurants and movies domain

In our example, we have the following sets of subjective characteristics in the restaurants and the movie domains corresponding:

A_{a1}^I *={attractive place, imaginative cuisine, efficient service}*

A^{I}_{a2} = *{original movie, inspired actors, interesting script}*

A snapshot of this case on the subjective characteristics would show the table 14.

The subjective features at the *SUM* are the following:

A^{S} = *{attractive, imaginative, efficient, original, inspired, interesting}*

The corresponding graphs are:

ρ^{S}_{a1} = *{(attractive place, attractive, 0.7), (imaginative cuisine, imaginative, 0.8), (efficient service, efficient, 0.1)}*

ρ^{S}_{a2} = *{(original movie, original, 0.8), (inspired actors, inspired, 0.5), (interesting script, interesting, 0.5)}*

Table 14. Values of subjective attributes of the Smart User Model of Juan Valdez in his Smart User Model.

A^{I}_{a1}		A^{I}_{a2}		A^{S}	
Attributes	Values	Attributes	Values	Attributes	Values
Attractive place	0.7	original movie	0.8	Attractive place	0.7
Imaginative cuisine	0.8	inspired actors	0.5	Imaginative cuisine	0.8
Efficient service	0.1	interesting script	0.5	Efficient service	0.1
				original movie	0.8
				inspired actors	0.5
				interesting script	0.5

In our example, we have the following information of Juan Valdez at the restaurant and movie domains:

$A^{I}_{a1} = \{0.7, 0.8, 0.1\}$

$A^{I}_{a2} = \{0.8, 0.5, 0.5\}$

The values of Juan Valdez *Smart User Model* from two domains are the following:

$A^{S}_{JV} = \{0.7, 0.8, 0.1, 0.8, 0.5, 0.5\}$

6.3.3 Emotional features

In this section, we illustrate the acquisition and use of the emotional dimension of the *SUM*.

6.3.3.1 Initialization example

Let's suppose the user Juan Valdez whose Emotional Intelligence Test results are shown in the Figure 14.

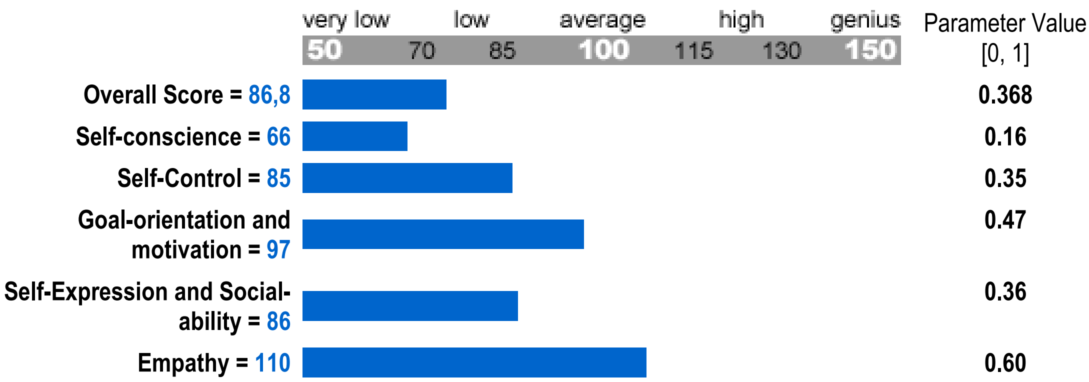


Figure 14. The EIT for Juan Valdez

Step 1: Parameter Distribution

First of all, we distribute the ***self-conscience*** value to all the corresponding moods. That is,

Mod(self-conscience) = {weak, afraid, anguished, frightened, helpless, scared, confident, courageous, cowardly, lively, stimulated, happy}

So, value(weak) = value (afraid) = value (anguished) = value (frightened) = value (helpless) = value (scared) = value (confident) = value (courageous) = value (cowardly) = value (lively) = value (stimulated) = value (happy) = 0.16

Analogously, we distribute the rest of the parameters. Table 15 summarizes the overall distribution.

Table 15. Relations between EIT parameters and valences through the moods of Juan Valdez

Parameter \ Valence		(- -) [0, 0.2)	(-) (0.2, 0.4)	(- +) (0.4, 0.6)	(+) (0.6, 0.8)	(+ +) (0.8, 1]
Self-conscience	**0.16**	Weak = 0.16	Afraid = 0.16 Anguished = 0.16 Frightened = 0.16 Helpless = 0.16 Scared = 0.16	Confident = 0.16 Courageous = 0.16 Cowardly = 0.16	Lively = 0.16 Stimulated = 0.16	Happy = 0.16
Self-control	**0.35**	Aggressive = 0.35 Desperate = 0.35 fed up = 0.35 Intolerant = 0.35 Vengeful = 0.35	Annoyed = 0.35 Discontented = 0.35 Disgruntled = 0.35 Disgusted = 0.35 Exasperated = 0.35 Furious = 0.35 Hopeless = 0.35 Impatient 0 0.35 Tense = 0.35 Worried = 0.35	Agitated = 0.35 Amazed = 0.35 Anxious = 0.35 Astonished = 0.35 Calm = 0.35 Curious = 0.35 Excited = 0.35 Nervous = 0.35 Relaxed = 0.35	Eager = 0.35 Jubilant = 0.35 Passionate = 0.35 Serene = 0.35	Ecstatic = 0.35 Elated = 0.35
Goal-orientation and motivation	**0.47**	Apathetic = 0.47 Dejected = 0.47 Listless = 0.47	Bored = 0.47 Confused = 0.47 Despondent = 0.47 Disappointed = 0.47 Discouraged = 0.47 Disdainful = 0.47 Dismayed = 0.47 Gloomy = 0.47 grief-stricken = 0.47 Hesitant =0.47 Tired = 0.47	Carefree = 0.47 Doubtful = 0.47 Resigned = 0.47 Stubborn = 0.47	Hopeful = 0.47 Interested = 0.47 Satisfied = 0.47	Contented = 0.47
Self-expression and social-ability	**0.36**	Angry = 0.36 Depressed = 0.36 Sad = 0.36 Unhappy = 0.36	Ashamed =0.36 Embarrassed = 0.36 Nostalgic = 0.36	Indifferent = 0.36 Shy = 0.36 Surprised = 0.36 Regret = 0.36	Fascinated = 0.36 Joyful at ease = 0.36 Fascinated = 0.36 Grateful = 0.36 Inspired = 0.36 Joyful = 0.36 Sensual = 0.36	Affectionate = 0.36 Cheerful = 0.36
Empathy	**0.60**	Lonely = 0.60 Offended = 0.60 Outraged = 0.60 Repelled = 0.60	Distrustful = 0.60 Embittered = 0.60 Jealous = 0.60 Hostile = 0.60	Compassionate = 0.60 Earnest = 0.60 Proud = 0.60	Enthusiastic = 0.60 Humble = 0.60 Respectful = 0.60 Tender = 0.60 Warm-hearted = 0.60	Amused = 0.60 Delighted = 0.60

Step 2: Valence Aggregation

This step is compound by two sub-steps: Valence computation and Global Mood of the user.

