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Formalising Human Mental Workload as Non-monotonic Concept for Adaptive and Personalised Web-Design

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Abstract. Web Design has been evolving with Web-based systems becoming more complex and structured due to the delivery of personalised information adapted to end-users. Although information presented can be useful and well formatted, people have little mental workload available for dealing with unusable systems. Subjective mental workload assessments tools are usually adopted to measure the impact of Web-tasks upon end-users thanks to their ease of use and are aimed at supporting design practices. The Nasa Task Load Index subjective procedure has been taken as a reference technique for measuring mental workload, but it has a background in aircraft cockpits, supervisory and process control environments. We argue that the tool is not fully appropriate for dealing with Web-information tasks, characterised by a wide spectrum of contexts of use, cognitive factors and individual user differences such as skill, background, emotional state and motivation. Furthermore, in this model, inputs are averaged without considering their mutual interactions and relations. We propose to see human mental workload as non-monotonic concept and to model it via argumentation theory. The evaluation strategy includes coparisons with the NASA-TLX in terms of statistical correlation, sensitivity, diagnosticity, selectivity and reliability.

Keywords: Human Mental Workload, Non-monotonic Reasoning, Argumentation Theory, Human-Computer Interaction, Web Design.

1 Introduction

Interaction and Web Design have been continuously evolving with Web-sites becoming more complex and structured. This shift is mainly caused by the increasing degree of personalisation of information presented to end-users and by the increasing adaptivity new interactive Web-based systems incorporate. Although information presented can be useful, interesting and well formatted, people have little mental workload available for dealing with unusable interfaces [1]. A burdensome interface has a negative impact on the analysis of data and decision-making processes of individuals consuming information over the Web. Similarly, boring and monotonous interfaces are skipped and avoided by end-users as not

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engaging. Designers are usually focused on creating user-friendly interfaces. However, poor usability impedes individuals to properly seek and consume information, and in turn Web-sites loose visitors [2]. If designers can measure the mental workload of end-users, during interaction, then specific structural interface or system changes can be evaluated in the design process. Interfaces that generate low mental workload on end-users (underload), are usually perceived being boring and not interesting. High mental workload (overload), instead, is synonymous of complex and tiresome interfaces. Both the levels should be avoided, bringing workload to proper fitting load. Mental workload assessment techniques can be small scale, representing a discount and cheap method for enhancing testings of usability. Nasa Task Load Index [3] is a subjective mental workload assessment technique adopted in Web-based systems. Although it has been taken as a reference tool for its simplicity, it has a background in aircraft cockpits, supervisory and process control environments. In this proposal, we argue the tool is not fully appropriate for dealing with Web-information tasks, characterised by a wide pool of cognitive and environmental factors affecting mental workload. NASA-Tlx a multi-dimensional rating procedure that infers an overall workload index based on a weighted average of ratings on six sub-scales: mental, physical and temporal demands, own performance, effort and frustration. We argue that this set of factors is limited to properly assess workload on Web-tasks because it does not consider individual differences such as the skills, the background and the motivation of operators along with the context of use. Furthermore, in this model, inputs are averaged without considering their mutual interactions and relations.

1.1 Human Mental Workload

Human Mental Workload (MWL) is a multifaceted complex construct mainly applied in psychology. A plethora of definitions exists in the literature [4,5,6,7]. Intuitively, mental or cognitive workload is the amount of mental work necessary for a person to complete a task over a given period of time. Generally, it is not a inherent property, rather it emerges from the interaction between the requirements of a task, the circumstances under which it is performed, and the skills, behaviour and perceptions of the operator [3]. All these factors can be combined in different ways, supporting and contradicting each other. Some of them can be uncertain and contraddicting. For this reason we propose to see the construct of mental workload as a non-monotonic concept. The basic idea of non-monotonic inferences is that, when more information is obtained about a concept, some inference that were earlier reasonable may be no longer so. In modeling mental workload, pieces of evidence can be aggregated following a defeasible reasoning process, and the conclusion they support can change in the light of new evidence. For instance, if the time spent for executing a task is known to be high, this is a reason to believe that the mental workload elicited is high as well. However, if the objective activity on the same task is also available, and it is known to be low, then there is a new reason to infer the mental workload is low. Yet, if the end-user is known to be not skilled, then is believed that workload is high, thus justifying the high time for executing the task. Further evidence can be part of this reasoning process [8], known to be defeasible due to the fact that arguments are not infallible, instead they can be defeated by new information.

