HCI methodologies and Data Visualization to foster user awareness

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Abstract

The purpose of this research concerns the integration between Human-Computer Interaction (HCI) and Data Visualization to increase users' awareness of issues of public interest. In particular, it wants to investigate how to design and develop meaningful and effective interactive data visualization and which HCI methodologies can be useful to design and validate these systems that can become effective tools to support communities of users in decision-making processes about issues such as sustainability.

Keywords

Data Visualization, User Awareness, Sustainability

1. Introduction

Nowadays, the number of information and data from different sources and in various formats is continually increasing, leading to the problem of how to represent this large amount of data and how the user can extract knowledge from them. Those data can be the result of a datafication process that aims to transform a phenomenon into data that can be studied and analyzed [1] or can be constantly generated consciously and unconsciously by every kind of people or Internet of Things (IoT) devices. For these reasons, the area of Data Visualization has become increasingly important and widely studied in the literature to foster user awareness.

In this context, the need to investigate the interaction between users and data emerges. The interaction can be tangible [2, 3, 4], it can exploit Augmented, Virtual, or Mixed Reality to make users feel more immersed and engaged with the data [5, 6], and it can be enjoyed through different types of smart devices, such as computers, smartphones, or wearable devices [7]. Therefore, the Human-Computer Interaction (HCI) field is fundamental as a multidisciplinary research area aiming at designing such interactive systems.

To better investigate the integration between these two fields in a way that it is possible to create systems to increase user awareness about topics of public interest, it is important to define a specific area of interest and identify a community of interest for the defined issue. Therefore, as a case study, the focus is on sustainability and sustainable development, one of the greatest challenges our society is facing and an issue that emerged following the approval, in 2015, of the 2030 Agenda for Sustainable Development from the general assembly of the United Nations. This agenda highlights the 17 Sustainable Development Goals (SDGs) to achieve a

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better and more sustainable future by 2030 [8, 9]. These 17 SDGs must be pursued not only by governments but also by companies, institutions, and citizens [10]. The university community, made up of students, professors, researchers, and technical-administrative staff, was identified as the community of interest.

Hence, the purpose of this research concerns the integration between HCI and Data Visualization to design and evaluate graphic visualizations and increase awareness about sustainability, creating effective tools to support a specific community for decision-making processes. In particular, this research focuses on three main questions:

- **RQ1**: How to design and develop interactive data visualization tools to make the understanding of Big Data related to the environment effective but simple by the intended users?
- **RQ2**: How to design and develop interactive data visualization tools to foster users' awareness about issues of public interest?
- **RQ3**: How to validate such interactive data visualization tools and which HCI methodologies can be exploited?

The rest of this paper is organized as follows. Section 2 provides an overview of some previous and relevant studies focused on how HCI and Data Visualization can be used to communicate sustainability issues and engage communities of users to foster their awareness. In Section 3 the contribution will be presented, highlighting the preliminary results. Finally, in Section 4, the future works coming from more detailed and redefined research questions are presented.

2. Related Work

Data Visualization is the representation of data in some systematic form to communicate the information extracted more clearly and effectively, exploiting the cognitive abilities of the human being, and to create an efficient tool to amplify users' cognition, increase user awareness and support the decision-making process, highlighting patterns or abnormalities within the data [11, 12, 13, 14, 15, 16]. However, there are still many studies in the literature that highlight the presence of open issues and challenges, such as i) the increasing amount of data to be displayed, ii) the way to represent them, iii) the avoidance of misinterpretation, iv) the creation of relevant knowledge and insight, and v) the final evaluation [17, 18, 19]. Analyzing how users interact and understand data could be essential to face some of the previously mentioned challenges, hence, the need to integrate the Data Visualization field with HCI. Nevertheless, one of the new challenges of HCI is making the visualization and analysis of big data usable by interested communities [20]. Data Visualization can, therefore, become a means of involving users that are central in this field. The reason for this is not only the desire to make knowledge accessible to all but also to make the users aware of the surrounding environment, increasingly interconnected and smart and capable of producing large amounts of data from smart objects.

Being aware of the environment is also important from a sustainability perspective.