Step 2.1 Valence Computation

Let's start with the computation of the (--) valence. The moods corresponding to this valence, *mood(--)*, are the following:

Mod(--) = {(weak, aggressive, desperate, fed up, intolerant, vengeful, apathetic, dejected, listless, angry, depressed, sad, unhappy, lonely, offended, outraged, repelled}

Then, the individual computation of the (--) valence is performed according to equation (6.7) as follow:

VAL(--) = [VAL(weak) + VAL(aggressive) +VAL(desperate) +VAL(fed up) + VAL(intolerant) + VAL(vengeful) + VAL (apathetic) + VAL(dejected) + VAL(listless) + VAL(angry) + VAL(depressed) + VAL(sad) + VAL(unhappy) + VAL(lonely) + VAL(offended) + VAL(outraged) + VAL(repelled)] /*Nm*

VAL(--) = [0.16 + 0.35 + 0.35 + 0.35 + 0.35 + 0.35 + 0.47 + 0.47 + 0.47 + 0.36 + 0.36 + 0.36 + 0.36 + 0.60 + 0.60 + 0.60 + 0.60] /17

VAL(- -) = 0.4211

Analogously we can compute the value of the rest of the valences:

VAL(-) = 0.3924
VAL(- +) = 0.3804
VAL(+) = 0.4119

VAL(+ +) = 0.4062

Step 2.2 Global Mood of the user

Finally, we compute the global mood of the user according to the equation (6.8).

$$GlobalMood_i = \frac{\sum_{j=1}^{j=Numval} VAL(valence_j)}{Numval}$$

GlobalMood = VAL(--) + VAL(-) + VAL(-+) + VAL(+) + VAL(++)/Numval

GlobalMood = [0.4211 + 0.3924 + 0.3804 + 0.4119 + 0.4062]/5

GlobalMood = 0.4024

Step 3: Labelling

The global mood of Juan Valdez has been a positive value = 0.4024. This value corresponds to the ***Neutral*** label. More precisely, the evaluation of MF is $\mu(x = 0.4024) =$ 1.

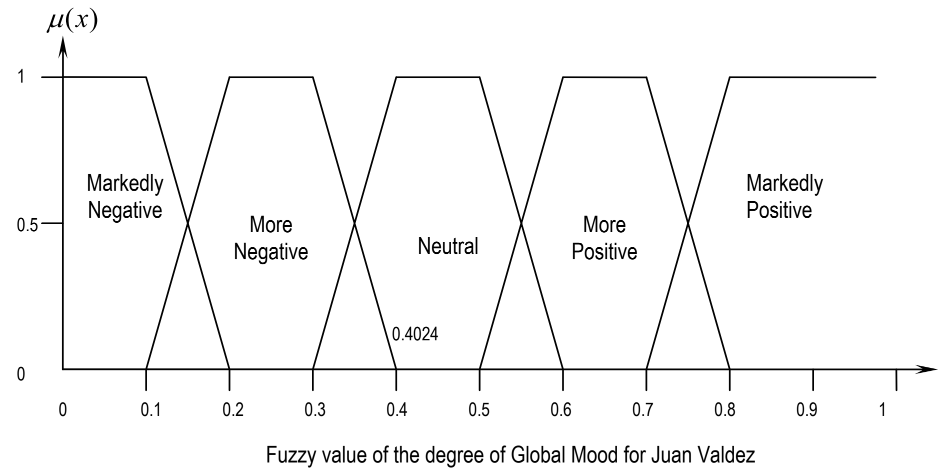


Figure 15. Global Mood of Juan Valdez

We can conclude that the emotional state of Juan Valdez at this initialization stage is neutral. Such emotional information can help to do recommendations in his benefit.

Consequently, we improve recommender systems, and make them more pleasant to the user through the perception of his/her emotional states.

6.3.3.2 Advice example

Let's suppose that the excitatory attributes in the restaurant domain are: *price, capacity, curiosity, food quality, quality/price relation, efficient service.*

$$A^E = \{price, capacity, curiosity, food\ quality, quality/price\ relation, efficient\ service\}$$

First of all, our mechanism consists in marking the attributes with the sign, (+) in case of activation and (-) in case of inhibition according to the emotional state of the user performed. The following table summarizes the activations and inhibitions for the restaurant domain:

Table 16. Advice mechanism to activate and inhibit excitatory attributes

Excitatory attributes	Markedly Negative	More Negative	Neutral	More Positive	Markedly Positive
Price	-	-	-	+	+
Capacity	-	-	-	+	+
Curiosity	+	+	+	+	+
Food quality	+	+	+	+	+
Quality/Price relation	-	-	-	+	+
Efficient service	+	+	-	+	+

Since Juan Valdez has a neutral emotional state, the following activations and inhibitions hold:

- Activate: curiosity, food quality
- Inhibit: price, capacity, quality/price relation and efficient service.

With this activations and inhibitions the Juan Valdez *Smart User Model* advises the recommender system in order to decide more suitable items in restaurant domain according to the current emotional state of Juan Valdez.

6.3.3.3 Update example

In our example, the recommender system has suggested to Juan Valdez a restaurant getting the following feedback from the user: 0.9 We know the global mood of Juan Valdez, which is Neutral. His $GlobalMood_{to} = 0.4024$.

The paarmeter of the system evolution dynamics, $\varphi = 0.5$

According to (6.9), the updated global mood is:

$$GlobalMood_{to+1} = 0.5 * 0.4024 + (1 - 0.5) * 0.9$$

$$GlobalMood_{to+1} = 0.6512$$

This new global mood corresponds to the “more positive” emotional state.
The feedback that the recommender system has suggested to Juan Valdez has changed slightly his global emotional state from neutral towards more positive.

6.4 Smart Multi-Agent Architecture

In order to make the *SUM* operational in open environments we propose the multi-agent architecture shown in Figure 16. The multi-agent architecture consists of two classes of agents: The *Smart User Model agent* and the *Intelligent Wrapper agent*. The first is responsible of the *SUM* managing. The second class of agents corresponds to the agents that interact with each service that require the use of the *SUM*. Since not all services can be agent-based, the main role of the wrapper agents is to implement the interface between the services and the *SUM*.