1.2 Argumentation Theory

Argumentation theory has become an important topic in the field of Artificial Intelligence and Computer Science, resulting from a multi-disciplinary approach at the intersection of Philosophy and Law, and with elements drawn from Psychology and Sociology. It systematically studies how pieces of evidence, built as arguments, can be expressed, sustained or discarded in a defeasible reasoning process, as well as the validity of the conclusions reached [9]. Argumentation theory gained importance with the introduction of formal and computable models, inspired by human-like reasoning. These models extended classical reasoning models based on deductive logic that appeared increasingly inadequate for problems requiring non-monotonic reasoning, commonly used by humans, as well as explanatory reasoning, not available in standard non-monotonic logics such as default logic [10]. Argumentation Theory implements non-monotonic reasoning [11] that differs from standard deductive reasoning because in the former a conclusion can be retracted in the light of new pieces of evidence, whereas in the latter the set of conclusions always grows. Argumentation lends itself to explanatory reasoning because argumentative reasoning is composed of modular and intuitive steps, thus avoiding the monolithic approach of many traditional logics for non-monotonic reasoning. *The reasoning required in defining and modeling the concept of human mental workload is both non-monotonic and explanatory.* Argumentation theory is also suitable when the available information may be uncertain and conflicting. This is the case of mental workload, where there may be relevant but partially uncertain and conflicting evidence.

2 Proposal

We propose to extend the well-known work of Dung, on abstract argumentation frameworks [10], for rationally measuring mental workload and for aggregating available evidence, in a given Web-context, towards a unique representative level of workload. Practically, we propose to design a context-aware and user-centered framework in which human mental workload can be defined, measured, analysed and explained taking into consideration individual differences and contexts of use. The research question **RQ** is:

> **As human mental workload can be seen as a non-monotonic complex construct, what is the impact of non-monotonic reasoning techniques in approximating it as a usable computational concept and in enhancing the quality of human mental workload assessments?**

Two sub-research questions can be defined: **sRQ1**: To what extent can Argumentation Theory support the measurement of subjective mental workload? **sRQ2**: To what extent can an argument-based model foster/enhance the assessment of subject mental workload in Web-based information systems?

3 Evaluation Strategy

The evaluation is aimed at assessing the quality of the outcomes of the arguments-based computational model by means of comparisons against the outcomes of the Nasa-TLX model in terms of statistical correlation and differences in sensitivity, diagnosticity, selectivity and reliability. This evaluation process is as following:

1. selection of a set of Web-interfaces X;
2. design of a set T of Web-tasks for each x in X;
3. implementation of structural changes on each x in X resulting in a set X^{mod};
4. execution of designed tasks T by two groups of end-users on X & X^{mod};
5. subjective assessment of workloads, after execution of tasks T, both by the designed arguments-based model (AM) and the Nasa-TLX;
6. evaluation of AM comparing its outputs against the ones of Nasa-TLX's (on X & X^{mod}) by means of statistical correlation;
7. evaluation of the sensitivity, diagnosticity, selectivity and reliability of AM.

4 Key contributions

The research will contribute to the field of Web design, proposing a novel executable paradigm capable of human mental workload assessments in the field of Web-based information systems. The expected outcomes are to produce an applicable context-aware and user-centered methodology more appropriate for assessing subjective mental workload in Web scenarios. The contribution will provide reference and case studies for the application of a tool useful for promoting mental workload-aware Web systems contributing to the appreciation and support of design, personalisation and adaptation practices in HCI.

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