Toward Usable Intelligent User Interface

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Abstract. Context-awareness of interaction with intelligent user interface has been considered as a potentially important factor of their usability. A fair amount of research has been conducted to identify and help developing advanced adaptations in order to streamline interaction with systems. However, it has to be noted that adaptations could have an adverse impact when it does not meet users expectations. Thereby 'Context-awareness' as well as 'user-centeredness' become more crucial to improve the quality of interaction as well as UIs. Inter-twinned with intelligent techniques, HCI proved an ability to be more intuitive, nevertheless a significant lack of transparency and controllability and predictability were detected. This work is aimed to improve the quality of interaction to fit intelligent user interface performance. We focus on interaction as a key factor for improving the user satisfaction and the interface usability during use. This paper considers major issues and challenges of improving interaction with user interfaces during their use by considering the ISO2941. It presents a methodological proposal for guiding UI developers to designs predict and evaluates interaction quality with regards to well-defined dialog principles.

Keywords: Adaptation · Intelligent user interfaces · Controllability · Predictability · Transparency · ISO2941-110

1 Introduction

The complexity of interactive intelligent systems relies mainly upon three factors: system, human and interaction [4, 5, 8]. Recent works focus on context-awareness and user-centeredness for improving the User Interface (UI) quality and reducing interaction complexity. Adapting UI during use to the user, the platform and the environment is a promising means towards accessible technologies. The literature shows that adaptation manifests in different modalities regarding the human intervention degree. Adaptations range from user-controlled adaptable mode to fully-automatized (intelligent) adaptive mode. Existing adaptation approaches present their pros and cons. Adaptable systems promote controllability and maintain a high understandability and satisfaction level. This advantage is the main pros of such approach, because customization (personalization) dialogues overload users and present a significant barrier for end-users with different profiles and abilities. On the other side, despite their advanced mechanism to automatically adapt to user preferences and the insignificant

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required workload, adaptive systems are still showing a high unpredictability and are considered confusing. Adaptive UIs (fully-automated) demonstrate their capacity to improve tasks achievement in terms of time and finality [2], to increase accurateness [11], users performance [10, 32].

However in most of the cases, adaptive behavior is at the root of inconsistencies that lead to decrease UI usability levels. Such adaptations are often seen as not transparent and lack controllability and reduce the predictability level [2]. This illustrate an increased yield spread may also be explained in terms of a more general customizability/human-cost tradeoff, which relies on user cognitive skills that acquire, process, decide and act at runtime. This was a critical issue discussing the advantages and disadvantages of intelligent UI and direct manipulated interfaces [29]. However with the growing complexity of UI direct manipulation is no more sufficient to handle interaction. Maes [30] claims for augmenting interface with intelligent behavior to improve usability and act on behalf user.

We believe that adaptivity and UI intelligence are not less relevant than direct manipulation for usability. Intelligent User Interface (IUI) challenges for usability are widely discussed, related development methods, adaptations technique, and maintainability [19]. The research in [20] identifies main proprieties for evaluating interactive system from different scopes and provides extensive definitions of concepts. However the issue is still intensified. Three main criteria were defined in the literature to assesse and criticize interfaces: (1) *Controllability*: it represents the capacity and tolerance of system to support user-initiated customization of the interface [31]. (2) *Predictability* which focuses on the extent to which past and present interface allows user to determine the outcome of future interactions, it is about actions and effects [16, 27], and (3) *Transparency* that concerns the honesty [27] of system. It presents the capacity of the user to understand adaptation and interpret perceived information.

In this work, we aim at promoting those criteria within a methodological structure to guide UI development and improve reliability and usability of intelligent UIs. The structure of this paper is as follows: Sect. 2 presents an overview of previous works. Section 3 presents a background of intelligent system usability and challenges that they are facing. Section 4 introduces the well-balanced model for intelligent usable adaptation and focuses on issues of predictability, transparency and controllability of adaptation. Section 5 concludes the paper and discusses future directions.