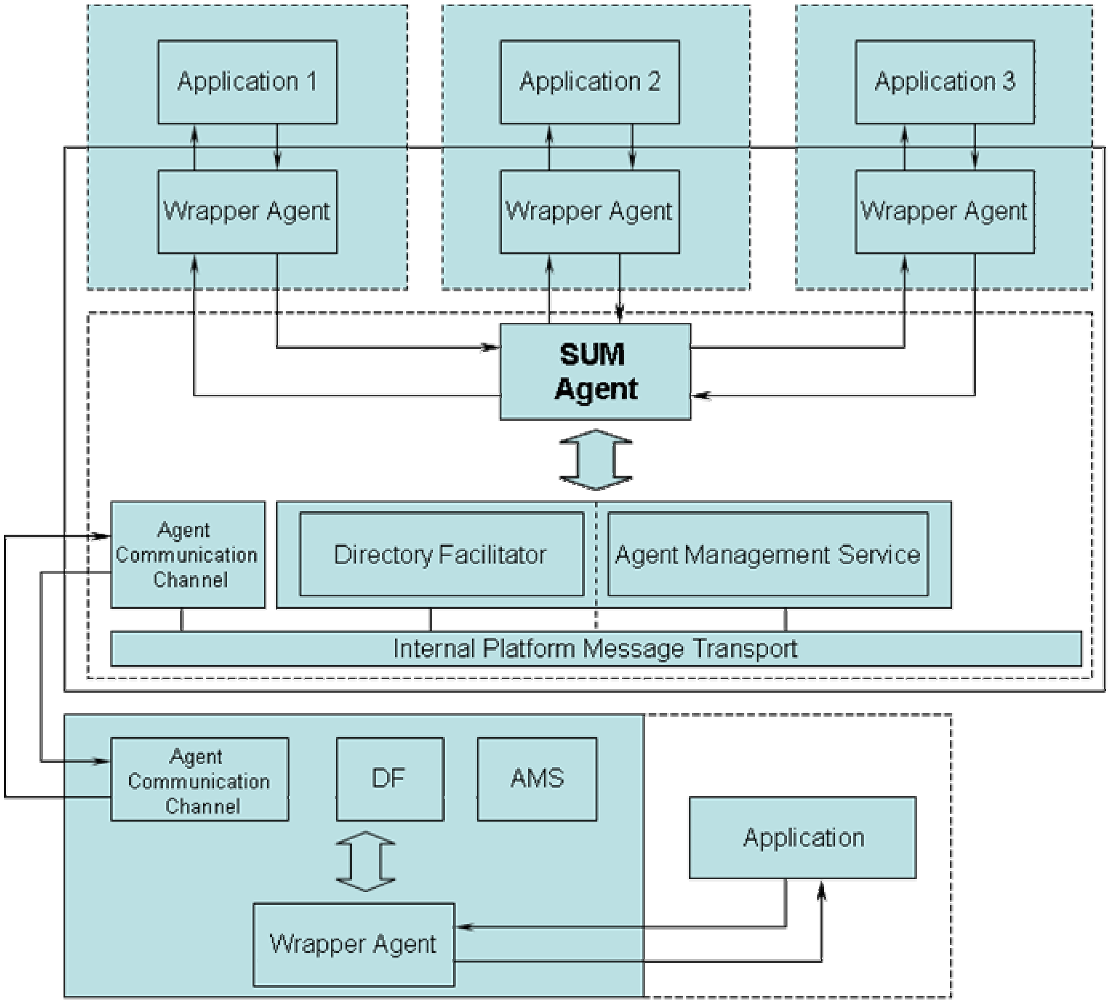


Figure 16. Smart Multi-agent System Architecture

7 Thesis Proposal

We have specified a generic user model according the main features of the user: Objectives, subjective and emotional features. Such generic user model that we have called *Smart User Model* is in line with the next generation of user models in open environments. It incorporates the human factor to improve the suggestions of the recommeder systems, a fundamental issue that several authors claim for **[Carroll, 2001]**.

We have presented a well detailed approach to specify formally a *Smart User Model*. We have defined the cognitive level, the computational level and the domain level, and their relationships. Then, we have defined a methodology to learn the *Smart User Model*, to make advises with the *Smart User Model* and to update the *Smart User Model*, with the aim of improving the recommendations to the user taking into account her/his emotional state.

Our method is based on a graphs representation. Graphs occur whenever there are connections between users, agents and domains throught its features and attributes.

Our methodology emphasizes the use of existing applications, so no extra- effort of the user is required.

Finally, we adopted a method of best practices in agent technology: We require to agentify existing applications by means of wrappers.

Our objectives are then partially fulfilled:

- We have a generic user model.
- We represent and use the emotional state of the user.
- We avoid annoying the user.
- We reuse information of existing applications.

However, additional tasks should be performed to achieve our goals, as well as to deal with additional challenges.

In this chapter we will review all the contributions towards we will steer our research during the next two years in order to achieve the results that allow the author to obtain the Ph.D. degree.

This chapter is organized as follow. In the first section we describe the main contributions and the breakthrough of the Ph.D proposal. In the second section we outline the work tasks and the temporalisation of the future work.

7.1 Contributions and Breakthrough

Main contributions of this research will be:

- Contribute to develop a formal specification of a *Smart User Model.*
- Contribute to study of the human factor in computational environments
- Allow the portability of the sensibility of the user through of the transferency of objective, subjective and emotional features contained in his/her *Smart User Model* towards several domains.
- Contribute to the study of non-intrusivity user models while sharing knowledge of the user among of different domains.
- Build an independent and re-usable user model to adapt it to other systems that require knowledge about preferences, behaviours and habits of user.
- Combine advanced machine learning techniques to predict user behaviours on several domains.
- To guarantee the interoperability of the multi-agent system using standard tools, including ontologies regarding user features.

7.2 Work Scheduling

This section comprises the scheduling of the Ph.D. First, we provide the different tasks and then a temporalisation of them. Some of the task have been already completed (as for example, the state-of-the-art and the exploratory work), and other ones should be initialized.

7.2.1 Working tasks

T1. State-of-the-art

In this task we realize a holistic approach on user modeling.

T2. Exploratory Work

The goal of this task is provide a basic Smart User Model definition and methodology.

T3. A first prototype

The goal of this phase is to develop an independent and reusable software component to provide personalisation service based in the Smart User Model provided in the previous tasks. This component will operate as service for other Multiagent systems that require it. This phase allows developing a prototype for easing the development and deployment of service applications in the domains described.

T4. Implementation of a MAS framework

This phase include the previous design and the development of a multiagent system that supports reconfiguration, self-organisation and autonomic behaviour in new/existing open distributed platforms. This phase we will allow the deployment of the Smart User Model on the restaurant, movies and marketing domain.

T5. Design of experiments and methods for experimentation

In this phase, we will design the experiments, and define the evaluation measures and methods to prove the overall system. We are thinking on the use of a user simulation as much as it is possible to develop it. A preliminary step could be the analysis of computational complexity of the system.

T6. Experimentation and results

In this task, we will evaluate the benefits by using the *SUM* with real data. As much as possible we will try to compare these results with other approaches.

T7. Write thesis

This phase is a continuos work that will be based on several documents. We have already one publication on an International Workshop. Our intention is to continue with the publications of the results in International Congresses (such AAMAS'04, CIA'04, UM'04) and publications recognized by the Science Citation Index (SCI). The writing of the final document of Ph.D. thesis and its presentation are included in this phase.

T8. Collaboration with a foreign research center

Once we have a first prototype and in order to compare our approach to other advances in the area, we are thinking on doing a stay in another foreign research center. From the collaboration, one publication is expected.

7.2.2 Temporalisation

The Figure 17 shows the time assignment for each phase of the thesis proposal.

