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Current Challenges and Applications for Adaptive User Interfaces

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1. Introduction

In this chapter we present the current advances in the field of adaptive user interfaces, analysing the different research efforts, the challenges involved as well as the more recent and promising directions in this field. Initially, we introduce the foundations of adaptive user interfaces, also referred in technical literature as Intelligent User Interfaces (IUIs), then we move to explore the motivation and rationale for their use, and finally we discuss the challenges they currently have to deal with. In this context, IUIs are presented as a multi-disciplinary field, with relevant research and cross-fertilized ideas derived from different areas, however special emphasis is put on the approaches taken by three core disciplines: Artificial Intelligence (AI), User Modelling (UM) and Human-Computer Interaction (HCI). After providing the foundations for IUIs, an in-depth revision for each approach is presented including the most recent findings in models, algorithms and architectures for adaptive user interfaces.

Although, adaptive user interfaces are considered a recent research field, this chapter is enriched with a state-of-the-art of IUIs applications. The material included presents the most relevant developed IUIs applied in different real domains either as a research prototype or as a complete system. A methodological analysis of these systems is presented, contrasting its advantages, limitations and domain-dependence for its success and acceptance by users. The analysis aims to uncover common principles for effective IUI design. Also, this chapter details our proposed taxonomy which is applied for the comparison of the different IUIs systems.

Finally, the chapter presents the gaps left by the approaches under analysis and concludes with a discussion of the challenges currently open, presenting a number of possible future research directions.

User interfaces (UI) for the computing systems have changed in the last 20 years. The first UIs based on text that used a command prompt to access the operating system resources, have been replaced for user graphics interfaces (GUIs) that are manipulated through entry devices like keyboard and mouse. At present, user interfaces attempt to be more intuitive to the user by presenting graphic elements visually associated with real elements by the use of metaphors (Dix et al, 2003.)

An interaction paradigm widely use in the current operating systems is the use of multiple windows to present information as well as the use of icons to represent environment elements such as folders, files, devices, etc, and the use of menus and buttons, that facilitate the interaction with the system. This paradigm known as WIMP (Windows, Icons, Menus, Pointers) was developed by Xerox PARC in the 80's, and was initially used by Apple Macintosh computers and currently present in others operating systems such as Microsoft Windows, OS/ Motif, Risc OS and X Window System (Shneiderman & Plaisant, 2004.) However, still with these advances and the functionality offered by current GUIs, most of current GUIs are still limited as to how to handle the differences existing between the different UI users, being clear that exists limitation in the development of systems that can be personalized and adapted to the user and to the environment.

Intelligent User Interfaces is a HCI sub-field and its goal is to improve the interaction human-computer by the use of new technologies and interaction devices, as well as through the use of artificial intelligence techniques that allow exhibiting some kind of adaptive or intelligent behavior.

2. Applications and usage for the IUIs

IUIs attempt to solve some of the problems that traditional user interfaces, known as direct manipulation cannot handle appropriately (Shneiderman, 1997).

- *Create personalized systems:* There are not two identical users and each one has different habits, preferences and ways of working. An intelligent user interface can take into consideration these differences and provide personalized interaction methods. Since a IUI might know each user preferences, it's feasible to use that knowledge to set the best communication channel with that particular user.

- *Filtering problems and information over-load:* Trying to find the required information in a computer or in the Internet can be a complicated task. Here an intelligent interface can reduce the quantity of relevant information to look at in a large database. Also, by filtering out irrelevant information, the interface can reduce the user's cognitive load. An IUI can suggest to the user new and useful sources of information been unknown at that moment.

- *Provide help for new programs:* The information systems can be very complicated to manage and user productivity cab be reduced at the beginning when user gets to know application features. Unfortunately, as the user begins to understand the program functionalities, new versions or upgrades appear including new functionality. In this situation an intelligent help system can detect and correct an inapropiate usages or sub optimal task accomplishments by explaining new concepts and providing information to simplify the tasks.

- *Take charge of tasks on behalf of the user:* An IUI can see what tasks the user is attempting to accomplish, understand the context and recognize his attempt, and finally deal with the execution of a complete set of certain task, allowing the user to focus its attention to others tasks.

- *Other interaction mechanisms:* Currently the most common interaction devices of a computer sytem are the keyboard and the mouse. An important and active IUI research area within HCI known as Multi-modals Interfaces aims to discover new ways of interaction. Multimodals user interfaces attempt to find new paradigms for input/output interaction between systems and users. It is believe that by providing multiple means of interaction, people with disabilities will be able to use complex computational systems.