2 Related Work

Quite few studies in the literature paid attention to different IUI adaptations approaches shortcomings and called to consider an intermediate adaptivity level [5, 15]. Proposed solutions were mainly devoted to overcome the transparency and controllability deficiencies while keeping advantages of automatic adaptivity [5]. IUI shortcoming involve allowing the personalization by giving the user control over the UI design, making the system predictable so that it gives consistent reaction given the same user's feedback within the same context, and making the system transparent so that the user can understand approximately internal system inferences.

One way to achieve this performance consisted on allowing the user a partial control on adaptation. This solution defines a mixed-initiative adaptation method that combines adaptable and adaptive behaviors. Researchers in [9, 13] argues for mixing both behaviors to balance out the controllability and the predictability levels. Bunt presents a literature review discussing the relevance of the Mixed-initiative UI topic and stresses the necessity of the current adaptive systems to provide end-users with an adaptive mechanism assisting the personalization process [3]. Along the same lines, A Mixed-initiative solution MICA was proposed by [21], it consists on an adaptable system allowing users to personalize the UI, while assisting them by recommending customization. The system reinforces the comprehensibility. Evers [13] addressed controllability in adaptive UI by integrating the users in the system's self-adaptation loop. Both implicit and explicit controls were supported, implicit control defines the user's influence and the explicit control allows the user to change the adaptive behavior of the application [13].

Transparency was addressed from different perspectives, Dessart et al. [10] targets the transparency via animated transitions displaying the adaptation process explicitly to the end user. The transparency was addressed in a different way by self-Explanatory UI, which have the capacity to provide the end-user with information about its purpose, structure and design. Predictability was stressed as a crucial evaluation criterion for adaptive UI [15, 16], however the majority of works don't address transparency in an explicit way with focused solutions.

Table 1 establishes the coverage of analyzed works for each criterion. The analysis of existing works leads to identifying one significant issue: None of existing methods takes into accounts all of these criteria with an integral prospect. While these considerations need to be taken into account simultaneously to ensure that the approach is in compliance with the extents outlined in technical criteria.

Further we believe that the interaction quality and the UI usability concerns exceed these criteria. On the other hand, despite the authoritative nature of international standards for usability, many of them are not broadly considered. Commonly, standards

Table 1. Visual analysis and comparison of existing works coverage

Legend ● Completely fulfills ◖ Partially fulfills ○ Does not fulfill * Not specified	**Controllability**	**Predictability**	**Transparency**
Bunt 04	●	◖	○
Bunt 09	●	◖	*
Garcia 10	*	○	●
Dessart 11	*	○	●
Ever 12	●	○	*
Gajos 04	●	◖	*
Demeur 08	○	○	●
Eisenstein00	*	◖	*

are established to provide valuable tools for promoting HCI best practices. Their completeness, their relevance to practices as well as their cost/benefits are widely discussed [4, 17]. To overcome such a weakness we believe that establishing standards to support interaction quality and system usability is of great importance. We argue for complete covering and support of standard principles within a well-established structure. To that end we refer to the ISO9241-110 to define a methodological guidance structure for supporting interaction with intelligent user interface.

3 Requirements and Challenges

3.1 Requirement for IUI Usability

The above-defined criteria were of paramount importance to the assessment of the literature and expected to contribute the improvement of their usability are: Controllability, Predictability and Transparency [6, 7, 14, 15, 27]. By the analysis of the related works and tools, as presented previously, the main IUI shortcoming is still the lack of systems that reinforce and support all criteria from early development stages (in a powerful, robust, and complete manner). We present here identified requirement:

R.1 The support of **controllability** represents the capacity and tolerance of system to support user-initiated customization of the interface [27]. Many works (e.g. [21, 29]) argues for providing user full control over automatic adaptations as a major requirement of acceptable adaptive systems. An intelligent UI require an improved support of user, in which user, depending on their preferences and need must be able to adjust their UIs and then being able to accept or decline system decisions [22].

