Towards the Quality Improvement of Web Applications by Neuroscience Techniques

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Abstract: User-centered design not only requires designers to analyse and anticipate how users are likely to use a Web application, but also to validate their assumptions with regard to user behaviour in real environments. Cognitive neuroscience, for its part, addresses the questions of how psychological functions are produced by neural circuitry. The emergence of powerful new measurement techniques allows neuroscientists and psychologists to address abstract questions such as how human cognition and emotion are mapped to specific neural substrates. This paper focus on the validation of user-centered designs and requirements of Web applications by neuroscience techniques and suggest the use of these techniques to achieve efficient and effectiveness validated designs by real behavior of potential users.

1 INTRODUCTION

Neuroscience is a heterogeneous field, consisting of many and various sub-disciplines (e.g., Cognitive Psychology, Behavioral Neuroscience, and Behavioral Genetics). In order for our understanding of the brain to continue to deepen, it is necessary that these sub-disciplines are able to share data and findings in a meaningful way;

Neuroeconomics (Karmarkar, 2011) is an interdisciplinary field that seeks to explain human decision making, the ability to process multiple alternatives and to choose an optimal course of action. It studies how economic behavior can shape our understanding of the brain, and how neuroscientific discoveries can constrain and guide models of economics. Behavioral economics (Karmarkar, 2011) emerged to account for these anomalies by integrating social, cognitive, and emotional factors in understanding economic decisions. Neuroeconomics adds another layer by using neuroscientific methods in understanding the interplay between economic behavior and neural mechanisms. By using tools from various fields, some scholars claim that neuroeconomics offers a more integrative way of understanding decision making. More specific for our purposes is Neuroinformatics (Adee and Sally, 2008) which is a research field concerned with the organization of neuroscience data by the application of computational models and analytical tools. These areas of research are important for the integration and analysis of increasingly large-volume, high-dimensional, and fine-grain experimental data. Neuroinformaticians provide computational tools, mathematical models, and create interoperable databases for clinicians and research scientists. There are three main directions where neuroinformatics has to be applied (INCF, 2013):

- The development of tools and databases for management and sharing of neuroscience data at all levels of analysis,
- The development of tools for analyzing and modeling neuroscience data,
- The development of computational models of the nervous system and neural processes.

Neuromarketing is a new field of marketing research that studies customers' sensorimotor, cognitive, and affective response to marketing stimuli. In fact, marketing field is related to quality with the strategic idea that we have to assure that the software product is accepted by the customer. So, we can use all these techniques and cross them with neuroinformatics to achieve the quality improvement of Web applictions and Web applications development process. Actually, neuromarketing research raised interest for both academic and business side. In fact, certain companies, particularly

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those with large-scale goals, have invested in their own laboratories, science personnel and / or partnerships with academia (Karmarkar, 2011). Then, Neuroscience is currently an interdisciplinary science that collaborates with other fields like economics, marketing or informatics. This science could be useful to be applied to quality improvement of Web applications and Web applications development process. Regarding quality, we mean that the Web application must fulfill all requirements that customers really demand. In addition, it is very important to control that the software development process is the most adequate for software developers to design the software product that we are looking for our customers. Thus, neuroscience applies to achieve quality improvement in Web applications and Web applications development processes.

As regards quality, it is a relevant aspect to consider in the software engineering context. There are several different definitions in the literature like, for example, conformance to user expectations, which is often described as the "fitness for purpose" of a piece of software. Another definition of quality related to software quality measures concerns the high quality of software design (quality of design) and the high level software conforms to that design (quality of conformance). In fact, regarding quality, we basically focus on quality of the software product or quality of the software development process. On the one hand, quality of software product really means that the software product meets all requirements and needs that customers demand. On the other hand, it is very important to control the software development process to perform the software product effectively and complete all customers' needs. Then, to implement customer's requirements is a key aspect for customers to accept software products.