In the literature, there are several studies related to the use of Data Visualization and HCI in favor of environmental sustainability and saving energy, paper, and even money [21, 22]. In particular, the use of interactive visualizations, including data visualization and infographics, is

investigated to provoke reflections on sustainable behaviors and behavioral change to facilitate and support daily actions that are more aware.

For example, Salmon et al. created a dashboard (the Campus Energy Education Dashboard) to display the energy consumption inside a university campus [23]. The final aim of this project was to improve energy efficiency and increase the awareness of its occupants. Also, in [24], the authors analyzed interactive energy visualizations and used Fogg Behavior Model [25] to categorize interactive visualizations. They focused on how users behavior and, consequently, their energy consumption changes based on the visualization to prove that visualizations can increase awareness and motivate users to decrease their energy consumption. Also, artwork and public displays can influence users behavior as they both create a more engaging experience [26, 27]. Odom et al.[27] developed an Eco-Visualization enjoyable through situated displays on campus to create competition between dormitories. They aim at improving students' long-term behavior about energy and resource consumption.

In addition to the energy aspect, several studies were carried out concerning food waste, air quality, environmental issues, and health. For example, an augmented bin and the relative Facebook application is employed to put users in front of their conscious and unconscious behaviors concerning their waste management [28, 29]. This particular project emphasizes the importance of the social component, which relies on every user's desire to be accepted inside a community and the sense of guilt and shame for the bad habits. Also, the authors use gamification to increase users' awareness and their behavior. The achievements and the food waste savings were displayed in the form of a tree and gold bars.

Go and Grow is a system that displays a living visualization to increase users' awareness and promote a more active lifestyle [30]. The author implemented an online dashboard and the visualization of a living plant as a metaphor for an active lifestyle: through the user's personal data, such as the steps taken, the plant is watered. Their final aim was to prove that abstract or living visualizations are more emotionally engaging and, therefore, more capable of influencing users' behavior. Instead, USC AiR is a mobile-based application that shows air quality data inside a campus, exploiting also Augmented Reality (AR) to make the visualization more immersive and inspire users to contribute to the reduction of air pollution [5]. Often, Data Visualization is combined with AR to make users feel more engaged with the data and inspire them to improve their behavior.

In [31], Jacobs et al. investigated the usage of the artwork A Conversation Between Trees to stimulate public conversation about sustainability. The artwork displayed on two large displays environmental data, captured and streamed live from trees in the Atlantic forest. Finally, Imprint wants to stimulate discussions about paper usage and waste [32]. Five different visualizations are exploited to display commonly printed words, the popularity of a community member, clusters of workers based on the documents they printed, the time that printers are working, and the total amount of energy used.

3. Contribution and Preliminary Results

The IoT and the Big Data generated from it could become a means to increase the awareness of the target users about the surroundings. However, for this to happen, it is necessary to find

the right way to communicate this large amount of data in a clear and simple way through interactive data visualization tools.

In [33], we present Smart Campus, a system consisting of sensors infrastructure to collect real-time data (temperature, humidity, air pressure, and Particulate Matter) inside the Cesena Campus of the University of Bologna, and a web-based application to interact with hyper-local data, available in a public interactive display, situated at the entrance to the campus. The web interface shows the 2D map of all the campus building floors and displays the data from the sensors and the Points of Interest (PoI), such as toilets, stairs, and elevators. Also, the application provides information about classrooms, labs, professors' offices, and class schedules to the university community. To validate the system, we involved 135 students through a survey, and we extracted meaningful insights from the interactive sessions with the public display. From the results, it emerged that the community can be an active component within an intelligent environment and not just a passive beneficiary. Furthermore, through the analysis of qualitative and quantitative data collected through interviews on the web application and web session logs (for a total of more than 10.000 interactions) the role and participation of the campus community within a Smart Campus was demonstrated. Moreover, the platform can act as a tool to facilitate the participation of students and to increase the potential of hyper-local data, with the final goal of benefiting the whole campus community.

