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ROLE OF ARTIFICIAL INTELLIGENCE IN IMPROVING UI/UX DESIGN FOR DEVELOPING GREEN AND SUSTAINABLE SOFTWARE APPLICATIONS: A MULTIVOCAL LITERATURE REVIEW PROTOCOL WITH PRELIMINARY RESULTS

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Abstract

Context: *One of the critical phases in software development that must be done accurately is the design of the user interface and user experience design. The way in which users are involved with a system is predominantly shaped by two essential elements: user interface (UI), which refers to the look and feel of the product, and user experience (UX), which encompasses the entire process of the interaction by the user. Our study focuses on the relationship between sustainability and UI/UX design, examining how these design components can be used to create environmentally friendly software with little negative effects on the environment. This protocol describes how factors and principles of sustainable UI/UX design can be ascertained systematically with a special focus on the use of AI in green software engineering. This paper investigates sustainable UI/UX by reviewing literature through a Multivocal literature review (MLR), followed by empirical validation with UX practitioners and researchers. Some specific interesting fields to work are the concept of less but better, energy saving, and AI approaches to the problem. The outcomes are intended as a pathway to a more environmentally responsible design to help researchers and practitioners.* ***Objectives:*** *The objectives of this study is to find key factors and principles of UI/UX design that help in making software more eco-friendly, study the role of AI in enhancing UI/UX design, and explore AI-based practices that contribute to sustainable software development.*

Keywords: *AI, Artificial intelligence, UI UX design, User Interface Design, User Experience design Factors, principles, Sustainable, environmentally friendly interfaces.*

Introduction

Designing the user interface and user experience (UI/UX) is essential to creating web and mobile applications. UI and UX design are two distinct but connected fields. User interface design states the graphical and visual components of web and mobile applications that users view and interact with. Part of it is designing the user interface's layout, typeface, color scheme, buttons, and other visual elements. Conversely, User Experience (UX) design outlines the entire user experience when utilizing mobile or web applications. It includes the application's ease of use for users. It entails creating the user experience as a whole, which provides for information design, content planning, user flows, and usability testing[1]. The main function of UI and UX design is how individuals relate to applications. These two features are closely linked and have an important impact on how customers observe the product as a whole[2]. UI/UX Product Designer Sachin Gopal presents that research in the area of green UI UX design offers a structure that not only highlights user needs but also integrates ethical attention and environmental awareness into the design process[3]. Artificial intelligence(AI) tools are useful in the design industry and can assist designers in a number of ways. The assisted design level plays an important role in UI UX design where the designer uses AI tools to get help in and optimize their design process. The AI apparatuses support the designers suggest designs, doing their tasks automatically, and picking out kinds of stuff like fonts, colors, and designs. They also support tasks that take a lot of time, like exchanging image size, unifying data, and creating prototypes[4]. The literature Point out that while hardware accounts of 2% of IT sector CO2 emissions, 98% accounts from software, emphasizing its serious role in sustainability. Although green hardware design has gained attention, the importance of software as a driver for hardware requirements is increasingly recognized. Conversely, maximum studies concentrate on hardware, leaving gaps in software solutions[5]. To address this, we conducted an MLR to explore AI's role in enhancing UI/UX design for sustainable software and plan an empirical study, including expert interviews, to validate and expand upon our findings.

1. BACKGROUND

Human-Computer Interaction (HCI) suggests a field dedicated to improving human interaction with applications, present prior to the occurrence of User Interface and User Experience design fields. Its essential effort lies in understanding user needs, behaviors and intentions[6]. UI/UX design is important to making user-friendly and visually attractive digital products. UI emphasizes graphical elements like colors, buttons, typography, and layout to ensure reliability. While UX improves the overall user journey, from first interaction to task completion how users interact with the system[1]. UI/UX design is spirited not only in IT but also in web design and marketing, joining psychology, engineering, and design principles. UX certifies users have a satisfying experience, while UI emphases on look and interaction, creating interfaces user-friendly and visually appealing. Together, they directly influence user insights, playing a critical role in a product's success[7]. Software that has minimal direct and indirect negative effects on the economy, society, human population, and environment as a result of its development, deployment, usage, and disposal is considered sustainable software. Additionally, software that promotes sustainable development is considered sustainable. In application design, sustainability states to the practice of