Normally, good references from satisfied customers enable business growth in most companies. A software development company that is responsive to requesting and demonstrating a "can do" attitude will gain competitive advantages. In general, these benefits are obtained from medium to long-term periods. Internal benefits, including cost reductions from improved quality levels, are often achieved much faster. Production costs can be reduced when production processes are streamlined or when their effectiveness increases. This can be achieved through an improved process control that reduces the undesirable production of unable parts. Shortened machine setup times and immediate availability of complete production information can further improve productivity. Quality professionals have studied valuable improvement techniques that lead to reduce production costs through quality improvements.

This paper comprises the following sections. After this introduction, Section II analyzes some related works and concepts found in the literature. Then, Section III proposes the NDT methodology to capture and define Web application requirements and psychological/emotional experiences to be expected by users. NDT is a Model-Driven Web development approach for the development of Web applications which is mainly focused on requirements. Section IV proposes QuEF for the definition of a Quality Model from the requirements and psychological/emotional experiences defined by the NDT methodology. QuEF provides templates and methods to define the Quality Model and defines a life cycle for the Quality Model that ensures the quality continual improvement of the model. Then, Section V explains how this Quality Model can be validated by neuroscience techniques. Concluding the paper is Section VI by stating some learned lessons and ongoing work.

2 RELATED WORKS AND CONCEPTS

As far as quality in Web applications based on neuroscience is concerned, lots of papers describe the necessity of assuring quality and controlling the development process of these Web applications or software products.

Barsalou (Barsalou, 2012) explains that the human conceptual system contains people's knowledge of the world. The conceptual system represents components of experience, such as knowledge about settings, objects, people, actions, events, mental states, properties and relations, rather than containing holistic images of experience. Componential knowledge in the conceptual system supports a wide variety of simple cognitive operations including categorization, inference, representation of propositions and productive creation of novel conceptualizations.

Wang and Patel (Wang and Patel, 2009) explore the basic properties of software and look for the cognitive computer foundations of software engineering. They explain that the nature of software is characterized by computer, behavioral, mathematical and cognitive properties. The authors identify a set of fundamental cognitive constraints of software engineering, such as intangibility, complexity, indeterminacy, diversity,

polymorphism, inexpressiveness, inexplicit embodiment and unquantifiable quality measures.

Hofman (Hofman, 2009) examines non-technical aspects of software quality perception and proposes further research activities on this subject. Cognitive science, psychology, microeconomics and other human-oriented sciences do analyze human behavior, cognition and decision-making processes. Therefore, this paper recommends that the professional product perception should be analyzed as a software product.

Jean-Michel Hoc reviews the state-of-the-art of cognitive cooperation in Hoc (Hoc, 2009) to extend an individual cognitive architecture and handle these situations, by combining private and cooperative activities that are highly task-oriented. In Hoc (Hoc, 2009), cooperation is tackled as the management of interference between individual activities to facilitate the team members' sub-tasks and the team's common task, if any. This review of the literature is a step towards finding out a theoretical approach that could be relevant to evaluate cooperation and design assistance in diverse domains.

Zaytsev et al. (Zaytsev and Morrison, 2012) identify multiple areas where continuous integration can be employed to further increase the quality of neuroinformatics projects by improving development practices and incorporating appropriate development tools. Finally, they discuss what measures can be taken to lower the barrier for developers of neuroinformatics applications to adopt this useful technique.

As regards international standards for software products quality, ISO/IEC 25000:2005 (ISO/IEC 25000:2005, 2014) provides guidance on the use of the new series of International Standards named Software Product Quality Requirements and Evaluation (SQuaRE). This guide aims to offer a general overview of SQuaRE contents, common reference models and definitions, as well as the relationship among the documents, allowing users of this guide to better understand these series of International Standards, according to their purpose of use.