R.2 The support of predictability focuses on the extent to which past and present interface allows user to determine the outcome of future interactions, it is about actions and effects [15, 16, 27, 31]. Gajos [15] considers that an adaptive system is predictable if it follows a strategy users can easily model in their heads, and evaluated predictability effects on user satisfaction. We assume that the accuracy and the predictability of the UI increased user satisfaction. Tsandilas [31] draw attention to the negative effect of inadequate adaptation accuracy on user performance in adaptive menus. Intelligent UI should maintain a height satisfaction level among their users. Accordingly providing accurate adaptation for the user context enhances such satisfaction and increases the subjective predictability of the system's behavior.

R.3 The **support of transparency** concerns the honesty [27] of system. It presents the capacity of user to understand adaptation and interpret perceived information. [19] argues for transparency as one on main usability principal for intelligent user interfaces. Only few approaches were aimed to increase the transparency of automatic adaptations have been published [10, 14]. Dessart et al. [10] suggest animated transitions for viewing the adaptation process to the user and develop a catalogue of "adaptation operations" to support continuity in the UI perception at runtime. Other approaches aim at a deeper user understanding of the system's adaptations by providing detailed justifications [19, 27]. However, it seems questionable if and how these approaches can match perceptual, cognitive and motor impairments in users.

All above-mentioned shortcomings agreed on the fact that successful adaptations must not result a confusing situations and should avoid the trouble of losing control over the user interface for end-users who must be at the heart of adaptation. Their involvement could be achieved by providing non-technical designers and typical users with user-friendly techniques for managing adaptations depending on their aptitudes at different levels: perceptual, cognitive and motor. Existing works promote above selected criteria in different ways and by different policy, however they still suffers from shortcomings and most of existing methods covers partially such concepts [19].

3.2 Challenges

Context-aware interaction requirements were investigated within different perspectives. Nowadays, the adequacy of interaction scenario to the user and the context is an essential requirement. Interaction depends on the context of use and situation complexity but above all on user preferences and abilities. The main interaction issues could be summed within three points: incomplete user model, lack of user involvement and complex adaptation model [27].

Improve Users Support: Establishing an effective personalization requires recognition of user's preferences. However it is difficult to obtain accurate and sufficient user representation from user profile and abstract user models. A new trend of user centered adaptation focuses on accruing information on users based on their interaction and feedbacks. Back to the year 1983, [18] defines feedbacks as "information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way". This seems promising to improve their involvement in system decisions and consequently their satisfaction. The consideration of user feedbacks and preferences during interaction for adaptations is intended to increase the user satisfaction degrees by time and reduce the system complexity [27].

Improve Decision-Making Process: The system involves several complex models that require more inferences to support too high functionality such as acquiring, considering up-to-date contextual facts and adapting the UI at runtime. Although there were successful adaptive systems, they did not often make use of particular users' preferences and context's circumstances at runtime. A context-aware adaptation should have a cross-cutting impact on the software design and appearance depending on the interaction's context with an insignificant cost [33]. Designing a responsive adaptation at runtime is still a challenge in HCI since there is no agreed technique for learning and executing appropriate adaptations during interaction neither an approach to manage unanticipated situations. UIs adaptivity over time considering acquired data during use is still a major UI requirement. However, system adaptation and decision-making is a double-edged sword. On one hand, it enhances UIs pervasiveness and proactivity. On the other hand it could increase the user's workload leading to frustration. Accordingly, systems that adapt and change their behavior to better-fit users' requirements could disturb user and interrupt predictability, further perceptual transparency is not enough to maintain understandability. Context-aware interaction involves three main basis: (1) giving the user control over the system, (2) making system decisions predictable so that it always agree with users' expectations, and (3) ensuring system transparency so that the user can understand internal inferences. These requirements are widely revealed in the literature [19, 32].

We aim at improving interaction by considering effectively usability principles. This improvement can enhance the user experience and maintain UI usability within the growing complexities of interfaces functionality and their changing contexts. To overcome this complexity we put forward user as the heart of interaction and adaptation process. Reliability to human behavior is a requirement. We consider Rasmussen's model, which has been extensively used over the last two decades for human behavior modeling. The model rationalizes the Human (user) behavior controlling a complex dynamic system [28]. This model sum up human performance within three levels of behavior: skill, rule, and knowledge. The purpose is not only to advance adaptation; it is to address the challenge of usable adaptation, taking into account different user needs with an integral prospect.