developing systems and products with the least probable harmful environmental impact while maximizing long-term viability. In order to minimize the use of resources like memory, CPU, and network traffic, code must be improved for efficiency[8]. Artificial intelligence (AI) makes machines intelligent, enabling them to reason, learn, and make judgments using techniques like machine learning and deep learning. AI is widely used in industries like finance, healthcare, and transportation. In UI/UX, AI acts as a co-designer, streamlining processes like creating specifications, generating visuals, and automating usability testing[9]. Tools like Figma integrate AI to build UI elements and optimize workflows. While AI improves energy efficiency and supports creative design, it raises ethical concerns and often overlooks sustainability in prototyping and testing stages. Web 4.0 reflects these advancements, reshaping design through personalized user interactions[10].

2. MLR PROTOCOL FOR THE ROLE OF ARTIFICIAL INTELLIGENCE IN IMPROVING UI/UX DESIGN FOR DEVELOPING GREEN AND SUSTAINABLE SOFTWARE APPLICATIONS

To achieve the goals of our study, we used a Multi-vocal Literature Review (MLR) method to look into the most recent innovative trends in UI/UX design and find areas that need more investigation in the future. SLRs that integrate with both academic and Grey Literature(GL) sources were referred to as Multivocal Literature Reviews (MLR) in the context of educational research[11]. Garousi et al. (2016) pointed out that MLR should be done as primary studies, especially in the field of SE, since software engineers frequently use grey literature as the most popular means of sharing information about new techniques, approaches, and skill-driven advancements. Based on Kitchenham and Charters' SLR guidelines, which we have found to be well-classified and suitable to MLRs, we adopt three phases for conducting reviews[11].

1) Planning the review
2) Conducting the review
3) Reporting the review

2.1. Planning the review

We started by examining publications and conferences to see if any reviews focused on AI-based green and sustainable user interfaces. However, we found little reviews in academic or white literature. Most existing research focuses on specific issues in UI/UX design, highlighting the need to identify key elements and principles that support using AI for sustainability. This led us to conclude that a Multi-vocal Literature Review on AI in UI/UX design is essential.

2.2. Research Question

RQ1: What are the principles and factors of UI/UX design that helps in making software more eco-friendly?

RQ2: What is the role of Artificial Intelligence in improving UI/UX design for developing green and sustainable software?

RQ3: Do applying Minimalist UI/UX Design Principles considerably decrease energy usage in software applications?

RQ4: What are the practices for designing an AI-based green and sustainable user interface?

2.3. Designing Search Term

The group of Kai Petersen et al[12] formed a technique known as PICO, that stands for "Population", "Intervention", "Comparison", "Outcomes" to find keywords.

Population: UI UX designers/ Web Designers, AI

Interventions: Factor/principles/practices

Outcome of relevance: Designing Sustainable and environmental friendly interfaces.

2.4. Search Strategy and Searching

Determine the population, intervention, and outcome to generate search terms. Identify substitute spellings and synonyms and Add Boolean Operators.

2.4.1. Identification of search term

We identified key terms ('population,' 'intervention,' and 'outcome') from the research question, found alternative synonyms and spellings, and confirmed keywords in relevant papers. Logical operators ('OR' for synonyms and 'AND' for main terms) were used to construct search strings. For databases with limitations on string length, we combined or split the strings as needed. These steps led to the desired search results.

2.4.2. Development of Search String

In our research, we have 4 research questions divided into two groups. Group One consists of RQ1 and RQ2, while Group Two consists of RQ3 and RQ4.we performed two different MLR for each group i.e. MLR1 for Group 1 and MLR2 for Group2.

