Towards Qualitative and Quantitative Data Integration Approach for Enhancing HCI Quality Evaluation

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Abstract. Over the two past decades, various HCI quality evaluation methods have been proposed. Each one has its own strengths and its own shortcomings. Different methods are combined to enhance the evaluation results. To obtain better coverage of design problems and to increase the system performance, subjective and objective methods can complement each other. However, the variability of these methods features poses a challenge to effectively integrate between them. The purpose of this paper is to enhance the evaluation of HCI quality by suggesting new approach intended for improving evaluation results. This method supports a mapping model between evaluation data. It aims to specify new quality indicators that effectively integrate qualitative and quantitative data based on a set of pre-defined quality criteria. Qualitative (items) and quantitative data are respectively extracted from highly cited HCI quality questionnaires and from existing tools.

Keywords: Human-Computer Interface, HCI evaluation, subjective, objective, qualitative, quantitative, integration, mapping; data, indicator.

1 Introduction

The evaluation of Human Computer Interaction (HCI) quality is an important issue increasingly attracting researchers in the field of the software engineering1]. Quality[1] evaluation is a process assessing the extent of the system's functionality; the impact of the interface on the user; and identifying the specific system problems [2].

Over the past decades, several quality evaluation methods and tools have been proposed. Some of them provide a quantitative (objective) evaluation based on analytic and quantitative data retrieved from various tools such as electronic informers [3]. Other methods perform a qualitative (subjective) evaluation exploiting for instance questionnaire and/or interview methods [4] [5]. They focus on the direct interaction with users to ask them about their opinions and their preferences about the evaluated interface. However, all the methods do not perform the same measuring procedures.

[1] In this paper, we address by the quality evaluation to the quality of the user interface evaluation.

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Some of them use only questionnaires and others include additional tools to perform more accurate evaluation [6]. Many authors have argued for employing various methods for quality evaluation so that these methods supplement each other rather than compete [7] [8]. However, strengths and limitations of each evaluation method can guide researchers and practitioners. It can help them to determine how these methods complement each other. Nevertheless, the variability of these methods features and drawbacks poses a challenge to effectively integrate between them. This integration is an important issue in order to obtain better coverage of design problems and to increase the system performance.

In this paper, we are interested to enhance the evaluation of quality by proposing a new evaluation approach. This approach is intended for improving evaluation results issued from both various tools. It supports a mapping model between evaluation data. It specifies new quality indicators integrating qualitative and quantitative data.

The reminder of the paper is organized as follows. Section 2 reviews the works related to existing approaches that combined multiple HCI quality evaluation methods. Section 3 explains on one hand, an accurate description of our approach of the defined mapping models and indicators. On the other hand, it explains our approach using a case study between some items from CSUQ questionnaire and the tools based on quantitative data. Section 4 draws conclusions and future work.

2 Related Works

Several research efforts about quality evaluation have been established. They concern various methods and approaches for evaluating HCI quality (e.g. the questionnaires or the interviews as subjective tools [19] and the electronic informer as an objective tool [3]). Recent researches have investigated the possibility of employing different methods to improve evaluation results [10] [11].

The need for supporting evaluation using different methods has been emphasized by Grammenos et al. [12] in their framework for defining an integrated environment supporting guidelines: the Sherlock guideline management system. It is structured following a client/ server architecture and aims to facilitate the detection of usability problems. The evaluation has been preceded by two methods independently employed. The first is a static method for assessing interface presentation quality. The second present a dynamic method that uses two IBM usability satisfaction questionnaires (i.e. After Scenario Questionnaire (ASQ) [23] and Computer System Usability Questionnaire (CSUQ) [21]) for measuring the user's subjective opinion in a scenario-based situation.

Some approaches have suggested combinations of various evaluation methods for improving evaluation [11] [13]. In [13], authors are interested to use three evaluation tools separately: (1) the eye tracker for capturing information about the user eye movements and view localization during tasks execution, (2) the electronic informer for capturing user action, and (3) the questionnaire for measuring users' satisfaction. However, this approach has used a paper questionnaire. It's will be better if it is used an automatic questionnaire to facilitate the evaluators task.

In [11], authors are suggested an evaluation framework named RITA (useR Inerface evaluaTion frAmework). It combines between three different evaluation tools, respectively: a questionnaire, EISEval electronic informer and the ergonomic guidelines inspector. Despite this approach leads to inspect a broad outfit of utility and usability problems in user interfaces, it has two main limits. On one hand, the questionnaire was developed based on a set of predefined questions without taken into consideration the existing predefined questions that can be extracted from standardized questionnaires which have a good score in terms of validity and reliability measures. In the other hand, the evaluation results are presented with a separate manner, which implies the lack of the integration aspect.