Id		Nombre de tarea	Duración
1		START	0 mss
2		State-of-the-art	16 mss
3		Exploratory work: Methodology to build Smart User Models	6 mss
4		A first prototype	5 mss
5		Implemetation of the Multi-agent System framework	9 mss
6		Design of experiments and methods for experimentation	7 mss
7		Experimentation and results	11 mss
8		Write thesis and presentation	6 mss
9		Collaboration with a foreign research center	4 mss
10		END	0 mss

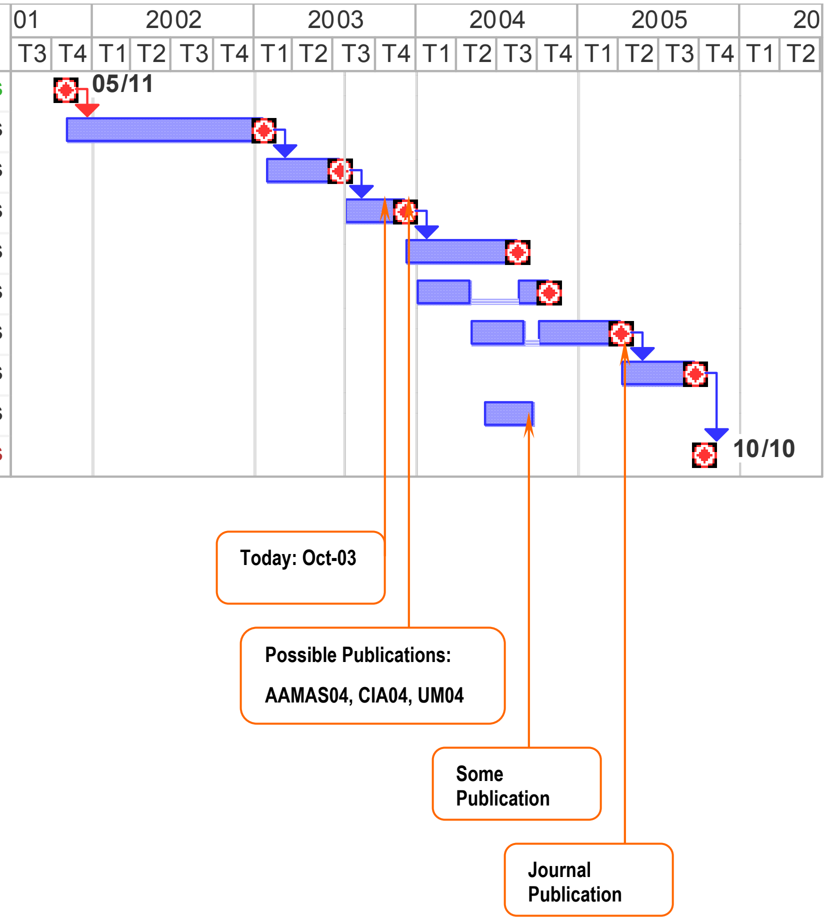


Figure 17. Gantt diagram of work 2003-2005

9 References

[Aguilar, et al.; 2002] Aguilar, M., Peña, C. and Fabregat, R. "SMIT: diseño e implementación de un agente sintético de presentación para las Unidades de Soporte a la Docencia del PLAN-G". JENUI 2002. Cáceres (España), 10-12 July 2002.

[Amato and Straccia; 1999] Amato, G., Straccia, U.: User Profile Modelling and Applications to Digital Libraries. In: Proceedings of the Third European Conference on Research and Advanced Technology for Digital Libraries, Paris, France. 1999

[APR; 2002] APR Ltd. Recommend. On Line. Internet. Available at: http://www.aprsmartlogik.com/apr/index.asp

[Armstrong, et al.; 1995] Armstrong, R., Freitag, D., Joachims, T., and Mitchell, T. WebWatcher: A learning apprentice for the World Wide Web. In Proceedings of the 1995 AAAI Spring Symposium on Information Gathering from Heterogeneous, Distributed Environments. 1995.

[Arcos and Plaza; 2001] J. L. Arcos, E. Plaza. Context Aware Personal Information Agents. 5th International Conference on Autonomous Agents (Agents'2001). April 2001.

[Armengol, 1997] Armengol, E. A Framework for Integrated Learning and Problem Solving. PhD dissertation. Universitat Politècnica de Catalunya. Departament de Llenguatges i Sistemes Informàtics. 1997

[Armengol and Plaza, 2000] Armengol, Eva and Plaza, Enric Bottom-up Induction of Feature Terms, Machine Learning Journal, Vol. 41(3), 2000 pp. 259-294. Previous draft available online

[Bandura, 1986] Bandura, A. Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, N.J.: Prentice-Hall, 1986.

[Bates, et al.; 1991] Bates, J., Loyall, A. and Reilly, W. Broad agents. In Proceedings of AAAI Spring Symposium on Integrated Intelligent Architectures, Stanford, CA. Available as a special issues of SIGART News, summer 1991.

[Benyon; 1993] Benyon, D., "Intelligent Interface Technology: Employing Intelligence at the Interface".Handbook of UI. 1993.

[Billsus, et al.; 2000] Billsus D, Pazzani, M. J., and Chen, J. "A learning agent for wireless news access." Proceedings of the 2000 International Conference on Intelligent User Interfaces , 2000, Pages 33 - 36.

[Bothé, et al. 2000] Bothé, Sander M., Langdon, William B., La Poutré, Han. On Current Technology for Information Filtering and User Profiling in Agent-Based Systems, Part I: A Perspective. Technical Report. CWI, Centre for Mathematics and Computer Science. 2000.

[Bothé, et al.; 2000] Bothé, S., Langdon, W. and La Poutré, H. On Current Technology for Information Filtering and User Profiling in Agent-Based Systems, Part I: A Perspective. 2000

[Borriello, 2002] Borriello, G., Key Challenges in Communication for Ubiquitous Computing: In IEEE Communications Magazine. May 2002.

[Bowne; 2003] Bowne & Co. Inc. On Line. Internet. Available at:
http://www.bowne.com/

[Brown, et al.; 1997b] Brown, Scott M., Robert A. Harrington, Eugene Santos Jr., and Sheila B. Banks, User Models, Intelligent Interface Agents, and Expert Systems, UM 97 Workshop: Embedding User Models in Intelligent Applications, Ed. Vadim Stefanuk, Chia Laguna, Sardinia, Italy, June 2-5 1997.

[Brajnik and Tasso; 1994] Brajnik, G. and Tasso, C. A shell for developing non-monotonic user modelling systems. Int. I. Human Computer Studies, 40, 1994: pp. 31-62.

[Breese et al.; 1998] Breese, J., Heckerman, D. and Kadie, C. Empirical Analysis of Predictive Algorithms for Collaborative Filtering. In Proceedings of the Fourteenth Annual Conference on Uncertainty in Artificial Intelligence (UAI-98). San Francisco, CA: Morgan Kaufmann, 43-52. 1998.

[Brown, et al.; 1997a] Brown, Scott M., Robert A. Harrington, Eugene Santos Jr., and Sheila B. Banks, User Models, Intelligent Interface Agents, and Expert Systems, UM 97 Workshop: Embedding User Models in Intelligent Applications, Ed. Vadim Stefanuk, Chia Laguna, Sardinia, Italy, June 2-5 1997.

[BroadVision; 2003] BroadVision Inc. On Line. Internet. Available at:
http://www.broadvision.com/OneToOne/SessionMgr/home_page.jsp

[Brusilovsky; 1999] Brusilovsky, P., InterBook Home Page [online]. Pittsburgh, PA, April 1999. Available from at:
http://www.contrib.andrew.cmu.edu/~plb/InterBook.html**.**

[Brusilovsky and Schwarz; 1997] Brusilovsky, P., and Schwarz, E. "User as Student: Towards an Adaptive Interface for Advanced Web-Based Applications." In Anthony Jameson, Cécile Paris, and Carlo Tasso (Eds.), User Modelling: Proceedings of the Sixth International Conference, UM97. Vienna, New York: Springer Wien New York, 1997, pp. 177-188.