This work suggests a well-balanced guidance model to counterbalance the cost of adaptation principles with cognitive user behavior. It also suggests that system adaptation have to be examined and matched in terms of the level of focus (knowledge, skill, rule) and usability principle that they provide.

4 A Methodological Structure

To address previous provoked requirements, a set of key points were analyzed and lead to the definitions of consistent design decisions for usable intelligent UI (Table 2). The solution focused on two main points: the support of human behaviors for improving the

Table 2. Requirements and associated design decisions for context-aware intelligent interaction

Shortcoming	Requirements	Design decisions
S1: Limited controllability	R1: Provide users an interaction model regarding their ability and experience: Improve the support of user intervention	DD.1 Support of user behavioral model: Processing layer. Provide users an adequate interaction, and a compliant controllability depending on their skill and ability etc.
S2: lack of predictability	R2: Improve the support of user preferences and reduce the gap between system decision and user expectation: Enhance the support of user expertise and competence	DD.2 Support of user affective model: Executive layer: Regarding the rule engines, to provide inference and reasoning, user preferences and expectations should be considered
S3: Partial transparency	R3: Support of user expertise level. Improve the transparency of adaptation changes (display): Advance the transparency of system decision-making mechanism	DD.3 Support of user cognitive model: Perception layer: Varied complexity levels must be supported for users with different expertise levels and various knowledge

reliability of interfaces and the consideration of dialogue principles ISO9241-110 to streamline the interaction. Table 2 illustrates a categorization of dialogue principle within three layer regarding human performance and interface quality.

4.1 Support of Human Behavior

The human performance consequences of particular types of interaction constitute primary evaluative criteria for adaptation and interaction design. Accordingly, user reliability is a key factor for performing usability evaluation [1]. Several works focused on reliability for guiding and structuring the assessment of usability. This need results from the need for context-awareness [1]. Usability support tools aim at a better understanding of the emergent dynamics of interaction. Reliability is concerned with identifying, modelling, and quantifying the probability of human errors during interaction with systems.

Existing reliability methods are based on a cognitive model more appropriate to clarify human behavior. It is evident that any attempt at understanding human performance needs to include the role of human cognition. Such understanding includes many relevant findings from cognitive psychology, behavioral science, neuroscience, human factors and human reliability analysis. Several models were developed to support human models. Most of existing works refers to Rasmussen proposal (1984), for instance [11, 12, 26]. Rassmussen models is based on classification of human behavior divided into skill-based, rule-based, and knowledge-based, compared to the cognitive level used. The terms skill, rule and knowledge refer to the degree of conscious control exercised by the individual over his or her activities. Supporting skill- and rule-based behaviors in familiar tasks, more cognitive resources may be devoted to knowledge-based behaviors, which are important for managing unanticipated events accordingly improve system transparency and predictability [12]. This support enhance system' problem-solving and decision-making, and action execution.

4.2 Support of Dialogue Principles: ISO9241-110

Dialogue principles are a valuable reference to confirm design quality. The aim is to offer an effective user experience during interaction. The international standard ISO9241-110 [20] addresses the ergonomic design of interactive systems and defines seven values supporting interaction. These values of dialogue design are recommended to be applied during analysis, design and evaluation of interactive systems. We assume that such guidelines involving current best practices can assist stakeholders and enable controlled analyses and unified evaluation tool.

ISO9241-110 design principals are defined "without reference to situations of use, application, environment or technology (Table 3)". Existing works applied design principles within different user-centered design process, (e.g. [23–25]).