Al-Wabil and Al Khalifa [8] have developed a framework for integrating usability evaluations methods by matching the methods' capabilities and limitations through a classification of usability problems. The adopted evaluation approach is based on the usability problem profile of Chattratichart and Lindgaard [20]. It is initially based on the classification of the usability issues according to usability problem profile and secondly on the classification of these problem profiles according to the usability evaluation methods. This approach considers three usability evaluation methods: (1) the eye tracking method which deals with the problems related to visibility of user interface elements, (2) the card sorting usability evaluation method for detecting the problems related to disorientation, and (3) the focus group discussions for assessing subjective satisfaction. Although this framework is interesting, it remains very critical. On the one hand it is related only to evaluate web user interfaces. On the other hand, this approach is focused mainly in determining how the combination between usability evaluation methods can complement each other rather than how combining usability evaluation methods with integrated and complementary forms.

In a study, Nikov et al. have proposed an approach that combines between subjective and objective usability parameters for inspecting usability problems [14]. This approach exploits a neuro-fuzzy model to aggregate between data. Furthermore, it was implemented in a MS EXCEL software tool. Nevertheless, there are some limits to consider; this approach is only dedicated to evaluate web user interfaces. Moreover, the selection of the gathered measurements is still ambiguous mainly when these data are not extracted using universal usability evaluation methods.

A recent research method proposed by Kerzazi and Lavalée has been designed for combining both objective and subjective usability evaluations [15]. It aims to provide more complete view of usability. However, gathering qualitative and quantitative metrics and analyzing it in a separate manner presents a weakness that can only be solved through the combination of qualitative and quantitative data.

This section describes a panorama of existing approaches based on combining different evaluation methods to enhance evaluation results. Indeed, these approaches attempt generally to combine methods in a separate manner. However, they do not consider the specificities of evaluation data and the possibility to combine them with in integrated form. There is still a lack to determine how effectively integrate qualitative with quantitative data for improving evaluation results. In consequence, a new approach for integrating qualitative and quantitative evaluation data will be presented in the next section.

3 Proposition of an Evaluation Approach for Integrating Qualitative and Quantitative Data

We are interested in proposing an evaluation method including a mapping model aiming to define new quality indicators integrating qualitative and quantitative data based on a set of quality criteria. These data are relatively related to both ergonomic and functional aspects of interactive systems. That is why our aim is: (1) to identify the tools used to extract the qualitative and quantitative evaluation data, and (2) to determine how to integrate these data.

3.1 Specification of the Tools Used for Extracting Qualitative and Quantitative Data

As the proposed method integrates and synthesizes the data issued from different evaluation tools, it exploits different tools that have been developed to facilitate and to automate a variety of quality evaluation aspects.

The tools related to the quantitative data are:

- The ergonomic guidelines inspector [11]: aids for ergonomic quality evaluation of interactive systems. It evaluates the ergonomic consistency of a HCI according to ergonomic guidelines in order to detect the ergonomic inconsistencies. It consists on comparing a referential model entitled the evaluation model to an object model [11]. This parses the interface graphical components attributes. The evaluation model is defined as the configuration specified by the evaluator before starting the usability test [11]. It provides the evaluator by a set of ergonomic recommendations. Comparison results are generated as textual files.
- EISEval electronic informer (Environment for Interactive System Evaluation) [3]: is a generic and configurable electronic informer used for agent-based interactive systems [3]. It is based on Petri Nets for modeling the interaction sequences between the user and the system to evaluate to detect eventual usability problems in the evaluated user interface [9]. Moreover, it automatically captures Human-Computer Interaction information as user actions and their consequences on the interactive system. Thus, it analyzes these various captured interaction information using its confrontation module [3].

To perform a qualitative evaluation, we use questionnaires as tools for inspecting users' satisfaction degree to the evaluated interface. Over the past twenty years, several questionnaires have been putted forward by researchers for HCI quality evaluation. For our study, we performed a large state of the art of the most known and the most validated questionnaire tools. In the first stage, 23 questionnaires with good scores in validity and reliability measures are selected. In the second stage, we only selected five questionnaires considering various constraints such as the higher reliability degree and the type of application for which they are defined. These questionnaires are: QUIS[2], PSSUQ[3], SUMI[4], SUS[5] and CSUQ[6].