[Brusilovsky; 2001] Brusilovsky, P. Adaptive Hypermedia. Peter Brusilovsky, User Modelling and User-Adapted Interaction 11: 87-110, 2001.

[Bueno, et al., 2001] Bueno David, Conejo Ricardo, Amos David. METIOREW: An Objective Oriented Content Based and Collaborative Recommending System. Lecture Notes in Computer Science. 2001.

[Byun and Cheverst; 2001] Byun, H.E. and Cheverst, K. Exploiting User Models and Context-Awareness to Support Personal Daily Activities. In Proceedings of Workshop on User Modelling in Context- Aware Applications. 8th International Conference on User Modelling UM2001. July 2001 in Sonthofen (Germany).

[Carroll, 2001] Carroll, J. M. Human--computer interaction: Psychology as a science of design. International Journal of HumanComputer Studies, 46(4), 1997, pp. 501--522.

[Castells, 2003] Castells, M. The Internet Galaxy: Reflections on the Internet, Business and Society. Oxford: Oxford University Press, 2003. ISBN: 0199255776

[Chen and Sovrin; 2001] Chen, Harry; Tolia, Sovrin. Steps Towards Creating a Context-Aware Agent System. In HP Labs 2001 Technical Reports HPL-2001-231.

[Conati and VanLehn; 1996] Conati, C. and VanLehn, K. POLA: a student modelling framework for Probabilistic On-Line Assessment of problem solving performance. In UM-96: Fifth International Conference on User Modelling: Proceedings of the conference. Kailua-Kona, HI: User Modelling, Inc. pp. 75-82. 1996.

[Crabtree, et al.; 1998] Crabtree, B. Soltysiak, S. and Thint, M. Adaptive Personal Agents. In: Personal Technologies Journal (1998) Vol. 2, No. 3, pp141-151.

[de la Rosa et al.; 2003] de la Rosa, J.Ll., López, B., del Acebo, E. and Montaner, M. Intelligent Information Agents: The Agentlink Perspective. Lecture Notes in Artificial Intelligence. Klusch, M. Bergamaschi, S. Edwards, P. and Petta, P. (eds.). Springer Verlag. Printed in Germany. 2003.

[Dickinson et al.; 2003] Dickinson, I., Reynolds, D., Banks, D., Cayzer, S., Vora, P., User Profiling with Privacy: A framework for Adaptive Information Agents. In Lecture Notes in Artificial Intelligence. 2586. Springer Verlag. 2003. pp. 123-151.

[Eisenstein and Rich; 2002] Eisenstein, J.; Rich, C., "Agents and GUI's from Task Models", ACM International Conference on Intelligent User Interfaces, ISBN: 1-58113-382-0 pps 47-54, January 2002.

[Ekman, 1982] Ekman, P. 1982. Emotion in the human face. 2nd Edition. Cambridge University Press, Cambridge, UK.

[Encarnação; 1997] Encarnação, L. Miguel, "Multi-level user support through adaptive hypermedia: a highly application-independent help component." Proceedings of the 1997 international conference on Intelligent user interfaces, 1997, pp. 187-194.

[Etzioni and Weld; 1994] Etzioni, O. and Weld, D. A softbot-based interface to the internet. Communications of the ACM 37(7):72–76. 1994

[Felder and Silverman; 1988] M. R. Felder and L. Silverman, "Learning and Teaching Styles in Engineering Education", In Engineering Education 78(7), 1988, pp. 674-681.

[Fink and Kobsa; 2002] Fink, J. and Kobsa, A. "User Modelling for Personalized City Tours". Artificial Intelligence Review. Kluwer Academic Publishers. Printed in the Netherlands. num. 18. 2002: p. 33–74.

[Fink and Kobsa; 2000] J. Fink and A. Kobsa. A review and Analysis of Commercial User Modelling Servers for Personalization on the World Wide Web. User Modelling and User-Adapted Interaction, Special Issue on Deployed User Modelling, 10(2-3):209-249, 2000.

[Fink, et al.; 1996] Fink, J., Kobsa, A., and Nill, A. "User-oriented Adaptivity and Adaptability in the AVANTI Project." Conference Designing for the Web: Empirical Studies. Microsoft Usability Group, Redmond, WA, 1996. Available at: http://fit.gmd.de/hci/projects/avanti/publications/ms96.html.

[Fink, et al.; 1997] Fink, Joseph, Alfred Kobsa, and Andreas Nill, "Adaptable and Adaptive Information Access for All Users, Including the Disabled and the Elderly." In Anthony Jameson, Cécile Paris, and Carlo Tasso (Eds.), User Modelling: Proceedings of the Sixth International Conference, UM97. Vienna, New York: Springer Wien New York, 1997, pp. 171-173.

[Fischer; 2000] Fischer, G. User Modelling in Human-Computer Interaction. User Modelling and User-Adapted Interaction. Kluwer Academic Publishers.2000.

[Fischer, et al.; 1985] Fischer G., Lemke, A.C. and Schwab, Th. 1985. Knowledge-Based Help Systems: In Proceedings CHI'85, 161-167. ACM, New York.

[FOLDOC; 2003] Imperial College Department of Computing. Free On-Line Dictionary Of Computing. On Line. Internet. 5 March 2003. Available at: http://foldoc.doc.ic.ac.uk/foldoc/index.html (Consulted April 2003.)

[Fukuda, et al.; 1994] Fukuda Manabu, Katsumoto Michiaki, Shibata Yoshitaka. Kansei Retrieve Method based on User Model. Department of Information and Computer Sciences, Toyo University.

[Garau, et al.; 2003] Garau, M., et al. The Impact of Avatar Realism and Eye Gaze Control on Perceived Quality of Communication in a Shared Immersive Virtual Environment. CHI, April 2003, Ft. Lauderdale, Florida, USA.

[González, et al.; 2002] González, G., López, B. J.L. de la Rosa; "The Emotional Factor: An Innovative Approach to User Modelling for Recommender Systems". Proceedings of Second International Conference Adaptive Hypermedia and Adaptive Web-Based Systems AH'2002. Workshop on Recommendation and Personalization in e-Commerce. Pages 90-99. May 28 2002. ISBN:699-8196-7. Printed in Spain.

[Gosh; 2002] Gosh, A. K.: Maintaining the Privacy in an Online World. IEEE Computer. IT Professional Magazine. September-October 2002. pp. 24-28.

[Goleman, D; 1995] Emotional Intelligence. New York, NY: Bantam Books. 1995.
[Green, et al., 2001] Gary Green, Andrew Batchelor, Mark Hymers, Sam Johnson and Will Woods, School of Neurology & Psychiatry, Newcastle University.

[Griss, et al.; 2002] Griss, Martin; Letsinger, Reed; Cowan, Dick; Sayers, Craig; VanHilst, Michael; Kessler, Robert CoolAgent: Intelligent Digital Assistants for Mobile Professionals - Phase 1 Retrospective. In HP Labs 2002 Technical Reports HPL-2002-55R1

[Gürer, et al.; 1995] Gürer, D. W., desJardins M. and Schlager M. Representing a Student's Learning States and Transitions In the 1995 AAAI Spring Symposium on Representing Mental States and Mechanisms, Stanford, CA; published as a AAAI technical report.