3 A MODEL-DRIVEN WEB DEVELOPMENT METHODOLOGY BASED ON WEB REQUIREMENTS TREATMENT

NDT (Navigational Development Techniques) (Escalona and Aragón, 2008), is a methodological approach oriented to the Web Engineering. Web Engineering is a specific line in the Software Engineering that offers specific models and techniques to deal with the special characteristics of Web systems. In the last years, several web approaches were defined: OOHDM, UWE, WebML or OOHare only some examples. However, comparative studies concluded that these approaches are mainly focussed on analysis and design phases and there is an important gap in Web requirements treatment.

NDT is oriented to cover this gap. Thus, it is mainly focussed on the requirements and the analysis phases, although in its last versions it covers the hole life cycle. It is an approach defined in the Model Driven paradigm and it offers a suitable and easy methodological environment. The most important characteristics of this approach are:

- It offers a friendly interface for the final user in the requirements phase.
- It is based on a set of MOF metamodels that are transparent to the development team. These metamodels are the base of NDT development process.
- It follows the traceability of the requirements from their definition until their analysis, offering a systematic process based on formal transformations defined by QVT that proceeds until implementation.
- NDT is completely UML based, so it is compatible with other approaches such as Métrica.

NDT is being applied in several real projects. It was a very applied methodology in real environment with very good results. Although NDT was initially supported by NDT-Tool, today it is not used and it is not being reviewed. In any case, in NDT-Tool section information about this tool can be found.

Today, NDT has evolved to be used in practical environments, and is now one of the best methodological proposals addressing the development of many software projects, specifically projects aimed at the web. IWT2 offers a suite of support tools that apply the NDT methodology to your software project. This toolkit is distributed under the name NDT-Suite (García-García et Al, 2012). Thus, with the NDT methodology not only is necessary to specify user requirements but psychological/emotional experiences to be expected by users.

4 A FRAMEWORK TO MANAGE QUALITY OF WEB APPLICATIONS

Once Web application requirements and psychological/emotional experiences to be expected by users is well defined, it is necessary to assure the quality continual improvement of these concepts on Web applications. Besides, it is necessary to define a quality model based on these requirements that must be validated afterwards by neuroscience techniques. QuEF (Quality Evaluation Framework) (Dominguez-Mayo et al., 2012a; Dominguez-Mayo et al., 2012b) is a framework to manage quality of any product or process, which aims to enforce quality and continuous quality improvement of Web applications and software development process by means of defining a quality model. QuEF is a framework to manage quality of entities (products, processes, services, organizations, etc.) in any context and domains. In previous works, this framework was used to manage quality of Model-Driven Web development methodologies (Dominguez-Mayo et al., 2012b). QuEF has been adapted for designers of any products and processes to analyze, evaluate, control and increase the quality and improve their design and results. In addition, this framework can be also used for consumers to identify the most suitable product or process for them and decide which one will be used depend on their project scope.

This framework describes templates and methods to define a specific quality model for the domain under study. It also offers a method in order to instantiate the quality model, evaluate it and calculate preferences of their elements. Besides, the framework includes the definition of a set of phases to enforce the quality continual improvement of the quality model. This is the most important aspect that all the quality management is centralized on the quality model.

The Quality Model represents the core of the framework and thequality management revolves around it. We propose a Quality Model metamodel consisting in a simplification and adaptation of ISO standards. Particularly, ISO/IEC 15939:2007 defines a measurement process applicable to system and software engineering and management disciplines. The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users. ISO/IEC 15939 (ISO/IEC 15939:2007 2012) so that the model instantiation can be more flexible and practical. The main objective concludes that quality management becomes strategically active. Therefore, all the strategic assets have to be identified and it is necessary to carry out capture, definition and validation of the Quality Model that will be used for quality management. The Quality Model contains: Features and Sub-Features (both are categories of an entity's properties). A Feature is a higher-level category of the domain description of an entity, while a Sub-Feature is a lower-level category. A Property points out the degree to which a Sub-Feature is measured. In simple terms, a Property is used for measuring Sub-Features. Below, different levels for Properties and Quality Characteristics are explained.