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[2] QUIS: Questionnaire for User Interface Satisfaction (http://lap.umd.edu/QUIS/about.html).

3.2 The Defined Mapping Model and the Quality Indicators: How to Integrate Qualitative with Quantitative Data?

The proposed mapping model and the quality indicators. Qualitative and quantitative data are related to a set of quality criteria such as the ISO 9241-11 standard criteria (i.e. satisfaction, efficiency, and effectiveness). These criteria can be evaluated first through questionnaires qualitative data and second through quantitative data extracted from the existing tools. Nevertheless, as explained in the last section, the combination or the integration of qualitative and quantitative data leads to use the evaluation data with a separate manner. The lack in determining how to integrate qualitative with quantitative data leads to an intensified need to define a full structural mapping model to specify new quality indicators based on the existing quality criteria.

As defined by the ISO/IEC 15939 [16], an indicator is a measure that provides estimation or evaluation of specified attributes. These attributes are quantified based on the type of measurement method which can be subjective or objective. To propose quality indicators based on the existing quality criteria, we first performed a deep study to define a mapping model between quality criteria used by the tools quantitative data and the questions (items) extracted from the selected questionnaires. This mapping model allows specifying the required attributes for the construction of indicators. It links each questionnaire item with the appropriate quantitative data with a complementary manner. Further, the proposed mapping model is based on both ISO 9241-11 quality criteria [17] and Bastien and Scapin ergonomic criteria [18] to evaluate both functional and ergonomic aspects of the interface. Figure 1 illustrates our proposed mapping model. As depicted in this figure, each item can be related in the same time to more than one quantitative data.

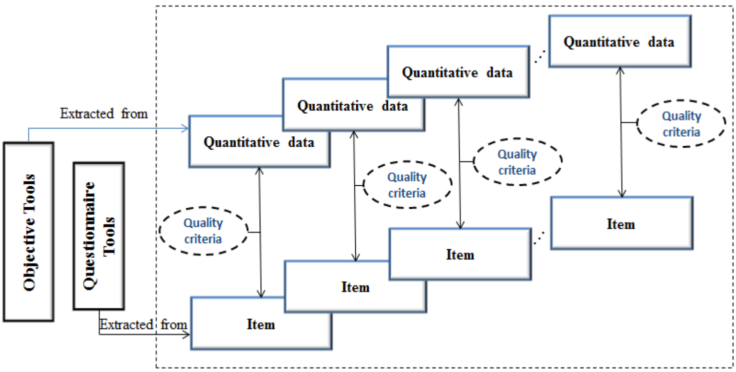

Fig. 1. Proposed mapping model

[3] PSSUQ: Post-Study System Usability Questionnaire [22].
[4] SUMI: Software Usability Measurement Inventory (http://sumi.ucc.ie/en/).
[5] ASQ: After Scenario Questionnaire [23].
[6] CSUQ: Computer System Usability Questionnaire [21].

Defining a mapping model is the first step to integrate qualitative with quantitative data. To ensure effectively this integration, defining and constructing new indicators (measures) based on this specified mapping model that combines qualitative with quantitative data is a crucial task. For our study, we adapted the ISO/IEC 15939 Measurement Information Model to define new quality evaluation indicators for HCI quality evaluation of interactive system. These measures are able to cross implicitly qualitative with quantitative data. As defined by ISO/IEC 15939, the Measurement Information Model is a structure linking the needs to the relevant entities to the attributes of concern. It describes how the relevant attributes are quantified and converted to indicators that provide a basis for decision making [16].

These indicators aim to directly measure the performance of quality criteria and enhance evaluation results.

Our approach is based on three models: (1) the initial mapping model, (2) the results mapping model with indicators, and (3) the reference model.

- The initial mapping model:
  It consists of three components: the evaluation criteria, the qualitative data, and the quantitative data. This model specifies the evaluation criteria with their corresponding data. This model links and associates each qualitative data with appropriate quantitative data.
- The results mapping model with indicators:
  This model presents the evaluation results. It is based on the specified initial mapping model. As illustrated in Fig. 2, it consists of six components: evaluation criteria, users list, the qualitative and quantitative measures values obtained after evaluation, the applied rules for each criterion, and the final decision of evaluation. This model can be divided into two main parts:

• The indicators: are qualitative and quantitative measures defined and constructed from data of the initial mapping model based on the standard ISO/IEC 15939. Different measurement functions[7] are applied to these data to make them computable measures.
• Decisions: are judgments, based on a set of rules to be applied, defined when constructing and defining indicators. They are used to judge the performance of the evaluation criteria.