3. Definition and Related Areas

Certainly through years numerous definitions of intelligence have been proposed in order to define systems and behaviors, however none consensus exist on what has to be considered an intelligent system or behavior. Nevertheless, most of proposed definitions associate the adaptation ability, ability to learn and handle new situations, ability to communicate and the ability to solve problems (Russell & Norvig, 2003)

A "normal" user interface is defined as a communication between a user (human) and a machine (Meyhew, 1999.) An extension of this definition for an intelligent interface is that computer uses some kind of human intelligence component to complete the human-computer communication. Likewise, they are also known as adaptive interfaces, since they have the ability to adapt to the user, communicate with him and solve its problems. A formal definition is as follow: *"Intelligent user interfaces (IUIs) are human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by representing, reasoning, and acting on models of the user, domain, task, discourse, and media (e.g., graphics, natural language, gesture)"*. (Maybury, 1999).

Since adaptation and problem solving are core topics in the artificial intelligence research area, a lot of IUIs are orientated to the use of AI techniques, however not all IUIs have learning or problem solving capabilities. Many of the currently denominated intelligent interfaces are aimed to improve aspects related to the communication channel between the user and the system (machine) by applying novel interaction techniques such as Natural Language processing, *gaze tracking* and facial recognition. HCI literature reveals that a lot of research fields have influenced the IUIs development to its current state. Related areas to IUI includes disciplines such as psychology, ergonomics, human factors, cognitive sciences and others as shown in figure 1.

One of the most important properties for IUIs is that they are designed to improve the interaction and communication channel between the user and the machine.

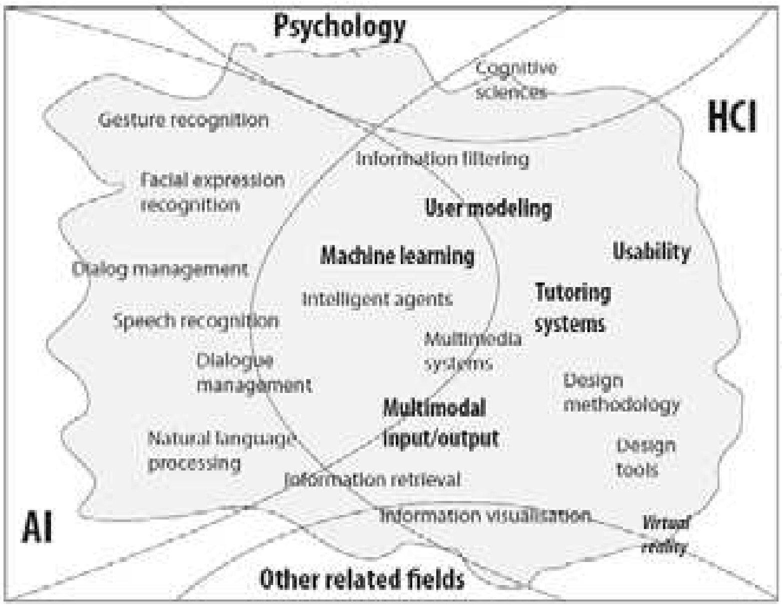

Fig. 1. Intelligent User Interfaces and its different disciplines involved

From an HCI point of view it is not so important what specific technique is used to get this improvement as long as the improvement is achieved. A number of techniques that are relevant are shown bellow:

- *Intelligent input technology:* It deals with the use of techniques to obtain user's input to the system. These techniques include natural language processing (speech recognition and dialog systems), gesture recognition, facial expressions recognition and lip reading.
- *User modeling:* This research area includes techniques that allow a system to keep or infer knowledge about a user based on the received information as input.
- *User adaptivity:* It includes all the techniques to allow that human-computer interaction to be adapted to different users and different usage situations.
- *Explanation generation:* It deals with techniques and mechanisms that aims to explain to the user in a logical and understandable form the underlaying reasoning in an intelligent user interface.
- *Personalization:* In order to be able to customize a user interface usually most current IUIs include some kind of user's representation. User's models logs data about users behavior, his knowledge and abilities. New discvored knowledge about user can infered based on new input data and user-system historical interaction loggins.
- *Usage flexibility:* In order to remain flexible, a number of IUIs integrates user adaptation and computational learning. Adaptation is accomplished by using the knowledge stored in the user model and inferring new knowledge using the current input. Computational learning is used when knowledge stored in the user model is changed to reflect new found situations or data.

4. Intelligent Interfaces and Intelligent Systems

It is common to assume that an IUI is also an intelligent system and confusion frequently arises. A system that exhibits some kind of intelligence not necessarily has an intelligent user interface. It is not rare for intelligent systems to have very simple user interfaces, even text-based user interface where no intelligence exist. Likewise, the fact that a system has an IUI does not reveal us anything about the system intelligence *per se*. See figure 2.