In [34] and [35], on the other hand, we wanted to investigate how a web-based data visualization system could promote more sustainable and efficient use of spaces (such as classrooms and laboratories) within a smart university campus. The case study is focused on the Cesena Campus of the University of Bologna, and it exploits a low-cost infrastructure to gather the people number in a classroom and the official open data of the University. Following a user-centered design (UCD), we use HCI methodologies to collect the requirements, involving all of the target users (faculty members, administrative staff, ICT staff, and students). Then, we create different data visualizations (real-time and based on pre-established periods of time) to meet the needs of all of the target users. In particular, we use pictorial charts, stacked bar graphs, and pie charts to display the occupation of spaces so that the University administrative staff could monitor the lessons that have an attendance rate much lower or greater than the capacity of the room assigned. The final aim is, therefore, to help the staff to make decisions about the class schedule to improve the space management on our campus and the energy consumption of the building.

Moreover, as mentioned before, Data Visualization could foster user awareness of a specific issue, such as sustainability. However, it is necessary to understand what are the main characteristics that a system of this type should have. All over the world, universities are increasingly emphasizing their actions to achieve the SDGs, also creating more awareness inside their community. Similarly, the University of Bologna is promoting several initiatives related to sustainability, such as the reduction of paper waste by resorting to dematerialization. To stimulate reflections about these initiatives, in [36], we designed and developed a system exploitable using different devices that shows data related to the paperless effort and benefits to the environment. The study was carried out on two very different infographics designed by two diverse groups of experts and researchers: one more "animated" and one more "aesthetic". The first infographic uses interactivity and animations to engage users and it exploits leaves on a tree as a metaphor for each project carried out by the University in an incremental single-page vertical layout. The second one exploits storytelling and aesthetics and shows the new Campus

green areas to correlate the trees saved to the ones planted in the area. Contrary to the first, this infographic has a horizontal layout with static frames. The final goal was to compare the two infographics and then present insights on the design of infographics able to increase the awareness of the actions carried on by the University of Bologna, targeting the specific community.

Moreover, we exploit an online questionnaire addressed to the university community as an HCI methodology to evaluate the two infographics and the increase of awareness. In particular, we examined six information quality dimensions (sinteticity, clarity, informativity, intuitivity, attractiveness, elegance) and six design quality dimensions (essentiality/redundancy, abstraction/figuration; functionality/decoration; density/lightness; originality/familiarity; multidimensionality/monodimensionality). 45 University members answered the questionnaire, among which Computer Science students, faculties, and staff members, recruited using the snowball sampling method. Finally, the answers were statistically evaluated using Pearson Correlation and the results showed a correlation between the preferred infographics and the different roles within the University (students and teachers / technical-administrative staff). Moreover, to confirm our approach, it emerged from the answers that, interacting with the infographics, users have increased their awareness about sustainability initiatives.

4. Conclusion and Future Work

The results obtained so far lead to further research questions, risen as sub-questions of previous ones. First of all, it is necessary to understand *which devices and types of interactions are the most effective for providing meaningful visualizations.* This research question can be linked both to RQ1 and RQ2. Some smart devices have already been used (such as public displays and desktop devices) to provide interactive data visualization to users, also exploiting different interaction techniques. At this point, it will be necessary to test and compare various types of devices (such as smartphones, desktops, and larger public displays) and various types of interaction (such as tangible interaction or interactions that exploit Augmented, Virtual or Mixed Reality) to try to understand which ones make the visualizations most effective for the target users.

Once designed and developed interactive data visualization that aims at increasing awareness, it will be necessary to understand *how to evaluate the actual increase of user awareness.* This research question can be considered as a sub-question of RQ2, as it was born in the attempt to answer it. It will be necessary to look at the literature to verify the existence of frameworks or scales to measure user awareness and, consequently, understand which can be the best to use, also concerning the context of sustainability.

Finally, it would be very interesting to understand if *Data Visualization can produce a change in the daily behavior of users by changing their habits, and how we can measure it.* This research question is also related to RQ2. Starting from interactive data visualizations that increase awareness, it is important to understand if they can also produce a positive behavioral change in the target users. We plan to develop data visualization systems aimed at increasing awareness in users with the idea of making a possible change in their daily habits by using long-lasting test sessions to monitor their behavior before, during, and after using the system itself, also in this case concerning the sustainability issue.

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