- The reference model:
  It presents the reference on which the model of mapping results with indicators is based, in order to specify its evaluation decisions after various comparisons. These comparisons are performed between the evaluation criteria and the qualitative and quantitative measures. They aim to select the applied rules and the appropriate evaluation decisions. As illustrated in Fig. 1, this model consists of four components: the evaluation criteria, the qualitative and quantitative measures, the applied rules and their evaluation decisions.

[7] Measurement function: is an algorithm or calculation performed to combine two or more base measures [16].

Fig. 2 synthesizes our approach for the integration of qualitative with quantitative data and illustrates the mapping phase and indicators.

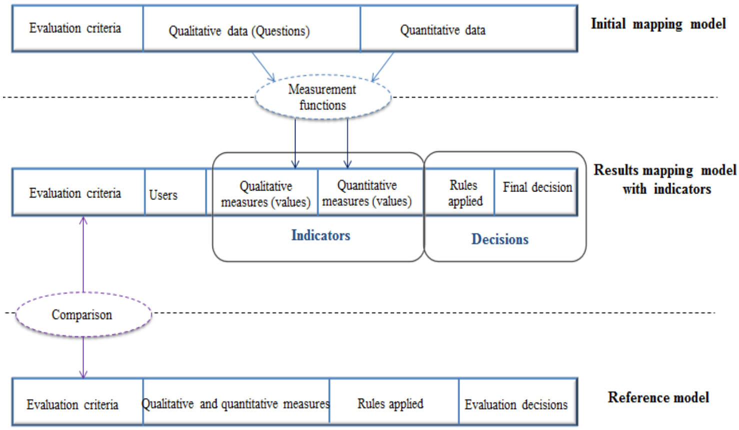

Fig. 2. The proposed approach (mapping model and indicators)

In the next section, we explain our approach through a case study between a set of items from CSUQ questionnaire and quantitative data issued from the specified tools. Thus, we introduce an example of an indicator of HCI quality evaluation. It is constructed for evaluating the effectiveness criterion defined by the standard ISO 9241-11 based on the defined mapping model data.

A case study of a mapping between CSUQ items with quantitative data. To demonstrate how our approach can be applied to evaluate the quality of interactive systems interfaces, we present a case study of the mapping between some items from CSUQ[8] questionnaire with the quantitative data of the specified tools based on a set of quality criteria. The mapping results are presented into the initial mapping model to illustrate how this mapping is specified for defining new quality indicators. This mapping involves three steps, starting with the identification of the specified tools' data and the evaluated quality criteria to the presentation of results.

Since our intention is to evaluate any WIMP interface of interactive systems, we opt as qualitative data some items of CSUQ. We choose CSUQ for our mapping study due to the fact that it is: (1) a successful record of practical and academic applications in its original; (2) a continuing relevance to current researchers; and (3) supporting an applicability in usability evaluation of computer systems in various areas as well as in research into the measurement of the construct of usability [19].

For the quantitative data, we opt for data extracted from the ergonomic guidelines inspector (e.g. writing size, writing color, informational density) and the EISEval elec-

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8 CSUQ (Computer System Usability Questionnaire) is an IBM questionnaire tool designed for the purpose of assessing users' perceived satisfaction with their computer systems in the field, modeled directly on the Post-Study System Usability Questionnaire (PSSUQ) for conducting this type of assessment at the end of a lab-based usability study. In its current form, the CSUQ is a 16-item instrument [21].

tronic informer (e.g. the rate of completion of correct tasks, time of tasks execution) to evaluate respectively the ergonomic and the functional aspects of the system interface.

The extraction, analysis and the mapping of the qualitative with quantitative data in this case study is based on the measurement of four quality criteria (the efficiency, the effectiveness, the guidance, and the workload). Efficiency and effectiveness criteria are selected from ISO 9241-11. The guidance and the workload criteria are selected from Bastien and Scapin criteria [18]. The ISO 9241-11 criteria are used to evaluate the functional aspect of the system interface. As defined by the ISO 9241-11standard, the effectiveness criterion refers to the accuracy and the completeness with which users achieve specified goals, while the efficiency criterion refers to resources expended in relation to the accuracy and the completeness with which users achieve goals [17]. Nevertheless, Bastien and Scapin criteria are used to evaluate the ergonomic aspects of the system interface. The guidance criterion refers to the means available to: advise, orient, inform, instruct, and guide the users throughout their interactions with a computer, including from a lexical point of view. Whereas workload criterion concerns all interface elements that play a role in the reduction of the users' perceptual or cognitive load, and in the increase of the dialogue efficiency [18].

