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SUSTAINABILITY ISSUES IN HUMAN COMPUTER INTERACTION DESIGN

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***Abstract*—The ICT market is growing rapidly and more business and social networking systems is crossing over to less developed regions. This IT usage expansion is associated with increasing environmental threats in the form of greenhouse effects and hardly decommissioned e-waste. For this reason sustainable development became an issue in the last two decades of the 20th century. Recently, sustainable software engineering has become a hot research topic; it spans sustainability aspects in all stages of software lifecycle. This paper discusses sustainability issues in the human-interaction design phase, and it suggests appropriate steps which would lead to tackle HCI sustainability issues such as lower power consumption, waste and saving the wellbeing of human users.**

***Index Terms*—Sustainability, HCI, e-waste, programming interaction design, sustainable interaction design, user interface.**

I. INTRODUCTION

Sustainable Human-Computer Interaction (HCI) is a research topic that overlaps with human, technology and environmental issues. Though there is an extensive research 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]. Currently sustainable HCI is gaining wider interest in HCI research community. This research aims to develop interaction systems which are human and environment friendly. The call for sustainable exploitation of natural resources ignited the need for adopting newer design philosophy in the engineering of all man-made artifacts. This includes software powered systems and devices.

II. SUSTAINABLE SOFTWARE ENGINEERING

Basically sustainability concerns are related to any engineering discipline, and in terms of software engineering, sustainability can be maintained in all stages of software lifecycle. Historically, software reuse can be regarded as one of the early attempts to develop sustainable software components. The aim is to reuse components of existing software to develop new systems and applications. This would contribute to saving cost and developers' efforts.

Though the sustainability issue is important to all software lifecycle phases, but we believe that requirements engineering phase should play a major role in fulfilling the sustainability issue in software industry. In this regard, all software requirements must be evaluated with a matrix of sustainability attributes such as power consumption, shelf-life of the software, user satisfaction, economical use of memory and consumables. The same set of sustainability attributes has to be employed in making decisions of the design phase. The power consumption of IT systems is influenced by many software design decisions related to:

- Programming techniques and style,
- Software and Hardware technology
- Software project documentation
- Design reuse
- Software project management practices

III. IT SUSTAINABILITY ISSUES

Sustainable development becomes an issue in the last two decades of the 20th century. But since 2010 greater attention is given to IT and software sustainability or the so called Green software [3]. In terms of sustainable ICT, the emphasis is more on sustainability issues such as increasing systems energy consumption and the ever escalating figures of dumped e-waste.

A. Power consumption

The widespread of software powered systems and other life style devices ignited the need for more business and household computing power. But the increasing computing power is leading to the exploitation of power-hungry machines in the form of powerful PCs, servers and huge data centers. The more energy consumption means more exploitation of petrol to generate power. This would eventually lead to higher percentage of air pollution that endangers living speciece in the whole planet. According to Ahmed and Shuaib[4], during the past two decades, the use of information technology (IT) has tremendously increased, causing an increase in IT-related power consumption and resulting in higher carbon emission. As a result there is a need for spending more efforts to develop sustainable IT systems. According to Steigerwald and Agrawal [5], software applications designed environmentally consciously consumes 40% less energy than other applications with the same functionality. This implies extra running cost for power-hungry information technology.

The rapid expansion of web technology systems is also contributing to more power consumption. Currently most of business transactions and social interactions are handled through the web. This involves extensive downloads and uploading of

business and social data that consumes more power. Though many data compression techniques are used to lower this impact but interactions with IT systems is getting wider scale.

B. e-Waste

The ICT market is growing rapidly as more business and social networking systems is crossing over to less developed regions. This involves the use of more electronic artefacts and chemical-based consumables used in the assembly and operation of ICT systems. Usually organizations and citizens practice the frequent replacement of IT systems and devices. This comes as a result of the rapid IT product innovations. According to Yates (as cited in Mankoff et. al. [6]), 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 [7]. This would definitely contribute to increasing the e-waste that endangering the environment and human lives.

Currently there is an urgent need for global efforts to manage the e-waste. This includes the mindset-change of IT systems designers. They should be trained to be more environmentally-responsible towards HCI design. For this reason, e-waste education become prominent issue in the electrical engineering community [8]. And as a result of extensive campaign towards more sustainable development, huge efforts being made not only to meet the energy demand by extracting resources from the discarded waste, but also reduce the environmental problem caused by the huge volume of End-of-Life products [9]. In addition to the electronic waste, there is also an associated waste in the form of papers. The use of paper as IT systems output is a common practice and very often software designers pay less attention to designing paper efficient outputs. For this reason HCI designers should adopt more sustainable means as systems output.

IV. SUSTAINABLE HCI DESIGN

The massive universal threat of the unsustainable world economy urges the need for new designing philosophy [10]. From the viewpoint of the interaction design, new design philosophy means the need for adopting a new interdisciplinary approach to HCI design. However, traditional interaction designers are not well informed about sustainability issues related to environment and users' healthy interaction. This of course dictates the need for urgent review of software design curriculum. A similar curriculum redesign effort is presented in [4].