- Feature (FT-<Level 1>): It is a general concept of an entity, a set of properties, but a higher-level concept of an entity's characterization that describes it broadly. A Feature has a set of Sub-Features.
- Sub-Feature (FT-<Level 0>): It is a specific concept of an entity. It is a set of Properties, but a lower-level concept of an entity's characterization. It is used to categorize the Properties of the entity in two levels (Feature and Sub-Feature).
- Property: A Property is used for describing and analyzing the Sub-Features of an entity.

As explained before, Quality Characteristics (hierarchical by Quality Characteristics (or QC-<Level 1>) and Quality Sub-Characteristics (or QC-<Level 0>) are the quality aspects together with these Properties that have to be assured on an entity. Subsequently, as shown in figure 1, the author would define the relations between these Properties and Quality Characteristics to identify how each Sub-Feature in each Quality Sub-Characteristic is influenced. These association links would represent dependencies between Properties and Quality Characteristics. They would show Quality Characteristics that are affected by Sub-Features or areas of the entity that would be significantly affected if it changed. Association links may be based on proven and real-world experience.

- Properties are the descriptive environment in which the quality management is going to be performed.

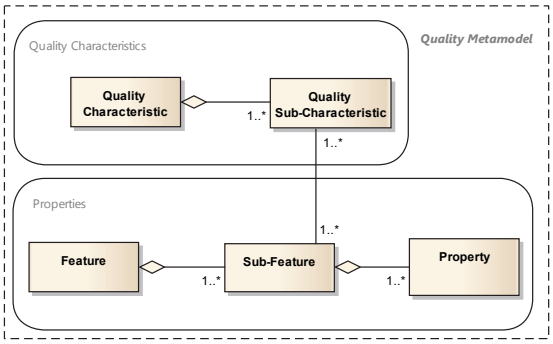

Figure 1: Quality Metamodel.

- Quality Characteristics are those quality aspects designers must ensure in the set of Properties that are offered to users.

On the contrary, Quality Characteristics and Quality Sub-Characteristics are quality aspects influenced by an environment description or Properties. In other words, Quality Characteristic is a higher-level quality aspect. Higher-level attributes are called Quality Characteristics and lower-level attributes are called Quality Sub-Characteristics, in a hierarchy of Quality Characteristics. A MoI (Matrix of Influences) relates Properties and Quality Characteristics Properties and Quality Characteristics are organized in rows and columns; Properties (hierarchical in Features and Sub-Features) are listed in rows and Quality Characteristics (hierarchical in Quality Characteristics and Sub-Characteristics) are represented in columns.

For instance, if a Web application is going to be evaluated from the point of view of users, all requirements have to be defined by the NDT methodology. As regards properties, all Web applications requirements have to be described like functions or their interfaces that the Web application offer to users. Once the properties are defined, quality characteristics must be defined following the defined strategies for the specific context. Then, for Web applications a very important aspect is the usability and functionality of the application. In fact, these two quality characteristics are based on ISO 25000 but, in the end, all these quality characteristics are abstract concept that have to be measured by some properties or defined metrics. So, as regards usability quality characteristic is concerned, to obtain some value from users, we can do them some questions like:

- Does the user feel that it is easy and efficient to get things done with the Web application?
- Does the user see the Web application as visually attractive?
- Does it feel pleasurable in hand? Does the Web application give me inspiration? Or wow experiences?
- Is it easy to learn?

As regards functionality, we can also do some questions to users like:

Does the user perceive the functions in the Web application as useful and fit for the purpose?