Development of Search String for MLR1

MLR1: UI UX design/ Web Design, Factor/principles, Sustainable and environmental friendly interfaces.

(Principles OR Factor) AND (”UI UX design” OR ”User Interface Design” AND ”User Experience Design” OR ”Web Design” OR ”User Centric Design” OR ”Application Design”) AND (”Sustainability” OR ”Eco Friendly” OR ”Environmental Friendly” OR ”Reducing Carbon Emissions” OR ”Green Design”).

Development of Search String for MLR2:

MLR2: Artificial Intelligence, UI UX design, Sustainable and environmental friendly interfaces, software.

(”AI” OR ”Artificial Intelligence”) AND (”UI/UX design” OR ”User Interface Design” AND ”User Experience Design” OR ”User Centered Design”) AND (”sustainable” OR ”sustainability” OR ”environmentally friendly” OR ”Eco-Friendly” OR ”Green”) AND (”Software” OR ”Software Design” OR ”Software Development” OR ”Application Development”).

2.4.3. Search String Breakup

The search string we are employing in the previous declared search string. However, some of the databases and libraries, for instance Science Direct, usually has limitations on the number of characters that can be used in the search strings. Therefore, we have divided the above said search terms into sub-string.

Search string 1 for MLR 1

(Principles OR Factors) AND (”UI UX design” OR ”Web Design” OR ”Application Design”) AND (”Sustainability” OR ”Eco Friendly” OR ”Environmentally Friendly”).

Search string 2 for MLR 1

(Principles OR Factor) AND (”UI UX design” OR ”User Interface Design” AND ”User Experience Design” OR ”User Centric Design”) AND (”Eco Friendly” OR ”Reducing Carbon Emissions” OR ”Green Design”).

Search string 1for MLR 2:

(”AI” OR ”Artificial Intelligence”) AND (”UI/UX design” OR ”User Centered Design”) AND (”sustainability” OR ”environmentally friendly” OR ”Eco-Friendly”) AND (”Software Design” OR ”Software Development”).

Search string 2 for MLR 2:

(”AI” OR ”Artificial Intelligence”) AND (”User Interface Design” AND ”User Experience Design”) AND (”sustainability” OR Eco-Friendly OR Green) AND (Software OR ”Application Development”).

2.5. Selection of Literature Resources

To choice the literature resources for this research, we have ordered this step in to two extra sub-steps i.e. resources to be examined for white literature (WL) and resources to be examined for Gray literature (GL).

White Literature

Following Kitchenham and Charters' 2007 guidelines, we used two search methods: The sources of data collection were the digital database searches and the snowballing technique. The target databases are IEEE explore, ACM Portal, ScienceDirect, SpringerLink, Wiley Online Library and Taylor & Francis. These were selected based on the fact that they are accessible via our institution as well as offer broad coverage of the software engineering research domain[19].

Gray Literature

In the selection of Gray literature, we used the search strategy proposed by Garousi et al. in their MLR guidelines (Garousi, Felderer, & Mäntylä, 2019)[13]. This involved a use of Google, ProQuest and Theseus Dissertations and Theses Global to identify relevant PhD and master's theses.

2.6. Publication Selection

Only articles related to our research questions on Sustainable UI/UX design and AI contributions were included, while articles with unrelated topics were excluded. With the help of the titles, keywords, abstracts, and full texts, specific criteria for inclusion and exclusion of articles were applied decently. Out of these, there were ambiguous instances, which had to be taken to a second appraiser for further assessment.

3. Conducting the review

In this phase we shall implement the previously set protocol. Which we will carry out more specifically in the following steps:

3.1. Data Extraction Strategy

To answer the research questions, selected studies will be extracted through data extraction procedure, such as Full text review for sorting out the relevant data. Areas of focus and data collection from articles are paper ID, review date, title, authors, associated database, method used in the paper whether through an interview, case study and so on, publication year, and the main and finally the data which answer our research questions and related to sustainable UI/UX design and specifically the role of AI for the development of sustainable UI/UX design[14].

