A Design Rationale Model for Green Human Computer Interaction Design

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***Abstract*—Curbing the global environmental threats become a worldwide issue. Over the years, significant scientific evidences emerged that highlighted the relationship between massive industrialization and global environmental threats. For this reason, all types of industrialization are undergoing radical re-engineering; the aim is to manufacture goods and services that are efficient, safer and environmental-friendly. In terms of software industry, sustainable software engineering has become a hot research topic; it spans sustainability issues in all stages of software life cycle. This paper proposes a design rationale model for human-computer interaction design. The proposed model is an adaptation of the QOC deliberation model, where green computing guidelines are used as criteria for the evaluation of interface design decisions. As part of the collaborative decision making process pertaining interactions design decisions, we believe that there is a need to provide designers with contextual guidance that help to construct a shared mental model about the design problem, and how it is influenced by the recommendations of the Green IT campaign. For this reason, we incorporated the Green computing guidelines within the elements of the proposed design rationale model. The paper is also presenting a prototypical implementation of the proposed model.**

***Index Terms*—green computing, sustainable software, design rationale, knowledge reuse, greenhouse effects**

I. Introduction

Human-Computer Interaction (HCI) is a research topic that overlaps with human, technology and environmental issues. Though there are extensive researches on sustainability issues in many disciplines, but there is little written specifically about sustainability and interaction design in the main corpus of the HCI literature [1]. Since 2010 greater attention is given to IT and software sustainability, better known as Green computing [2]. The primary goal of the Green computing campaign is the manufacturing and use of computing resources more efficiently, while maintaining the overall systems' performance. This campaign is expected to lower IT power consumption and the IT waste, and so leading to minimising the causes of global warming phenomena that endangers the universe. Contributions of the IT resources to this phenomenon are witnessed by the increasing demand for computing power to cater for managing the huge global business activities. This demand for computing power has increased during the past two decades, causing an increase in IT-related power consumption and resulting higher carbon emissions [3]. But the increasing use of computing power has led to exploiting more power-hungry machines in the form of powerful PCs, servers and huge data centers. Unfortunately, greater part of these systems and its consumables would be dumped later in the form of electronic waste (e-waste) that endangers the environment and all types of living species. In regard to software interaction design, decisions involved in this process have a major influence on the sustainability of the software services and products being designed. Therefore, design decisions related to the selection of hardware and software artefacts has to be in line with the Green computing guidance and recommendations.

The rest of this paper is organised as follows. In Section 2 we highlighted motivational attributes behind the Green computing campaign, and also presented the likely threats of manufacturing IT services and products in the conventional way. Section 3 briefly introduces the design rationale models, and the proposed model is described in Section 4. Section 5 shows a prototypical implantation of the proposed model. Section 5 ends with some brief concluding remarks.

II. Green Computing Issues

The main issues of Green computing campaign are: the increasing systems power consumption; and the ever escalating volumes of dumped e-waste. Alarming figures of power consumption rates is attributed to many IT related technologies and practices. For example, over the last decade, data centers have become a part of most organisational IT strategies, meanwhile, enterprise-scale data centers account for about half of corporate energy use and resulting carbon footprint [4]. In order to lower the impact of this problem, there are many new technologies emerged to rationalise the power requirements of the data centers, such as the virtualization,

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which is a technique that enables Intel to combine several physical systems into a virtual machine that runs on a single, powerful base system, thus significantly reducing power consumption [5]. Nonetheless, because of the increasing power consumption, and its wider scale of threats to the continent, green computing methods have become a high priority [6].

The rapid expansion of the web technology systems is also contributing to power consumption issue. Currently most of business transactions and social interactions are handled through the web. This involves extensive rates of downloads and uploading of business and social data that consumes more power [7]. The Green interaction design process can play a major role in this regard. In terms power consumption of interactive systems, screen technologies, interaction modalities and styles greatly impacts both: the rate of power consumption, and the volume of business data streaming. It is also contribute to lowering risks on human users' health and wellbeing. This includes all types of interactions scenarios that might cause physical problems to human users such as users' eye problems which is usually caused by the use of inconsistent interface colors and also the number of gaze changes as well as traveling length of eye gaze position on the computer screen [8].