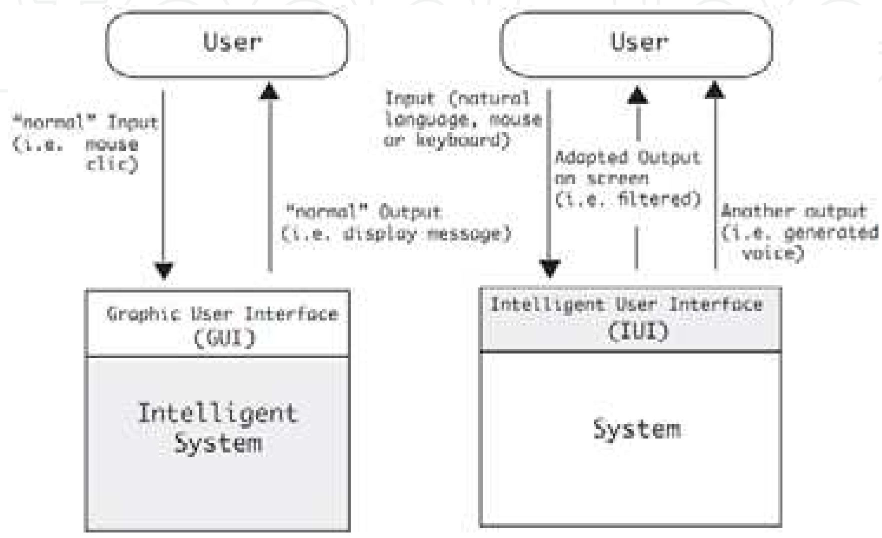

Fig. 2. The IUIs vs. an Intelligent System

Unfortunately the dividing border between a system and its user interface is not always clearly defined as it is shown in figure 2. Often times the technology the IUI is based on has an underlying connection with the core parts of the system, sometimes the IUI is actually the system itself. For practical purposes, in many applications for specific domains (i.e. power plants, utilities, etc.) usually not much attention is pay to the user interface side. An analysis, assessment and development assigned to an expert group in user interfaces and ergonomics is not always a reality. When developing an intelligent system the emphasis is put on the inner workings, algorithms and data manipulation, leaving out the user interface as another system component (Hook, 1999.)

5. Benefits and criticisms

IUIs research is a relatively new area, not yet unified and in constant evolution where a number of challenges remain open, still expecting a better approach or solution. Maybe the direct association between IUI and Artificial Intelligence has received skepticism from a part of HCI community. The central problem can be reduced to the fact that IUIs violate some of the long time established and accepted principles in the traditional (direct manipulation) user interfaces development. Maes's research work at the MIT Media Lab (Maes, 1994) and findings reported by Wernn (Wernn, 1997) present an extensive explanation of potential applications and domains for intelligent user interfaces, clearly establishing the points that have to be discussed and resolved before IUIs became widely accepted and used in commonplace.

A number of HCI researchers (Shneiderman, 1997) consider that an IUI or adaptive system is unpredictable and less transparent than a traditional user interface. If a system can adapt its response and cannot provide the same output twice for the same input, the system becomes unpredictable. A similar situation occurs regarding the control on the interface. Possible scenarios are that the user takes the control and decides the next action to accomplish. On the other hand the system could autonomously take control on the interface based on its partial knowledge and decides the next action. This situation has been confronted from different approaches resulting in specializing areas within the IUI discipline.

Adaptable interfaces grants the user full control over the interface by allowing him to manage and customize the adaptation through selections of available options to personalize and adapt the interface. On the other side we have the *Adaptive interfaces* where the system has sufficient intelligence and autonomy to evaluate the current state and make a decision to achieve some kind of adaptation without the user's intervention. A third interaction scheme that has been reported and received acceptance within the AI area is known a *mixed-initiative* or combined-initiative interfaces, where the interaction and control over the interfaces is share between the user and the system (Armentano, 2006). An in-depth discussion among user interface experts can be found in the reported work by Birnbaum (Birnbaum, 1997) where an analysis about the advantages and disadvantages between IUIs and traditional user interfaces is presented.

6. Machine Learning for the IUIs

The use of artificial intelligence techniques to design IUIs has been a widely accepted approach within the HCI interface community that has been applied to different applications and domains.

A wide spectrum of AI techniques have been applied for IUIs development, from traditional Production Systems (rule-based) to more sophisticated techniques such as planning and probabilistic graphic models (Horvitz, 1998) to recent techniques of IA such as autonomous agents (Rich & Sidner, 1996) (Eisenstein & Rich, 2002).

These AI techniques have been applied to generate different degree of intelligence (or adaptability) taking advantage of the knowledge the system has about the user and the tasks at hand to provide the best interaction experience using the system.

Machine Learning (ML) and related algorithms used to include the adaptibity component in IUI, have experience a fast growing development in the last ten years, gaining acceptance in AI community. Machine learning has been applied with relative success in several domains and applications, mainly in Web applications to collect information and mine data from user’s interaction and of navigation logs (Fu, 2000). Likewise, machine learning has been used as a mean to infer user's models (Stumpf et al., 2007) based on past data (history logs) aiming to discover unknown patterns and adapting the IUI behavior accordingly.