3.2. Preliminary Result

After applying search strings and inclusion/exclusion criteria, two MLRs were conducted: For Group 1 will be known as MLR1 which consist of Q1 and Q2 while for Group 2 will be known as MLR2 which consist of Q3 and Q4. Coalitional, for all the research questions, the article search produced 1,777 articles, of which 1011 were respective of Q1 and Q2, and 766 were respective of Q3 and Q4. At the first level of screening, titles and abstracts were analyzed for both MLRs, which gathered 125 articles for MLR1 and MLR2 that only 97 articles were obtained, or a total of 222 papers for both MLR1 and MLR2. Full text screening in the second stage brought this down to 41 articles for MLR1 and 30 for MLR2 giving 71 final articles to answer the research questions. Data sources with publication results for both MLRs are presented in Table 1 and Table 2. The Library-wise distributions of finally selected papers for MLR1 & MLR2 are illustrated in the figures below Fig 1 and Fig 2.

Table 1: Data sources with publication results for MLR1

Name of the database	No. of Publication found	Initial selection	Final selection
ACM	216	16	4
IEEE	12	7	1
SCIENCE DIRECT	383	12	3
SPRINGER LINK	113	14	5
MDPI	211	11	4
SNOWBALLING	19	19	9
GRAY LITERATURE		45	15
TOTAL	1011	125	41

Table 2: Data sources with publication results for MLR2

Name of the database	No. of Publication found	Initial selection	Final Selection
ACM	273	16	7
IEEE XPLORE	6	2	0
Springer Link	192	11	1
Science Direct	98	3	1
Taylor and Francisn	128	5	2
Gray Literature	69	52	17
Snow bowling		8	3
TOTAL	766	97	30