In regard to the issue of e-waste, this problem is escalating rapidly as a result of the swift growth of business markets which is even crossing over to less developed regions. This business expansion involves the use of more IT artefacts and chemical-based consumables which are used in the assembly and operation of ICT systems [7]. Usually organizations and citizens practice the frequent replacement of IT systems and devices. This comes as a result of the rapid advancement and innovations in IT industry. But most of the dumped IT aretfacts is made by very poisonous materials which endanger the living species and also the natural resources. According to Yates (as cited in Mankoff *et al.* [9]), the Forrester Research report projects the number of personal computers in use in the most populous countries to double to 2.25 billion by 2015 [10]. This would definitely contribute to increasing the rates of e-waste. For this reason, e-waste education becomes prominent issue in the electrical engineering community [11]. The aim to equip software and hardware engineering graduates with the proper knowledge about these global issues that influences their profession.

III. Design Rationale Models

Modeling is a purposeful abstraction of some part of reality [12]. And in terms of the design rationale management, design rationale models are used to capture an abstract view of designers' deliberations that takes place during collaborative discussions. It is mainly used to visually explain the rationale behind decisions taken as part of any product design activity [13]. This takes the form of pictorial hierarchy of designers' argumentation details.

The most common decision rationale models are: DRL [14], QOC [15] and IBIS [16]. They are all aimed to codify design decisions including the decisions' rationale. This involves capturing different issues, options, alternatives and justifications behind designers' decisions. These models vary in their ability to accommodate the deliberations with the adequate expressiveness power. The aim is strike a balance between expressiveness and computational complexity.

IV. The Proposed Model

Basically, the proposed model is an adaptation of the QOC design rationale model [15]. The QOC representation consists of a number of *Questions* that are each answered by a number of *Options*, which are judged against a number of *Criteria* used to judge between the *Options* available. The *options* (positions) demonstrate several given choices to solve a problem. The *Criteria* applicable to any particular *Question* is linked to all the answering *options*, either positively or negatively. This makes the *options* more easily judged against one another. This representation allows the characterisation of arguments by criteria and thus brings out influences in decisions taken.

TABLE I. Green Computing Issues for HCI Design

Issue	**Icon**
safer on eyes	
harmful to eyes	
Finger pain	
Harmful to health	
Environment friendly	
Power saving	
Contribute e-waste	
Higher power consumption	

Because the design process is a cognitive process in which the designer generates a design concept, makes design decisions and solves design problem using expertise, knowledge and situational information to satisfy design intents [17]. Therefore, we believe that there is a need to provide the designers with a contextual guidance that help to construct a shared mental model of the design problems being solved. This can further strengthen the design rationale model to become contextually rich, in terms of green computing context. A shared mental model of a problem is the combination of individual designers' knowledge about the task being performed, tools available to execute that task, other team members' skills and abilities, and the procedures for interacting with other team members [18]. Because of the importance of Green IT campaign, we believe that the incorporation of the Green computing factors within the rationale models used to capture the deliberations of HCI

decisions would provide a proper contextual framework for HCI designers. For this reason, and as shown in Fig. 1, we expanded the Criteria element of the QOC model to be contexualised by the characteristics of the Green campaign. This includes, lower power consumption; minimal e-waste, less harmful to users' health and well-being (See Table I). In addition to any other technical or business factors, the Green computing factors would give extra weight to relevant Options in the design space. Eventually this would have greater impact on the emergence green software and hardware industry.