QuEF can be used from two points of view: designers', who need to analyse, control, evaluate and improve entities and consumers, who need to compare entities (depending on their context) to decide the most suitable one for them. The main difference with other frameworks is that QuEF focus on the quality model and the framework also defines a life cycle in which all phases revolve around the quality model. It is based on ITIL v3 but with a big difference which is that is not focused on services but on a quality model. The same way to ITIL v3, it is composed by five phases to ensure the quality continual improvement of the quality model. The aim is to centralize all efforts of the quality management on the quality model. This means that it comprises several phases which include different objectives and artefacts:

- Quality Model Strategy phase: This phase is a strategic active that focuses on the definition of a strategy for the quality management. The past, the present and future view elements of the quality model in the domain under study are fundamental to achieve effective and efficient quality management.
- Quality Model Design phase: This phase is where the quality model is finally designed in terms of all strategic actives in the previous phase. This quality model is the model used in the next phase for operating for the quality management.
- Quality Model Operation phase: In this phase the quality model is used to carry out the Quality management. So, the Analysis and Evaluation management processes are performed within this phase.
- Quality Model Transition phase: If the domain or context is changed for the appearance of new trends, then this phase describes the processes that carry out the changes in the quality model but without affecting the Operation phase.
- Quality Continual Improvement phase: This phase performs all processes to improve quality of all processes in the life cycle and the very same quality model.

Then, we propose a process to capture, define, validate and manage the quality continual improvements of Web application requirements and psychological/emotional experiences to be expected by users. This process, as shown in figure 2, is based on a hypothetical quality model. This hypothetical quality model is built from the Web application requirements and psychological/ emotional experiences to be expected by users that have been captured and defined by the NDT methodology. Then, this hypothetical Quality Model must be validated using biofeedback. The steps include the following activities:

1. Definition of Web application requirements and psychological/emotional experiences to be expected by users (this step is covered by the NDT methodology)
2. Define the hypothetical Quality Model using templates and methods of QuEF and enforces the quality continual improvement of the Quality Model.
3. Neuroscience Research for quality evaluation.
   a. Measurement of selected parameters about biofeedback
   b. Validation of hypothesis by the evaluation of information.

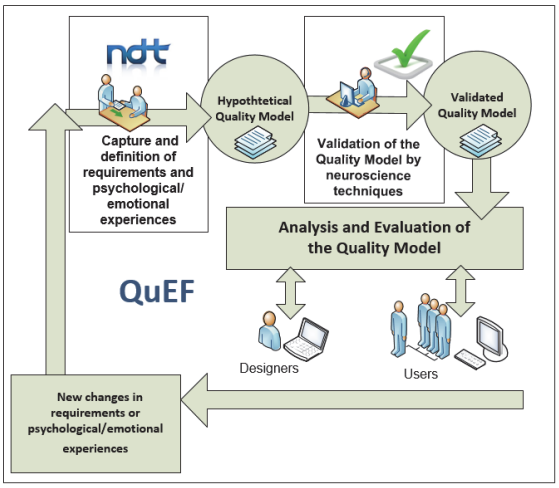

Figure 2: Process to capture, define, validate and to manage the quality continual improvements of requirements.

5 THE QUALITY MODEL VALIDATION BY USING NEUROSCIENCE TECHNIQUES

This way to evaluate quality by psychological and emotional experiences let us to express new other abstracter concepts (independently that ISO recommend) like directly the perception value of the Web application for users with question like:

- Is the Web application important to me? What is its value for me?

There is some cognitive neuroscience research methodology like Steady State Topography (abbreviated SST) which is a methodology for observing and measuring human brain activity. This methodology has been principally used as a commercial application in the field of neuromarketing and consumer neuroscience. In this case, there is a relation between the quality assurance of products and neuromarketing but with some differences. The main objective of neuromarketing is to sell the product while for the quality assurance of products is that the product to be accepted by users.