In ML terms, an intelligent user interface can be conceptualized like "*a software component that improves its capacity to interact with the user by generating and maintaining a user model base on the partial experience with that user*" (Langley, 1999). This definition clearly state that an intelligent interface is designed to interact with real, human users. Even more, if a user interface is to be considered intelligent, then it must improve its interaction with the user as time passes by, considering that a simple memorization of those interactions is not sufficient, but the improvement must come as results of a generalization of past experiences in order to establish new interactions with the user.

It is possible to identify two intelligent user interfaces categories with a ML approach which are different in the kind of feedback the user must provide:

- *Informative:* This kind of interface attempts to select or modify information and present only those elements the user might find interesting or useful for the task at hand. The most common examples are the recommender systems (i.e online bookstore as Amazon.com) and news filters, where users attention is directed within a wide option space. In these systems the feedback provided by the user involves to mark recommendation options as desirable or not desirable and ranking them. However this type of interfaces is intrusive and distracts users attention from the central task, since the user must provide feedback. IUI literature (Sugiyama, 2004) reports a group of less intrusive methods to obtain feedback by observing the access process.

- *Generative:* These kind of interfaces are aimed mainly to the generation of some useful knowledge structure. This category includes programs for documents preparation, spreadsheets, as well as planning and configuration systems. These interfaces support an enhanced feedback because the user can ignore not only a recommendation, but simply replace it with another one. The feedback is linked to the kinds of interaction supported by the interface. A number of systems require the user to correct not desirable actions, which pose an interruption problem, however recent systems integrates less intrusive schemes by observing the user's actions. (Franklin et al., 2002.)

One feasible approach reported in HCI literature to generate adaptive interfaces is through mining Web usage loggings. The access Web logging constitutes an abundant source of information that allows to experiment with real datasets. Adaptive Web systems provide the user better user interface navigation by providing personalized direct links. During the adaptation process, the user's data access are the central source of information and is used to build the user's model, which reflex the pattern the system inferred for the users and describes several user characteristics. Data mining using Association Rules has been used to mine the navigation logs from web sites and also to suggest new links based on collaborative filtering. (Mobasher et al., 2001.)

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7. User modeling of the user in the IUIs

User interface and User modeling (UM) can be seen as I two sides of a same component. User model consists of the algorithms that are implemented in the software level to show the personalization concept from the system's perspective. On the other hand, Graphic User Interfaces (GUI) display the content generated by the UM to the user, showing the personalization from the user's point of view as shown in figure 3.

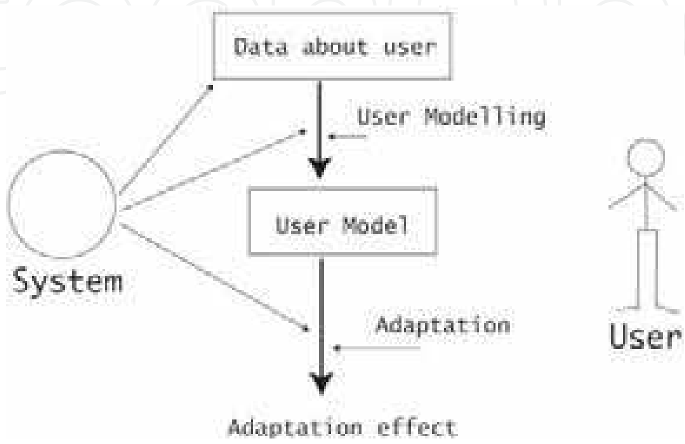

Fig. 3. Two perspectives for the User Model.

User modeling applications can be defined as applications where "*users with different objectives, interests, experience levels, abilities and preferences can adapt the program behavior to individual needs by using a user's profiles*" (Kobsa, 1994)

The UM purpose is collect, process and display adapted data to the interface level by a compilation of knowledge through two kinds of information:

- *Implicit:* This data compilation involves examining log files suchs as navigation history or the browser "cookies" (Fu, 2000). The discovery of patterns in data allows contents filtering and its addressing based on assumptions made on the user's behavior. For example, if a user regularly review certain particualr items, the UM will identify a pattern and can alter the user interface to unfold those elements and associate those elements in a web page accesible to the user. This is a UM automated technique that does not require a straight forward feedback from user in order to identify a behavior pattern and modifying the content according to it.

- *Explicit:* Explicit data gathering involves the data analysis entered by users, providing information about their preferences by filling out a user profile. For example: age, gender, city, shopping history, contents preferences and display data layout. This technique is known in the UM area as an informed technique and requires the user to enter data and a mechanism for recognizing patterns in the user preferences in order to modify the user interfaces based on those preferences.