In terms of the power consumption issue, HCI design is influenced by many hardware and software issues. From the view point of hardware technology, screen technology and sometimes contribute to higher power consumption of IT systems. Therefore, designers must negotiate with the customer to use power-friendly features of screen technology such as low power mode when not in use. The use of less screen sizes – when applicable- is a good practice as well. This eventually leads to less quantities of dumped e-waste. Another factor that influences the power consumption is the set of colours used in interface design. The use of colours in interface design should be well balanced. It is well known that bright colours in interface design contribute to more power consumption of related applications. Moreover, certain colour combination might cause harm to user's eye.

Sustainable HCI is not only restricted to interface as a product, it should also include the design process itself. The process model or lifecycle of HCI design also needs to take necessary measures and tools to be a sustainable process. For example, as part of the lifecycle of HCI design, designers usually use throw away prototyping as a way of involving the customers in the design process. These prototypes could be paper-based prototypes or electronic interface mock-ups. Though Shenoy & Eeratta [11] suggests that prototyping should be avoided to save it is cost, but we believe this action may compromise the quality of the developed systems in terms of the user satisfaction. HCI Prototypes usually help to elicit users' requirements more precisely. Instead, we believe HCI designers have to use reusable prototypes in any format. This would save the use of paper and also designers' efforts.

From the viewpoint of programming the user interface, although platform hardware designers work diligently to reduce the power consumption of components, one ill-behaving, power unfriendly software component on the system can thwart any power-management benefits built into the hardware [12]. This is because programming constructs and the code complexity has an impact on the power consumption [14]. For this reason Programming the HCI also plays a major role in the overall power consumption of interaction systems. Therefore, the chosen programming language and the programming constructs influence the energy consumption of the applications. In an observatory study made by Noureddine [13], it is found that the energy consumed by the same algorithm varies from language to language. For example, the C recursive version consumed nearly 268% more energy than its Java counterpart.

Back compatibility is another issue that influences the sustainability of IT systems. HCI programmers have to consider as well the back compatibility as a very important sustainability issue. This would help to avoid the disposal of incompatible hardware as e-waste. This problem usually arises as a consequence of software maintenance and upgrading of existing systems.

In addition to self-coded programming constructs, programmers sometimes use Application Programming Interface (API's). The use of API's is a common practice made by programmers but this sometimes contribute to the replacement of existing hardware due to incompatible software. For this reason, Shenoy and Eeratta [11] suggest that any API that are hardware-specific should be discouraged.

In addition to the electronic waste in the form of dumped IT devices and consumables, the use of IT systems involve an associated waste in the form of paper-based outputs. Output designers have to pay more attention to designing paper efficient outputs when needed. In fact the use of paper can be avoided or kept to the minimal by using electronic-formatted outputs such as Emails and SMS notifications.

The sustainable HCI should not only focus on saving the non-human resources. Saving the human health and wellbeing should be at the core of the HCI research. The HCI design decisions should take into consideration enhancing human users' health and preventing undesired consequences of ill-designed interface. This

includes the physical and cognitive efforts made by users to handle healthy interaction with respective systems. The physical load could be in the form of not well organized interface that involves awkward hand and eye movement to handle the interaction scenarios. Many efforts is going on among HCI researchers to reform human behaviours through the adoption of human cognition and interaction modelling. This research aims to apply persuasive technologies that aim to motivate people to behave in a more sustainable way [2]. In addition to saving users healthy interaction, the sustainable interface design muster public support for technological solutions that reduce greenhouse gas effects[16].

V. SUSTAINABILITY CHALLENGES

There are many technical, legal and economical challenges facing the sustainability and Green IT campaign. Though literature about sustainability emphasis economical motivations in the form of saving energy and e-waste, but Butler and Daly [15] argue whether the interest in Green IT contribute to cost reduction as well. From the legal and economical viewpoint, findings made by Bullock[8] concluded that national regulations sometimes burdens and impede the reuse and recycling. In many countries, national regulations actually discourage the responsible reuse and recycling of IT systems or devices.

Economic wise, Bullock conducted a survey study overseeing and implementing state policy concerning recycling the electronic waste within the university campus. The experiment concludes that it is cheaper for universities to dispose their equipment than it is to turn them over to a recycler, because the state charges them to do the latter. Incentives and motivating initiatives has to be introduced to lower the economical burden of IT recycling. The Returned Deposit system is an example of e-waste management system introduced in the United States. The core concept of the system is that consumers pay a deposit at time of purchase, a variable portion of which is returned when turned in at the end-of-life. This deposit should be sufficient enough to cover transportation and recycling cost of the product [17].

VI. CONCLUSION

This paper presents different aspects of the sustainability issue as a global concern. But it mainly focused on sustainable software engineering with more emphasis on sustainable human–computer interaction. The paper highlighted the impact of sustainability issues on the HCI design. It also discussed ways to mitigate the factors that influence the HCI design decisions related to the power consumption, e-waste and saving the wellbeing of human users. Though the interest in sustainable become a global issue, the paper also highlighted the challenges facing successful adoption of sustainable development in general.

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