Consistent with the aim of considering well established abstracted design principles to avoid major design weaknesses, We argues for their use at any stage of a user-centered development process. Interaction quality contributes in the improvement

Table 3. Association between requirements and respective Design Decisions taken

Interaction principals (Rasmussen Model)	ISO 9241-110	Definition
Transparency ***(Knowledge)***	Self-descriptiveness	Each dialog step is immediately comprehensible through feedback from the system or is explained to the user on his or her requesting the relevant information.
	Suitability for learning	The dialog guides the user through the learning stages minimizing the learning time.
Predictability ***(Rule)***	Suitability for the task	The dialog supports the user in the effective and efficient completion of the task.
	Conformity with user expectations	The dialog corresponds to the users task knowledge, education, experience, and to commonly held conventions.
Controllability ***(Skill)***	Controllability	The user is able to maintain direction and speed over the whole course of the interaction until the point at which the goal has been met.
	Error tolerance	Despite evident errors in input, the intended result my be achieved with either no or minimal corrective action having to be taken.
	Suitability for individualization	The dialog is constructed to allow for modification to the user's individual needs and skills for a given task.

of system usability. It depend on the context of use, the effectiveness of interaction differs with regard to user profile. Considering information about user behavior model and cognitive process can increase system usability and provide stakeholders guidance for designing and maybe evaluating interaction.

Further user characteristic (such as the age, preferences, gender), users cognitive models provide a significant improvement for UI. It will be useful to recognize user, knowledge, rules and skills in order to cover their preferences and enhance their interaction experience. The ISO9241-110 standard includes interaction-guiding principals that could assist the design of user interface dialog. In order to enhance the user centeredness of such principles, Table 3 presents ISO9241-110 classified with regards to the user cognitive model of Rasmussen. The KRS model provides a practical framework that link user's judgments, decisions, actions and experience. It provides a model of human performances for supporting the design and evaluation of UIs integrating quantitative and qualitative models.

4.3 Structure Supporting Intelligent Interaction

We assume that meeting users requirements and preferences effectively and efficiently during interaction should consider a conjunction of above detailed principal and concerns. Interaction is intended to maintain usability while keeping full visibility of user performance and behavioral model. The main purpose of this work is to make a step toward usable intelligent UI. It is aimed to provide system designers with a tool (structure) to help the development of intelligent interfaces that invoke a good representation among users. This tool consists on a guidance that allows bridging the gap between user expectation and system decisions during interaction in order to support usability improve reliability and enhance user satisfaction.

We assume that usability improvement relies to harmoniously integrating controllability, predictability and transparency above described. Human reliability during interaction could be achieved via a two different ways:

– In the anticipatory stage, as a post analysis of the potential situation of interaction and as assessment of the interaction quality.
– In post-interaction, to comprehend and recognize involved features that influence human performance during interaction in order to improve user satisfaction.

Satisfaction is then an obvious consequence. In particular, there was a need for further development regarding the integration of quality and human aspects for one exposure scenario. To that end, the proposed structure reflects Rasmussen user performance model within interaction principals. Further, such principal are endorsed by relating to ISO9241-110 dialogue principals for designing interaction. The advantage of this integration is the particular importance accorded to the end-user significance and/or involvement when determining and agreeing context-aware interaction with intelligent system. The human support during adaptation allows guiding, verifying and improving their accuracy rather than the improvement of system intelligibility to meet user expectation. System should learn through interacting with the user and its environment otherwise, it would only repeat its mistakes. Different technique support system intelligence (e.g. learning by observation or knowledge's).

We refer to cognitive aspects of user's performance and we consider three levels to model user behavior: skills, rule and knowledge (SKR) defined by Rasmussen. Considered layers (SKR) [28] enhance the user-centeredness and human reliability of the method. We define the adaptation process with a full coverage of three levels:

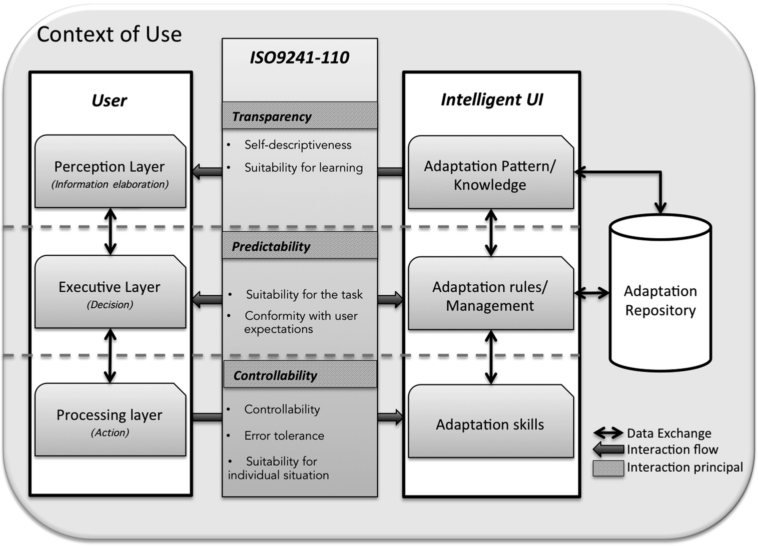

Fig. 1. Context-aware intelligent interaction architecture

The first layer hold **Skill** feature *(control* theory), it regards the concrete interaction flows allowing user to act and access to information. From the system side it denotes the capacity of system to support users intervention. As well, it presents the ability to take such intervention into consideration for the improvement of adaptation performance via the advanced algorithms allowing knowledge learning. Several solutions targeting controllability were convoyed and reviewed in the related works; most of them focus on the user feedback. This level has to do with controllability, errors tolerance and suitability for situation (context-awareness) principals.

The **Rules layer** regards the Executive layer of users. This layer concerns *predictability* and human situation assessment and decision making process. On the system side the implementation of decision-making algorithm and optimization strategies is responsible for the management of contextualization. The aim is to ensure greater convergence between human reasoning and the decision-making algorithms in order to prevent distortions of users and fraud. Accordingly predictability could not be seen only as a consequence of controllability, but require to be investigated in term of deduction, reasoning and problem solving algorithms. At this layer mainly two-dialog principals are to be considered: the suitability for the task and the conformity with user expectations.

The **knowledge layer** is aimed to ensure a common understanding of adaptations and interfaces changes. From the user side, the Perception layer is responsible for this feature. It concerns information processing bloc and refers to the acquisition of incoming information for instance comprehending, relating, grouping etc. The UI support this feature within different perspective. The main intent is to insure that users correctly interpret perceived information. We argue that a transparent adaptation improves accessibility among systems.

Within this prospect, we established the methodological structure view supporting a user-centered adaptation with regard to usability criteria. An approach supporting the aimed synergetic adaptation will be convoyed. First it solves the controllability issues and reduces the feeling of loosing control resulted from system-initiated adaptations by using different users feedbacks. Then it support a ML based adaptation management algorithm putting forward predictable solutions and avoiding confusing inconsistency. This interaction is held by a simple and comprehensible graphical representation supporting transparency.

5 Final Remarks and Conclusion

This paper presented a theoretical methodological structure for supporting the development of usable intelligent user interfaces. The proposal is aimed to support de-signers of an interactive system to enhance the user support when designing UIs. Based on identified shortcoming and observation, three main requirements were provoked which result the design decision of the proposal. There are still many open questions to be discussed in interaction with IUI, such as,

- The accessibility issues due to the extent of involvement of users during interaction to control, adjust and personalize the UI,
- The consideration of context-awareness and all its consequences,

– transparency of adaptation decision and adaptation display to end users.
– the reliability of end user, preferences, profile, expectation, needs etc.
– compatibility of interaction with usability principals.

The proposal focused mainly on interaction with an intelligent user interface. Interaction contributes the user's experience when using systems. Accordingly a well-designed interaction imparts a sense of trust to the system accordingly it enhances usability. The main structure benefits at this level are the consideration of the ISO standard for dialog in principle and forwarding human behavioral model throughout integrating Rasmussen models. This work will be extended by; (i) a methodological guidance for designing IUIs' interaction with regards to usability and UX requirements. (ii) a cost benefits analysis awarding the trade-off between providing greater implementation of context-awareness and avoiding frustrating automatized changes. (iii) an instantiation case studies.

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