User models can be used to create personalized services, adapting its elements to individual needs through information or collaborative filtering techniques (Carenini, 2003). Users can take control over the interaction by choosing explicitly based on user profiles through recommendation systems that establish associations between an individual purchase records or of navigation log with that similar users (Kirsh-Pinheiro et al., 2005.)

Adaptive user interfaces present users models at the user interface level by displaying personalized contents. (Eirinaki & Vazirgiannis, 2003). Likewise users also have the opportunity to interact directly with user model when creating and editing the profiles. User modeling and the adaptive user interface essentially both present personalized views for contents that can save time for locating information or guiding the users to available and unknown contents the user.

In summary, the UM is a solid alternative for presenting personalized content and it is considered a useful tool to the user that allows the use of Explicit data. On the other hand there is skepticism about the use of implicit data to create imprecise stereotypes based on complex inference algorithms (Peyton, 2003), since a large amount of literature reports few tests with real users. "*An UMUAI review in the last 9 first years reveals that a third part of the articles includes some kind of evaluation only. This is a very short percentage* (Chin, 2001.)

8. HCI in the IUIs

An HCI approach to solve the interaction problems has been centered on the use of different ways of interaction or means to communicate the user with the system. The central idea is to make this interaction in the most natural way, similar to that found between humans. If we take into account that we as humans perceive the world through our senses (touch; sight; hearing; smell and taste), then it seems logical the idea to unify this information in a computer capable to process it through different available devices (keyboard, microphone, camera; etc) in a multi-modal scheme, presenting what is known as multi-modal user interfaces. Multi-modal interfaces integrate two or more means of communication in order to improve the interaction channel between system and human.

Current state-of-the-art multi-modals interfaces can process two or more combined input modes based on recognition technologies, aiming to accurate identify and interpret the user communication intentions (Reeves et al., 2004). There are a number of multi-modals interfaces, including those that process voice and pencil input or through touch-sensitive screens and voice systems. Computational vision technologies and voice processing are fundamental to the development of this kind of interfaces and they are extensively reviewed in Oviatt's research (Oviatt et al., 2000.)

A novel approach in the multi-modals interfaces area is the integration of agent's technology, multimedia components and virtual reality with artificial intelligence techniques for the development of characters similar to humans who interact with the users in a more natural way. Throughout the use of computational vision and voice processing, these human-like characters or agents known as ECAS (*Embodied Conversational Agents)* represent a research line that integrates several areas (Cassell, 2000.) It has been revealed that in these ECAs virtual environments the user interfaces developed for interaction need to address new design challenges.

9. Related systems

A number of related systems reported in the user interface literature with relevant adaptivity features are presented in this section.

9.1 SurfLen System

One of the core elements in adaptive user interfaces is its capacity to anticipate the tasks the user will execute based on observing current actions, his behavior and the user model. A research line reported in IUI literature is based on setting future actions (tasks; navigation; plans; strategies, etc.) considering the analysis of history logging of the last actions of the user (or also of a group of users) by using AI techniques in order to complete some kind of reasoning on this information and deduce the action to do. Fu's work (Fu, 2000) is one of this kind, however it is focused on an on Web based information recommender system.

Author's hypothesis state that user's navigation logs contain sufficient information to discover knowledge about interesting pages for the user, without the need for a user to assigns a grade or input additional information, which is a disadvantage in current systems. Likewise authors express that it is possible keep track of what the user has read, in an active but silent way and collect the navigation logs in a centralized repository in order to apply AI techniques to discover knowledge. For example, if two users have read several similar pages, it's possible to infer that both users have similar interests. This knowledge about pattern navigation similarity is used to generate (infer) the recommendations.

To probe these positions, the authors developed a recommendation system prototype called *SurfLen* that suggests to users interesting pages on specific topics. Developed prototype uses Agrawal algorithm proposed by authors for generating a set of association rules with an *a-priori* optimization. The prototype evaluation reports that the number of correct suggestions by user increases as the navigation record becomes more representative of his interests.

A relevant part of this work is the use of the Agrawal *a priori* optimization algorithm applied to navigation logs but aimed at making recommendations. Likewise, suggested scheme with association rules offers advantages on similar systems since no intervention is required from the user. A weak part of its developed prototype and testing is that experiments were simulated and carried out in a well controlled environment. Prototype test results mentioned that it has advantages over other techniques; however no comparison with a similar system is mentioned. On the other hand, is not discussed either the fact that datasets creation as URL number increase (as well as the users) must be costly in terms of processing time, even with the optimization applied.