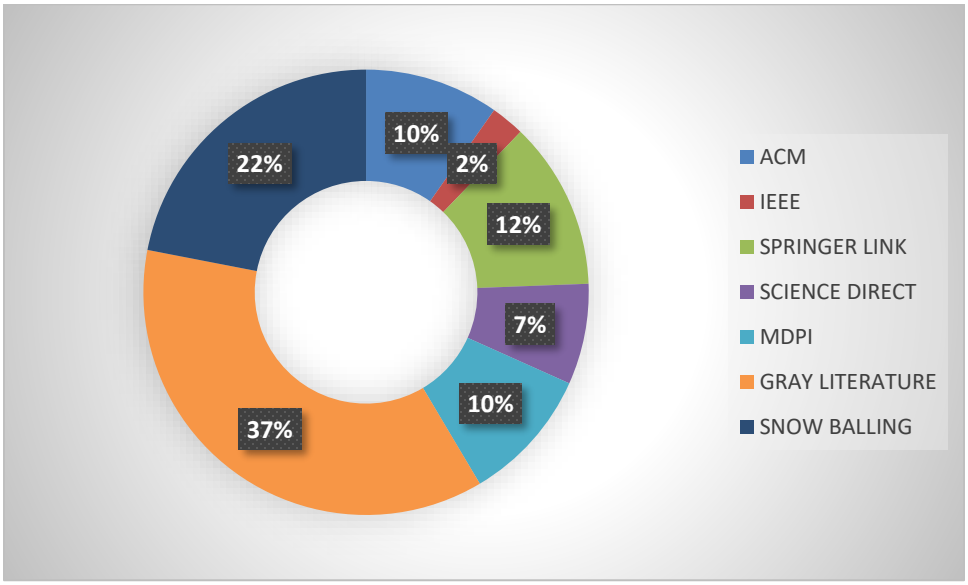

Figure 1: Finally selected papers for MLR1

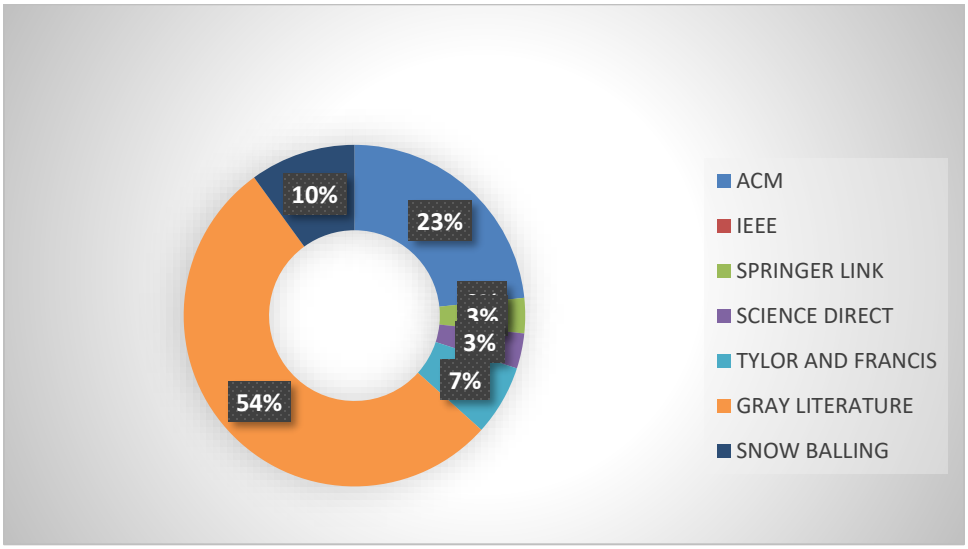

Figure 2: Finally selected papers for MLR2

3.3.Data Synthesis

The data has been be organized for MLR1 into two summary tables based on the 2 research questions. These tables include columns for serial numbers, Factors and principles, frequencies, and percentages, providing a comprehensive list of all factors and principles along with their frequency and percentage. Furthermore, a separate table has been created to record detailed information about each Factor and Principle mentioned in the summary tables. This table has columns for the Factors and principles group name, reference serial number, Factor and principle

subgroups, and paper reference. The same process will be applied to MLR2, following the approach used for Research MLR1.

3.4.Validation

The successful validation of the protocol began with an initial evaluation by the supervisors (co-authors) who applied essential changes. Then, the protocol was presented to the Software Engineering Research Group (SERG UOM) to collect input and response. Finally, an external reviewer evaluated the protocol and presented suggestions for changes, all of which were duly addressed.

4. REPORTING THE REVIEW

This phase is important for analysis and evaluate the quality of the systematic study performed. The key activities in this phase include: (i) reviewing the Data extracted during the previous phase, aiming at contextualizing the findings from the academic and practitioner viewpoints; (ii) assessing the threats to validity, especially these emerging in the process of devising the review protocol, as well as these that may emerged; (iii) developing several reports on the results of the study to be tailored to the audience. These reports are first scrutinized by the specialists in Multivocal literature reviews (MLRs) and the domain. Then, many of them are published in various scientific journals, conferences and professional magazines to be reviewed on the broader community.

5. CONCLUSION

This protocol paper outlines a systematic approach to investigating sustainable UI/UX design, emphasizing the role of Artificial Intelligence (AI) in enhancing environmentally friendly and energy-efficient practices. By addressing key research questions, the study will identify factors and principles that contribute to sustainability in UI/UX design, evaluates the methodologies used in existing research, and highlights AI-based practices for achieving eco-friendly software design. The findings contribute to the growing field of green software development by bridging the gap between theoretical concepts and practical applications in UI/UX design. Through a combination of literature review, method-based analysis, and empirical validation, the research provides actionable insights for both academics and practitioners, ensuring its relevance to a wide audience. Future work will aim to expand the scope of analysis by exploring emerging technologies and refining the proposed framework through further empirical testing. By doing so, this research sets the stage for continued innovation in sustainable design and contributes to the broader vision of a greener, more sustainable digital environment.

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