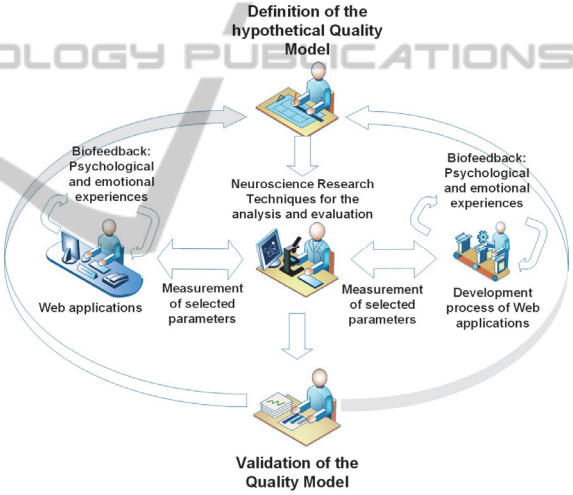

Figure 3: Activities to validate the hypothetical quality model for Web applications and the development of Web applications.

In addition, biofeedback may be used for the process of gaining greater awareness of many physiological functions primarily using instruments. Biofeedback may be used to improve health, performance, and the physiological changes which often occur in conjunction with changes to thoughts, emotions, and behavior. Some kown equipment and techniques that can be used are:

- Functional magnetic resonance imaging or functional MRI (fMRI) to measure changes in activity in parts of the brain. It is an MRI procedure that measures brain activity by detecting associated changes in blood flow. This technique relies on the fact that cerebral blood

flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases.)

- Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. EEGs can detect changes over milliseconds, which is excellent considering an action potential takes approximately 0.5-130 milliseconds to propagate across a single neuron, depending on the type of neuron. EEG measures the brain's electrical activity directly, while fMRI record changes in blood flow. In fact, fMRI are indirect markers of brain electrical activity. Anyway, EEG can be used simultaneously with fMRI.
- Heart rate, respiratory rate and galvanic skin response to learn why consumers make the decisions they do, and what part of the brain is telling them to do it. Heart rate refers to the speed of the heartbeat, specifically the number of heartbeats per unit of time. The heart rate is typically expressed as beats per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide.

For this case, a quality model is going to be defined by properties and quality characteristics. Properties are going to represent all requirements that describe a Web application and quality characteristics are going to represent psychological and emotional experiences of Web applications by users as shown in figure 3. Then, the goal of this quality management using QuEF is to identify and assess, on one hand, how changing elements of Web applications impacts on users behavior. And, On the other hand, how changing elements of a Web applications development process impacts on developers behavior. Thus, a quality model is going to be defined as a set of properties of Web applications or a set of properties of the development process of Web applications that have to be related to psychological and emotional experiences.

6 CONCLUSIONS AND FUTURE WORKS

This paper proposes a process to capture, define, validate and manage the quality continual improvements of user requirements and psychological/emotional experiences to be expected by users. It focus on the validation of user-centered designs and requirements of Web applications by neuroscience techniques and suggest the use of these techniques to achieve efficient and effectiveness validated designs by real behavior of potential users. For the specification of requirements and psychological/emotional experiences the NDT methodology is proposed. NDT is a Model-Driven Web development approach for the development of Web applications. In addition, a framework to enforce quality and the quality continual improvement of Web applications is proposed. QuEF is a framework to manage quality of any product or process. So, it can be applied to Web applications. It is composed by five phases to ensure the quality continual improvement of the quality model. The aim is to centralize all efforts of the quality management on the quality model. In addition, the framework also defines protocols and methods to perform each phase, so all protocols and methods are systematized.

The proposed process is based on a hypothetical quality model. This hypothetical quality model is built from the requirements that have been captured and defined by the NDT methodology and must be validated using biofeedback.

As far as Web applications development processes are concerned, we are currently working in the improvement of the NDT methodology and the QuEF framework. Furthermore, a tool support is also being implemented in order to implement this solution in real environments. So, we can get quality management in an automatic way using QuEF, automating the quality management of entities (products, processes, services, organizations, etc.) in order to reduce costs, minimize time and improve quality of the quality management process.

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