This prototype is relevant to HCI issues since it exhibits AI techniques that might be suitable and extensible to other domains such as those found in user interfaces for supervision and control, in power plants operation that aim to implement an adaptation mechanism. A possibility would be to analyze the navigation logs for operators (expert, beginner, medium) in different situations (normal, emergency) or in different stages (start; operation; shut down) to create a navigation pattern that allows to predict and recommend the next displayed screen (or action) based on the operators loggings (or loggings from a number of similar operators)

9.2 Adaptive Interfaces for Process Control

The reported system by Viano (Viano et al., 2000) is relevant because it deals with the adaptive user interfaces, particularly aimed at user interfaces for critical operations such as those used for process control. Additionally the presented prototype is designed to be used in two applications: systems for the power grids handling and a system for the supervision of a thermoelectric plant generation.

The authors argue that due to the increasing complexity in control systems, operators limitations to handle in real-time a large amount of information as well as in fault situations, along with the demands for keeping the operation continuity, allows a serious consideration for adaptive systems. These systems can alter its structure, functionality or interface in order to adjust its behavior to different individual requirements or groups of users. The adaptive approach proposed in this research, allows to assist the operator in acquiring the most relevant information in any particular context.

The central position of the article is that the operator's interface design is rigid; since it is established at design time, taking into account the best accepted practices or ergonomic guides recommended by HCI literature. However, once established this situation, it is kept immutable during the application execution. This mapping between the kind of information that is receiving from field and the way (and means) used to display it to the user, it is not unique, but the one the designer selects and considers more effective and efficient, however other possible mappings are discarded. So, no matter how good the initial design it is, it will be a static one from the design stage. This situation poses associated disadvantages since the user interface design is a rigid, not designed to fault or emergency situations, and so on. The adaptive user interface architecture proposed in this work considers the adaptation in the information presentation. Authors paper denominate their model as "Flexible Mapping" based on that current process state, environment and of human factors knowledge.

The paper proposes architecture based on multi-agents technology, where agents for the following functions are included: Process model, communication means, display resolution, presentation, human factor database and operator. Likewise two principles are considered to start the adaptation mechanism: When a deviation from normal process is detected and when there is an operator's deviation (not reacting accordingly to the expected procedure.)

Initially authors mention their suggested approach has benefits that are evaluated in two prototypes, however in the Prototypes section, it is stated that those prototypes are still in development. An important contribution from this research the hypothesis presented and the arguments presented for a description of the needs in the process control systems and why an adaptive approach is required and desirable.

Another relevant point fro this research is the architecture presented, still when the given explanation on the components and the interaction between them is scarce, since no other work in the electric area had reported this architecture based on multi-agents. On the other hand, a weak part of found is the fact that authors do not mention the coordination mechanisms, which represent an important aspect and a real challenge in the multi-agents systems. In general terms this work present at a high level overview but do not go deeper into details and the state of the art presented could include more related works in the area.

9.3 ADAPTS System

The ADAPTS system developed by Brusilovsky (Brusilovsky & Cooper, 2002) use the approach to include different models (tasks, users and environment) to adapt content and navigation in a hypermedia adaptable system. These features are relevant and open a possibility to extend research works in adaptive user interface models for other domains. E electrical and control processing domain are feasible domains for intelligent assistant system to aid in adapting the presented content, taking into account the user characteristic as well as the plant status.

ADAPTS system *(Technical Support Personalized And Diagnostics Adaptive)* is described as an electronic help system for maintenance that integrates an adaptive guide from a system of diagnosis system which has adaptive access to technical information covering both sides of the process: What to do and how to do it. ADAPTS is an extensive project, a result of the joint collaboration between the Naval Research Airs Warfare Center, Aircraft Division, Carnegie Mellon University researcher center, University of Connecticut and the Antech Systems Inc company.

A core component in ADAPTS architectures is the IETM (*Interactive Electronic Technical Manuals*) which provides a large amount of information about the system: how is built, its operation and what do in the event of specific problems, etc. ADAPTS is a complex adaptive system that adjust its diagnostic strategy according to who is the technician and what he is doing, dynamically adapting the configurations sequence, tests, repair or replacement procedures based on technician's answers. Likewise the system integrates domain knowledge of the control, maintenance tasks and users uniqueness.

User model proposed by authors determines which task must be accomplished, which technical information should be selected to describe the task and how to present it in the more adequate form for a particular technician. The problematic issue established in this research works has to do with the amount of potentially relevant information at a given moment in the process of repairing can become really large and is a challenge for a technician to find the more suitable information according to their experience level and work context. To accomplish this task it is necessary to find a way to permanently and dynamically evaluate the technician knowledge, his experience level, work preferences and context.

Also, the proposed model handles the experience level by calculating from several evidences of the technician's experience level. These evidences are silently collected by the system when interacting with the technician. Likewise ADAPTS uses Multi-Aspect Overlay Model that is a more expressive UM, but at the same time it is more complex to generate and maintain.