[Hashimoto, 1997] Hashimoto, S. Kansei as the third target of information processing and related topics in Japan in Proceedings KANSEI - The Technology of Emotion Workshop, pp. 101–104, 1997.

[Hernández and García, 2003] Hernández, J. and García, A. Endowing a virtual assistant with intelligence: a multi-paradigm approach. AMEC SIG meeting, 4th February 2003, Barcelona. On Line. Internet.Available at http://www.cs.uu.nl/people/dignum/hernandez.pdf

[Herlocker et al., 1999] Herlocker, J., Konstan, J., Borchers, A., and Riedl, J. An algorithmic framework for performing collaborative Filtering. In Proceedings of the 1999 Conference on Research and Development in Information Retrieval, August 1999.

[Hillsdale, et.al.; 1988] Hillsdale, NJ: Erlbaum. Facets of emotion: Recent research (pp. 241-243). In K. R. Scherer (Ed.) (1988). [Version revised by the members of the Geneva Emotion Research Group].

[Horvitz, et al.; 1998] Horvitz, E., Breese, J., Heckerman, D., Hovel, D. and Romelse K. "The Lumière Project: Bayesian User Modelling for Inferring the Goals and Needs of Software Users." Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence, Madison, WI, July 1998. Morgan Kaufmann: San Francisco, 1998, pp. 256-265. Available at: http://research.microsoft.com

[i33; 2003] i33 Technology Corporation. On Line. Internet. May 5 2003. Available at: http://www.i33.com/

[Ichida and Akiyoshi; 1998] Ichida, Y. and Akiyoshi, M. Collaborating Work on the Designing 3D Virtual-Reality with Agents. Information Processing Society of Japan SIGNotes. Human Interface. 1998.

[Imbert, et al.; 2000] Imbert, R., de Antonio, A. and Segovia, J.: The Bunny Dilema: Stepping between Agents and Avatars. Proceedings of the 17th Twente Workshop on Language Technology. The Netherlands. 2000.

[IntelliOne; 2002] IntelliOne Technologies Corporation. Agent Builder™. Smart*DER: Intelligent Agents For Distributed Control and Monitoring of Energy Resources. On Line. Internet. November 2002. Available at:
http://www.agentbuilder.com/AgentTechnology/agentApplications.html#CEC

[Intille; 2002] Intille, S.S. Designing a Home of the Future. IEEE Pervasive Computing, April-June 2002, pp. 80-86.

[iNET; 2002] iNET: Large-Scale Intelligent Open Service Environments http://eoi.cordis.lu/docs/int_37035.pdf

[IST-FP6, 2003-2004] European Commission. Information Society Technologies. A thematic priority for Research and Development under the Specific Programme "Integrating and strengthening the European Research Area" in the Community sixth Framework Programme. 2003-2004 Work Programme. Brussels: European Commission, 2003.

[ISO; 2000] ISO/IEC FDIS 9126-1: Software Engineering - Product quality - Part 1: Quality model. 2000.

[Jameson, et al; 1997] Jameson, A.; Paris, C. and Tasso C. "UM 97 Reader's Guide." User Modelling: Proceedings of the Sixth International Conference, UM97. On-line proceedings, 1997. On Line. http://w5.cs.uni-sb.de/~UM97/guide.html

[Jiang and Dasgupta; 2001] Jiang, Keyu and Dasgupta, Partha. SIMS: A Secure Information Management System for Large-Scale Dynamic Coalitions, The 2nd. Darpa Information and Security Conference and Exposition (DISCEX-II). July 2001.

[Joachims, et al.; 1997] Joachims, T., Freitag D. and Mitchell, T. Webwatcher: A tour guide for the world wide web. In Proceedings of IJCAI 97, August 1997.

[Johnson, et al.; 2000] Johnson, W., Rickel, J. and Lester, J. Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments. International Journal of Artificial Intelligence in Education 11:47-78, 2000.

[Joseph, 2001] Joseph, Sam.: AI., Japan Inc., November, 2001.

[Kass and Finin; 1988] Kass, R. and Finin, T.: Modelling the User in Natural Language Systems. Computational Linguistics 14(3):5-22.

[Kay, et al.; 2002] Kay, J, Kummerfeld, R. and Lauder, P. Personis: a server for user models, De Bra, P, P Brusilovsky, R Conejo (eds), Proceedings of AH'2002, Adaptive Hypertext 2002, Springer, 203 -- 212.

[Kay; 2000] Kay, J.: Accretion representation for scrutable student modelling. In: Gauthier, G., Frasson, C., VanLehn, K. (eds.) Intelligent Tutoring Systems. 2000. 514–523

[Kay; 1995] Kay, J. Vive la difference!: Individualised interaction with users. Mellish, C (ed), Proceedings of the International Joint Conference on Artificial Intelligence, Morgan Kaufman. 1995. p. 978-984.

[Kay; 1995] Kay, J. The um toolkit for cooperative user modelling, User Modelling and User-Adapted Interaction 4(3), Kluwer, 149-196. 1995.

[Kobsa and Wahlster; 1989] Kobsa A., Wahlster W. User Models in Dialog Systems. Springer, Heidelberg. Berlin: 1989.

[Kobsa; 1993] Kobsa, A.: "User Modelling: Recent work, prospects and hazards". In Adaptive User Interfaces: Principles and Practice. In Schneider-Hufschmidt, M., Kuhme, T., Malinowski, U. North-Holland, Amsterdam. 1993. 111-128.

[Kobsa; 1990] Kobsa, A.: Modelling the User's Conceptual Knowledge in BGP-MS, a User Modelling Shell System. Computational Intelligence, 6:193–208, 1990.

[Kobsa; 1995] Kobsa, Alfred. Supporting User Interfaces for all through User Modelling. Proceedings HCI International, Yokohama, Japan, 1995. p. 155-157.

[Kobsa and Pohl; 1995] Kobsa, A. and Pohl, W. The user Modelling Shell System BGP-MS. User Modelling and User-Adapted Interaction, 4 1995: pp.49-106.

[Kobsa, et al.; 2001] Kobsa, A., Koenemann, J., Pohl, W. "Personalized Hypermedia Presentation Techniques for Improving Online Customer Relationships". The Knowledge Engineering Review. vol. 16. num.2 (2001) : p. 111-115.

[Kobsa; 2001a] Kobsa, A. Generic User Modelling Systems, User Modelling and User-Adapted Interaction pages 49 - 63, 2001. Kluwer Academic Publishers. Netherlands.

[Kopecek, 2001] Kopecek, I.: Personality and Emotions - Finite State Modelling by Dialogue Automata. ; In Proceedings of UM 2001 Workshop on Attitudes, University of Bari, pp. 1-6, 2001.

[Kozierok and Maes; 1993] Kozierok, R. and Maes, P. A Learning Interface Agent for Scheduling Meetings. In Proceedings of the ACM-SIGCHI International Workshop on Intelligent User Interfaces, pages 81–88. New York, New York: ACM Press, 1993.

[Krenn, et al.; 2002] Krenn, B., Gstrein, E., Grice, M., What can we learn from users of avatars in net environments? Workshop: Embodied Conversational Agents: Let's specify and compare them! AAMAS 2002. www.flirtboat.at

[Krogsæter, et al.; 1994] Krogsæter, M., Oppermann, R., and Thomas, C.G. 1994. A User Interface Integrating Adaptability and Adaptivity. In Oppermann, R. (ed.) Adaptive User Support. Lawrence Erlbaum Associates, 1994:97-125.