The used data and mapping results for this example are specified in Table 1 which presents the initial mapping model.

Table 1. The initial mapping model

Evaluation criteria	**Mapped data**		
	Qualitative data		**Relative quantitative data**
	Items	**Items key-words**	
Effectiveness: ISO 9241-11	It is simple to use this system Strongly agree 1 2 3 4 5 6 7 Strongly disagree	simple	The rate of completion of correct tasks
	CSUQ questionnaire		EISEval
Efficiency: ISO 9241-11	I am able to complete my work quickly using this system Strongly agree 1 2 3 4 5 6 7 Strongly disagree	complete quickly	The rate of completion of correct tasks Time of tasks
	CSUQ questionnaire		EISEval
Guidance (readability): Bastien and Scapin criteria	The information provided with this system is clear Strongly agree 1 2 3 4 5 6 7 Strongly disagree	clear	Writing font Writing size Writing color
	CSUQ questionnaire		The ergonomic guidelines inspector
Workload (Informational density): Bastien and Scapin criteria	It is easy to find the information I needed Strongly agree 1 2 3 4 5 6 7 Strongly disagree	find, easy, information	Workload density Components dimension
	CSUQ questionnaire		The ergonomic guidelines inspector

As illustrated in the table above, the results of the mapping data from the initial mapping model provide evaluators with a combination of qualitative and quantitative data. It shows how the quantitative data can complement the qualitative data to increase the performance of the measurement of evaluation criteria and subsequently help evaluators to inspect accurately the quality problems. A quantitative data can complement different questionnaire items that cover diverse quality evaluation criteria. These mapped data will be as parameters used to define and to produce new quality indicators based on the ISO/IEC 15939 Measurement Information Model [16]. These indicators allow crossing items with quantitative data to inspect quality criteria. They aim to measure directly the performance of quality criteria and to enhance evaluation results. They are presented into the reference model. An example of a defined indicator, their related measures with their applied rules and evaluation decisions suggested by the indicator specification are presented in Table 2.

Table 2. An indicator example from the reference model

Evaluation criteria	**Indicator and decisions**		
	Qualitative and quantitative measures	**Rules applied**	**Evaluation decisions**
Effectiveness of correct performance of tasks in a HCI	- Rate of correct completion of each Task in a session (RT) - Number of tasks performed - Number of users involved in the evaluation (users: novice, medium (students) and experts in the field of HCI) - Response to question for each user (Rep) - Rate of Correct performance of Tasks for a user session (RCT) - Rate of user Responses to a question (RRep)	- Rule 1: More than the RCT measure is large (tends to 100%), more than the Rep measure is small (tends to the value 1: strongly agree) - Rule 2: More than the RCT measure is low (tends to 0), more than the Rep measure is large (tends to the value 7: strongly disagree)	• Case 1: compliance with rules - The interface is effective: If the majority of subjects (participants) respect the rule 1. - The interface is less effective: If subjects follow the two rules with an average way. The interface has some problems in term of execution of tasks - The interface is ineffective: If the majority of subjects respect the rule 2. The interface has a lot of problems in term of execution of tasks
			• Case 2: No respect for rules A problem of imbalance between the two measurements is detected. It requires a revision of the evaluated interface with taken into account the users' profiles.

Table 2 explains new quality indicator able to judge the performance of the effectiveness criterion in term of execution of tasks. This indicator is constructed based on a set of mapped evaluation data extracted from the initial mapping model. It performs the crossing between qualitative with quantitative measures which are the bases of the defined applied rules and the evaluation decisions.

This case study illustrates different examples of the mapped data specified into the initial mapping model and an example of a new indicator specified into the reference model. These two models will be the basis to provide evaluation and to obtain results based on the principle of the integration between qualitative and quantitative data. These results after evaluation will be presented into the model of the results mapping model with indicators.

4 Conclusion and Perspectives

A new proposition for the evaluation of HCI was presented in this paper. This proposition allows supporting quality evaluation. It aims to demonstrate how integrating qualitative with quantitative evaluation in order to enhance HCI quality evaluation results. For this purpose, this paper introduces a method that defines and constructs new quality indicators based on a mapping model that combine qualitative with quantitative evaluation data. These indicators integrate effectively data by crossing qualitative with quantitative measures.

As a part of our future work, different experimental tests will be done for ensuring the validation of our approach. This method will be implemented into a new quality evaluation tool.

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