ADAPTS authors presents the developed system, its proposed models and how they can be used to build an adaptive system, however it is not clearly stated or justified why the 20 suggested aspects used to evaluate the user experience are sufficient or the adequate ones. An uncertain aspect in the proposed model is that it is assumed that if a user asks the IETM for a display, he necessarily reads it. It would be appropriate to include a certain level of probability uncertainty or time before assuming this situation, as it is done in other similar systems. It is relevant the fact that scarce data on validation experiments is presented. More information regarding ADAPTS evaluation, real utility, application in the field, users satisfaction, and so on, might require more details, however it is fair to acknowledge that ADAPTs is a complex, large and complete system.

9.4 A Decision Making Model

The suggested approach discussed in Stephanidis (Stephanidis et al., 1997) conceptualizes Intelligent User interfaces as components that are characterized by its adapting capacity at run time to make several relating communication decisions such as "what," "when," "why" and "how" for interacting with the user, all this accomplished by the use of an adaptation strategy.

The use of models as central part to broaden our understanding on the processes involved in the adaptation of user interfaces has been widely discussed in the HCI area (Puerta, 1998) and a clear difference is known between a model, architecture and the objectives pursue by them.

Stephanidis conceptualize the adaptation strategy as a decision making process, where different attributes that involve aspects of the user interface are subject to adaptation and they are denominated by the authors as "*adaptation constituents.*" Likewise, the adaptation at run time involve certain monitoring at the interface level in order to evaluate the critical element state of the interaction and they are denominated as "*adaptation determinants*" which impact and set conditions for the adaptation decisions. Another considered aspect deals with the adaptation goals of the adaptation process itself. In the proposed scheme, authors establish that the adaptations will be made by a group of rules, called "*adaptation rules".* Essentially the proposed scheme works this way: adaptation rules assign certain *"adaptation constituent*" to "*adaptation determinants*", given a group of "*adaptation goals.*"

A motivation for the proposed scheme is the fact the even though several approaches have been reported in the HCI literature, there is no consensus regarding to which features, behavior and essential components must comprise an intelligent user interface. The core problem discussed by Stephanidis is that the critical elements of the adaptation process (determinants, constituents, goals and rules) are substantially different in current systems. Existing systems adapt certain predefined constituents, based on a predetermined group of determinants, through the use of specific rules, in order to reach pre-specified objectives.

This situation is discussed by authors and concludes that the adaptation process is not flexible and that it can not be easily transferred between applications. To confront the previous limitations the authors propose:

1. A methodological approach which allows the personalization for the set of adaptation determinants and adaptation constituents.

2. Integrate the adaptation goals at a base level as a core and essential component in the adaptation process.

3. A flexible mechanism to modify the adaptation rules, taking into account the adaptability objectives.

The central idea of the proposed scheme is based on establishing a clear separation between the adaptations attributes from the adaptation process. It is also discussed the hypothesis that by establishing this separation, the adaptation strategy attributes can be personalized in a more flexible way to different application domains and user groups, and eventually could be reused with minor modifications in other applications.

Stephanidis present a generalized architecture for an intelligent user interface, describing the components, the interaction between them and its relation with the adaptation strategy. Additionally, a formal representation for the adaptation elements is presented. The proposed work conclude summarizing the benefits of the proposed approach, however no experimentation is presented. Also, some of the claimed benefits are questionable and the proposed scheme seems too general and probably more detail is required for a particular domain application.

9.5 Mixed-Initiative Systems

Mixed-Initiative systems (MI Systems) have emerged as an alternative to the existent interaction schemes that allows to handle the interaction initiative from a more flexible perspective, even though is indeed a more sophisticated and complex scheme.

Research work reported by Bunt (Bunt et al., 2004) discusses the relevance of the adaptive support, a central topic in the field of Mixed-initiative user interfaces (Horvitz, 1999) and emphasizes the necessity of the current adaptive systems to provide the user with an adaptive mechanism to assist them in the user interface personalization.

In MI systems is established that at certain moments the system makes the adaptations automatically, assuming the associated problems such as lack of control, transparency and predictability, and at other times, the system offer mechanisms so the same user can take control of the interaction and complete the adaptation himself. However there are evidences that the user usually does not uses this available mechanism to make this adaptation and when he finally decides to do it, is not clear if he makes it in an effective way (Jameson & Schwarzkopf, 2002).

Bunt proposes a Mixed- initiative solution, where the system observes if the user is able to personalize efficiently by himself, and if he does, then no system initiated adaptation is required. If that is not the case, then the system can intervene to provide assistance to the user. Likewise, the personalization value is analyzed and how to offer what they call *adaptive support* (i.e. help users to take advantage of an adaptable user interface). An experimental study is presented and it is also analyzed the required aspects for users to complete the personalization of a menu-based GUI based on menus.

It is presented a relevant analysis regarding task characteristic and personalization behaviors that affect the user performance. Additionally a study is presented with a simulation of the process model using GOMS (*Goals, Operators, Methods, and Selection rules*) based on a cognitive model that generates predictions of the user performance. Authors analyses with data test the personalization process and if it's worth it and if there are real tangible benefits.