[Lieberman; 1995] Lieberman, H. Letizia: An Agent That Assists Web Browsing. Proc. of IJCAI-95, Montreal. pages 924-929, 1995.

[Lieberman; 1995a] Lieberman, H. Letizia: An Agent That Assists Web Browsing. Proc. of IJCAI-95, Montreal. pages 924-929, 1995.

[Luck, et al., 2003a] Luck, M., McBurney, P. and Preist, C. Agent Technology: Enabling Next Generation Computing. A Roadmap for Agent-Based Computing. Version 1.0. Southampton: Agentlink, 2003. ISBN: 0854327886

[Luck, et al. 2003b] Luck, M., McBurney, P. and Preist, C. Agent Technology: Enabling Next Generation Computing. A Roadmap for Agent-Based Computing. Version 1.0. Southampton: Agentlink, 2003. ISBN: 0854327886

[Mayer and Salovey, 1993] Mayer, J. D., and Salovey, P. The intelligence of emotional intelligence. Intelligence, 17(4), 433-442. (1993).

[Martin and VanLehn; 1995a] Martin, J. D., & VanLehn, K. (1993). OLAE: Progress toward a multi-activity, Bayesian student modeler. In P. Brna, S. Ohlsson, & H. Pain (Eds.), Proceedings of the World Conference on Artificial Intelligence in Education (pp. 410- 417). Edinburgh, Scotland: AACE.

[Martin and VanLehn; 1995b] Martin, J. & VanLehn, K. Student assessment using Bayesian nets. International Journal of Human-Computer Studies, 42, pp. 575-591. 1995. Available at: http://www.pitt.edu/~vanlehn/distrib/journal/HCS95.pdf

[Montaner, et al., 2002a] Montaner, M., López, B., de la Rosa, J. Ll., "Improving Case representation and Case Base Maintenance in recommender Agents". In Proceedings of the 6th European Conference on Case Based Reasoning (ECCBR'02). Susan Craw, Alun Preece (Eds.), Lecture Notes in AI Nº2416. Springer-Verlag. pp. 234-248. Aberdeen (Scotland). 4-7 September, 2002.

[Montaner, et al., 2002b] Montaner, M., López, B., de la Rosa, J. Ll., "Opinion-Based Filtering Through Trust". In Proceedings of the 6th International Workshop on Cooperative Information Agents (CIA'02). Matthias Klusch, Sascha Ossowski and Onn Shehory (Eds.), Lecture Notes in AI Nº2446. Springer-Verlag Berlin Heidelberg, pp. 164-178, Madrid (Spain). 18-20 September, 2002.

[Montaner, et al., 2003] Montaner, M., López, B., del Acebo, E., Aciar, S., Cuevas, I., "IRES: On the Integration of Restaurant Services". Awarded with the Special Prize of the AgentCities Agent Technology Competition. Barcelona (Spain). pp. 6-8 February, 2003.

[Moukas and Maes; 1997] Moukas A. and Maes, P. User Modelling in a MultiAgent Evolving System. International Conference on User Modelling '97, Machine Learning in User Modelling Workshop Notes, Chia Laguna, Sardinia, 1997.

[Moukas; 1996] Moukas, A. Amalthea: Information discovery and filtering using a multiagent evolving ecosystem. In Proc. 1st Int. Conf. on The Practical Applications of Intelligent Agents and MultiAgent Technology (PAAM), London, 1996.

[Moukas and Zacharia, 1997] Moukas, A. and Zacharia, G. Evolving a Multi-agent Information Filtering Solution in Amalthea. Proceedings of the First International Conference on 87 Autonomous Agents, Marina del Rey, CA, February, pp. 394-403. ACM Press, New York, NY. 1997.

[Murray, 2002] Murray, R.M. Control in an Information Rich World. Report of the Panel on Future Directions in Control, Dynamics, and Systems. 2002. Available at: http://www.cds.caltech.edu/˜murray/cdspanel/. To be published by SIAM

[Nagamachi, 1997] Nagamachi, M.; "Kansei Engineering: The Framework and Methods". In M. Nagamachi (ed.): Kansei Engineering, Kaibundo Publishing, Kure, pp. 1-9. 1997.

[NII; 2002] Nomadicity in the National Information Infrastructure (NII) http://www.lk.cs.ucla.edu/LK/lkxiwt/nomads1.html

[Miller, 1991] Miller, M. B. (1991). Understanding Skinner. American Psychological Society Observer, 4(3), 24. [letter]

[Nwana and Ndumu; 1999] Nwana, H. S. and Ndumu, D.T. A Perspective on Software Agents Research the Knowledge Engineering Review, January 1999.

[OASIS; 2002] The Organization for the Advancement of Structured Information Standards [OASIS] Committee Specification 01, J. Hodges, E. Maler, Glossary for the OASIS Security Assertion Markup Language (SAML). On Line. Internet. 31 May 2002. Avalaible to http://www.oasis-open.org/committees/security/docs/cs-sstc-glossary-01.pdf (Consulted Nov 11th 2002).

[Ortony, et al.; 1988] Ortony A., Clore G., and Collins A., "Cognitive Structure of Emotions", Cambridge: Cambridge University Press, 988.

[Pazzani, et al.; 1996] M. Pazzani, J. Muramatsu, and D. Billsus. Syskill & Webert: Identifying interesting Web Sites. In Proc. of the National Conference on Artificial Intelligence, Portland, OR, 1996.

[Peña, et al.; 2002] Peña, C., Marzo, J. and de la Rosa, J. Intelligent Agents in a Teaching and Learning Environment on the Web. 2ond IEEE International Conference on Advanced Learning Technologies (ICALT2002), Kazan (Russia), September 9-12, 2002, ISBN 0-473-08801-0.

[Peppers and Rogers; 1993] Peppers, D. and Rogers M. The One to One: Future Building Relationships. One Customer at a Time. 1993. ISBN 0-385-48566-2

[Petrelli, et al.; 1999] Petrelli, D., De Angeli, A., and Convertino, G., "A User Centered Approach to User Modelling." In Judy Kay (ed.), User Modelling: Proceedings of the Seventh International Conference, UM99. Springer Wien New York, 1999, pp. 255-264.

[Picard 1997] Picard, R. W.: Affective Computing. Cambridge, MA: M.I.T. Press.1997.

[Quenndom]2003]http://www.queendom.com/tests/iq/emotional_iq_r2_access.html

[Reagle and Cranor; 1999] Reagle and Cranor. "The Platform for Privacy Preferences" Communications of the ACM 42, 2 (Feb. 1999), Pages 48-55.

[Rich; 1979] Rich, E. User Modelling via Stereotypes, Cognitive Science, 3(4), 1979, 329-354.

[Rich; 1989] Rich, E. "Stereotypes and user modelling". User models in Dialog Systems. Kobsa, A. and Wahlster, W. 1989. Berlin: Springer-Verlag.1989.

[Ricci, 2002] Ricci, F. Travel Recommender Systems. IEEE Intelligent Systems. 55-57. November/December 2002.