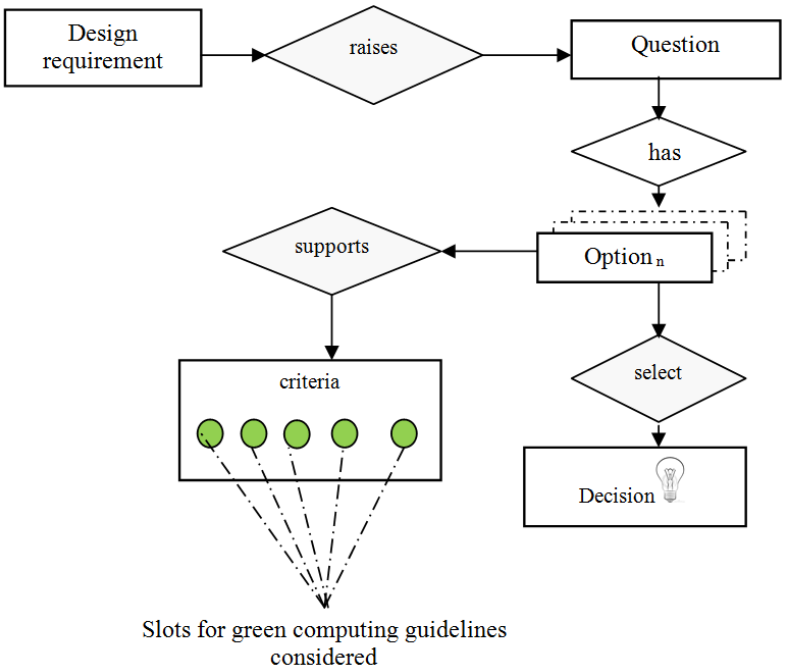

Figure 1. The enhanced QOC model

V. Prototypical Implementation

This section shows part of our implementation of the proposed model in capturing HCI designers' deliberation as part of an asynchronous HCI design sessions. The screenshot represented by Fig. 2 shows a sample of design space where two issues (i.e. design questions) are deliberated to formulate design decisions related to tackle these issues. Fig. 2 shows two questions which are deliberated namely: the forms of the software application outputs; and the colors used for the information presentation over the screen. Based on the design questions raised, few options are proposed together with criteria that support the validity of each option. In addition to any subjective criteria, a set of Green IT factors are proposed as shown in Table I. The weight of the validity and relevance of each proposed option is determined according to the availability or the lacking of respective green computing factors. Labeling the design alternatives (options) accordingly would help to reach rapid agreement among HCI designers, where sustainability issues are taken in consideration in all aspects of HCI design. We believe that the outcome this process is going to be huge in terms of its reflection upon the quality of software design. In addition to its positive reflection on the reduction of environmental threats caused by powers consumption and e-waste, the adherence to Green best practices in interaction design would also help to maintain the physical health and wellbeing of users of IT resources. This is realised by reducing physical and psychological fatigues of human users [8].

VI. Conclusion

Sustainability has become a very essential characteristic in the engineering of all types of products including hardware and software technologies. The aim is to design and develop IT artefacts and resources which can be used very efficiently with less harmful implications on humans and the natural resources. This paper proposes an adapted version of the QOC deliberation representation model which is traditionally used to capture details of any collaborative decision making sessions. The modified version of the QOC is designed in such way that caters to take in consideration the green computing guidelines as evaluation criteria. The paper also presented a prototypical scenario for the exploitation of the proposed model in a typical HCI design session. As a future work, we plan to extend this model further to include other comprehensive components, in the form of multimedia and hyper linked references that support the selection of Green-centered design decisions.

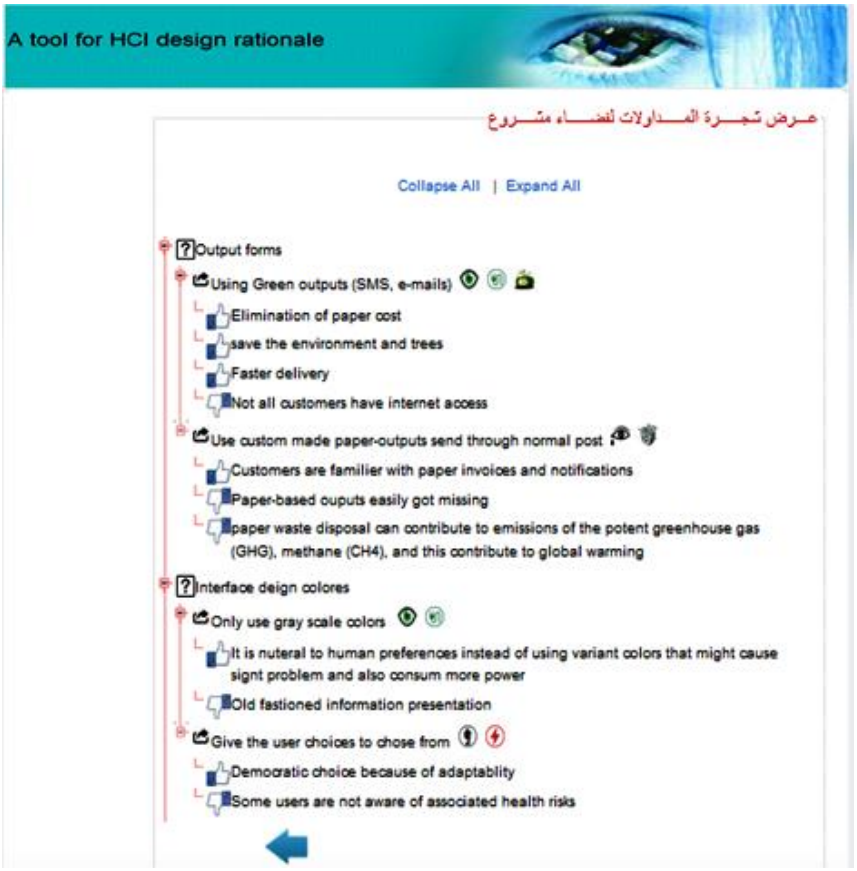

Figure 2. An implementation of the proposed model as part of HCI designers' discussion

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