This research presents 2 exploratory experiments using the GLEAN simulator (Baumeister et al., 2000.) In the first experiment author present a comparison of different strategies of personalization that differ from each other in the moment when they are applied, that is, when are made and analyze if the "*overhead*" of personalizing represents an advantage in some degree. In the second experiment they focus on comparing strategies that differ regarding which functionality the user chose to add to the personalize interface and its implications.

As a contribution of this research, could be considered the use of a GOMS model that allows simulating and evaluating the impact in the personalization taking into consideration the combined personalization strategy based on: the moment it is accomplished, the task execution frequency, its complexity and the user experience level.

The results from the experiments demonstrate the importance in performance terns derived from personalizing the user interface, and consequently strengthens the justification for this work of "*guiding*" the user to personalize the user interface, providing initial insights to consider the *adaptive support* as an important research line.

10. Discussion

Resulting from the revision of IUIs literature presented in this chapter, it is observed that most of the existing prototypes and experimental systems that integrates an intelligent user interfaces, are designed and applied to Web based systems and office applications. However, the system presented by Viano's research group (Viano et al., 2000) represents one of the few systems specifically targeted to critical applications for control and supervision such as that found in electric power plant.

Another model aimed at critical systems is found in MI-IAM (Alvarez, 2009), a model for adaptive user interfaces based on the integration of different sub-models using a mixed-initiative approach for supervision in electric power plants. MI-IAM model is aimed at critical and infrequent tasks, which is a specific area where more efforts are required and a reduced number of research work is reported in IUI literature.

ADAPTs system (Brusilovsky & Cooper, 2002) is similar in some aspects to the MI-IAM model, since it uses several models to achieve the adaptation, such as the user model, a control model and a task model similar to the MI-IAM approach. Likewise ADAPTs uses an intelligent system that reports faults diagnostic and uses an electronic manual to find the information that explains to the user how to accomplish a repairing. This situation seems to be similar to the MI-IAM which is also connected to a proprietary Operators Help System and makes the adaptation to navigation and contents.

An important difference between MI-IAM and ADAPTs is that the latter is an adaptive system, whereas the first is a Mixed-Initiative system scheme, offering more flexibility in the interaction with the user. Likewise, ADAPTs system emphasis is its complex and novel multi-aspects user model that allows in a dynamic way to set the user experience level at any given time. MI-IAM by having a comprehensive integration of different models, attempts to derive from them the key component to make a more accurate adaptation process, not by the amount of information collected but by presenting the more adequate information to the operator according to the power plant status. Other key difference is that ADAPTS is designed for maintenance purposes but not for critical or infrequent operational situations.

Since some IUIs build their models by observing their users behavior, a still open challenge is to generate useful models by using a small amount of datasets and efficient algorithms that make the pattern learning faster. The issue here in not related to CPU processing time, but to a reduce number of training datasets required to generate an accurate users preferences model. Most of data mining applications require a considerable amount of data, sufficient to infer and discover patterns and generate knowledge. In contrast, the adaptive interfaces depend on the user's time when using them and consequently require mechanisms for induction that can provide a high accuracy from a limited number of datasets.

An open challenge is the fact that currently exists a limited amount of empirical evaluation for the adaptive systems, and more research is necessary for setting measurable aspects to determine if an intelligent user interface is better in some measurable way compared to a non-intelligent user interface. A number of empirical usability evaluation methods have been used and extended to the adaptive user interface context, such as interviews, questionnaires, Think Aloud (Dix et al., 2003) and others that are essentially variations of the most traditional validations a evaluations methods, however its applicability to adaptive systems should be considered with limitations.

11. Conclusion

We have presented in this chapter the research in the area of IUIs, its challenges and approached solution with special emphasis on the fact that it is a multi- disciplinary field. It is observed in our discussion that the three approaches described are the ones currently used with superior success to confront the open challenges. At present it is our conclusion that there is still a lack of interchange in the findings between the involved areas in order to share conflicting problems, approaches and findings between experts.

Derived from the literature review it is detected in the area of IUI the necessity of a wider integration and interchange of ideas between the different disciplines that comprise this area. We foresee that the research aimed at the design of novel models for intelligent user interfaces that adapts and integrates components from several disciplines will help to find diverse and richer solutions. It is observed that in general terms the research currently in evolution tends to favors the use of the same knowledge, techniques and proven methodologies that are accepted within the same discipline, and the so called cross-fertilization is really necessary.

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In this book the reader will find a collection of 31 papers presenting different facets of Human Computer Interaction, the result of research projects and experiments as well as new approaches to design user interfaces. The book is organized according to the following main topics in a sequential order: new interaction paradigms, multimodality, usability studies on several interaction mechanisms, human factors, universal design and development methodologies and tools.

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