[Roseman, et al., 1990] Roseman, Ira, Martin S. Spindel, and Paul E. Jose: "Appraisals of Emotion-Eliciting Events: Testing a Theory of Discrete Emotions."

[Roush, 2002] Roush, W. The State of Information Technology: In Technology Review, MIT Press. June. 2002.

[Rusell and Norvig, 1995] Russell, Stuart and Norvig, Peter. Artificial Intelligence: A Modern Approach. Prentice-Hall, Inc.1995.

[Sadeh, et al.; 2002] Norman Sadeh, Enoch Chan, Yoshinori Shimazaki, Linh Van, "MyCampus: An Agent-Based Environment for Context-Aware Mobile Services", AAMAS02 Workshop on "Ubiquitous Agents on Embedded, Wearable, and Mobile Devices", Bologna, Italy, July 2002.

[Schafer, et al.; 1999] Schafer, J., Konstan, J. and Riedl J. Recommender Systems in E-Commerce. ACM Conference on Electronic Commerce. 1999.
[Serco Ltd; 2002] Serco Ltd. User centred design standards. On Line. Internet. December 2002. Available at:
www.usability.serco.com/trump/resources/standards.htm

[Seif, et al.; 1998] Magy Seif El-Nasr, Thomas R. Ioerger, and John Yen, "Learning and Emotional Intelligence in Agents," Proceedings of AAAI Fall Symposium 1998, FL, 1998.

[Seif, et al.; 1999] El-Nasr, M.S., Ioerger, T. R. and Yen, John. PETEEI: A PET with Evolving Emotional Intelligence. Proceedings of Autonomous Agents Conference '99, WA, 1999.

[Seo and Zhang, 2000] Seo, Y.-W. and Zhang, B.-T. Learning User's Preferences by Analyzing Web-Browsing Behaviors. Proceedings of the Fourth International Conference on Autonomous Agents (Agents-2000), pp. 381-387, 2000.

[Shubin, 1999] Shubin, H. User models as a basis for web design. Proceedings of ACM/SIGCHI annual conference on Human Factors in Computing Systems. Workshop on Organizing Web Site Information. Pittsburgh, PA, USA. May 15-20, 1999.

[Shortliffe, 1976] E. H. Shortliffe, Computer-based medical consultation: MYCIN, Elsevier, New York, 1976
[Simons; 1997] Joep Simons. Using a semantic user model to filter the World Wide Web proactively. pages 455-456. Springer, 1997.

[Soloman and Felder; 1993] Soloman, B. and Felder, R. Index of Learning Styles Questionnaire. On Line. Internet. Available at:
http://www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSdir/ilsweb.html

[Sparck Jones; 1990] Sparck Jones, K.: What's in a User? Proceedings of the 8th National Conference on Artificial Intelligence. Boston, Massachusetts, July 29 - August 3, 1990. AAAI Press / The MIT Press, p. 1140-1141 1990, ISBN 0-262-51057-X, 2 Volumes

[Specht and Oppermann; 1999] Specht M. and Oppermann R. User Modelling and Adaptivity in Nomadic Information Systems. In: Proceedings of the 7. GI-Workshop "Adaptivität und Benutzermodellierung in Interaktiven Softwaresystemen. Universität Magdeburg 27. 9.1. 10. 99, pp. 325 – 328.

[Strachan, et al.; 1997] Strachan, L., Anderson, J., Sneesby, M., and Evans, M. "Pragmatic User Modelling in a Commercial Software System." In Anthony Jameson, Cécile Paris, and Carlo Tasso (Eds.), User Modelling: Proceedings of the Sixth International Conference, UM97. Vienna, New York: Springer Wien New York, 1997. pp. 189-200

[Thomas and Fischer; 1996] Thomas, C. G., and Fischer, G. Using agents to improve the usability and usefulness of the World-Wide Web. In Fifth International Conference on User Modelling, 5–12. 1996.

[Tomofumi, et al.; 2002] Tomofumi Hayashi, Akio Sato, and Nadia Berthouze. A Hierarchical Model to Support Kansei Mining Process. In Proceedings Intelligent Data Engineering and Automated Learning - IDEAL 2002. Third International Conference, Manchester, UK, August 12-14, 2002.

[Tsiriga and Virvou; 2002] Tsiriga, V., Virvou, M. Initializing the Student Model using Stereotypes and Machine Learning. In Proceedings of the 2002 IEEE International Conference on Systems, Man and Cybernetics, 2002.

[UM; 2003] 9th International Conference on User Modelling. UM'03. On line. Internet. June 22-26 2003. Available at:
http://www.sis.pitt.edu/~um2003/docs/um03flyer.pdf (Consulted February 20 2003)

[UM; 2001] Workshop on User Modelling for Context-Aware Applications. UM 2001.

[VanLehn; 1993] VanLehn, K. Cascade: A simulation of human learning and its application. In Proc. Brna, S. Ohlson, & H. Pain (Ed.), World Conference on Artificial Intelligence in Education, (pp. 1-3). Edinburgh, Scotland: AACE. 1993.

[Van de Velde; 1997] Van de Velde, W. Co-habited Mixed Reality. In Proceedings of IJCAI'97. Workshop on Social Interaction and Communityware, 1997.
[Bernstein and Bushnell, 2002] Bernstein, D.S. and Bushnell, L.G. The history of control: from idea to technology. IEEE Control Systems Magazine. 2002. Vol. 22, 2, pages 21--23, April 2002.

[W3C; 2002] World Wide Web Consortium. The Platform for Privacy Preferences 1.0 (P3P1.0) Specification. W3C Recommendation. On Line. Internet. 16 April 2002. Available at: http://www.w3.org/TR/2002/REC-P3P-20020416/

[Wahlster and Kobsa; 1986] Wahlster, W. and Kobsa, A. Dialog-Based User Models. Internal Report. Saarbrucken: University of Saarbrucken. 1986.

[Weber and Specht; 1997] Weber, G. and Specht, M. User modelling and adaptive navigation support in WWW-based tutoring systems. Proceedings of User Modelling '97. 1997. pp. 289-300.

[Weiss, 1999] Weiss, G. Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence. Edited by Gerard Weiss. ISBN: 0-262-23203-0. 1999.

[Willmott, et al.; 2002] Willmott, S., O'Brien, P., Thompson, S., Cortes, U., Charlton. P., Bonnefoy, D., Girenko, A., Klusch, M., Luck, M. iNet: Large-Scale Intelligent Open Service Environments. 7th July 2002. Available at: http://www.agentlink.org/fp6/docs/agentcities-inet_eoi-response_07.06.02b.pdf

[Wooldridge and Jennings; 1999] M. J. Wooldridge and N. R. Jennings, (1999) "Software Engineering with Agents: Pitfalls and Pratfalls" IEEE Internet Computing 3 (3) 20-27.

[Wooldridge; 2002] Wooldridge, Michael. An Introduction to Multiagent Systems. Published in February 2002 by John Wiley & Sons (Chichester, England). ISBN 0 47149691X.

[Wu, et al.; 2001] Wu, H., De Kort, E. and De Bra, P. Design Issues for General-Purpose Adaptive Hypermedia Systems. Proceedings of the ACM Conference on Hypertext and Hypermedia, pp. 141-150, Århus, Denmark, 2001.