Usability Evaluation and Redesign of an IoE Portal

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Abstract. A smart building is one of the most typical Internet of Everything (IoE) applications nowadays. Usually, a smart building aims to reduce energy consumption and, consequently, costs, or to enhance the work environment by increasing indoor thermal comfort. In general, building managers and air conditioning system technicians of smart buildings take actions such as increase or decrease the indoor air temperature and ventilation based on the data collected about the rooms (temperature, humidity, overall thermal satisfaction, and others). However, it is not always an easy task to extract useful information from all the data generated from a smart building, given the huge amount of data produced and the particular characteristics of each set of data. Therefore, this paper presents a usability evaluation applied to a Web portal containing charts summarizing both the historical and real-time data collected in a smart building. Taking into account the findings from this usability evaluation, the Web portal was redesigned and re-evaluated, receiving a more positive feedback from users.

Keywords: Internet of Everything · Smart building · Usability evaluation

1 Introduction

One of the common issues of Internet of Everything (IoE) [1] systems is the huge volume of data frequently produced. Additionally, these data are often heterogeneous and must be handled very differently [2] – sensors data should not be handled and presented the same way as user inputs and senses, for instance. Thus, anyone who wants to analyze IoE data and take some action based on them need to easily understand what happened in the past and get an updated status of the whole IoE environment. Moreover, information visualization and architecture are critical areas to consider when designing a system to present overall data about an IoE solution.

One of the areas that are facing those IoE challenges are the smart building environments. Most smart building projects pursue energy efficiency by monitoring and controlling lighting, heating and cooling systems and room occupancy [3, 4]. In fact, energy consumption has become a great concern not only because of costs but also due to the increase of the awareness of climate changes and the regulatory policies adopted in some countries [5]. Other aspects that are noticeable in some smart building projects are comfort and user satisfaction, which consider key variables such as temperature, humidity, ventilating and lighting [6]. More specifically, thermal comfort is directly related to people's productivity in a work environment according to some researches

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[7, 8]. Therefore, and although there are trade-offs, an ideal smart building should take into account both energy efficiency and user satisfaction.

Based on these assumptions about smart buildings, an IoE system was implemented as a proof of concept in an ordinary office building with hundreds of employees in order to make it a smart building, able to monitor temperature, humidity, subjective user thermal comfort and room occupancy. To achieve this, small devices containing sensors were built and installed in several rooms. Additionally, to assist the building managers and the air conditioning system technicians to understand all data gathered by the devices and take appropriate actions if required, a Web portal was also developed to present consolidated information about the building, both historical and real-time. However, this Web portal was initially designed by software engineers without any user-centered design expertise. As a result, users complained about the usability of the Web portal, so that a redesign was required.

Thus, this paper presents the major issues reported by the users and the challenges of redesigning this Web portal. The next sections will present the IoE system, the issues discovered when users explored the Web portal and the major changes applied to the Web portal after a usability review.

2 The IoE System

The IoE environment object of this study is a resource to allow smart offices/buildings in the future, assisting building managers and air conditioning system technicians to reduce energy consumption while keeping the temperature of the rooms adequate for people to work. Then, as a proof of concept, 48 small, low cost devices with temperature and humidity sensors were developed and installed all over the offices of a building. Temperature and humidity are key parameters to estimate thermal comfort, as proposed by ISO 7730 [9]. However, in addition to temperature and humidity, many other factors impact on thermal sensation: people's metabolic rate, age, height, weight, clothing and even cultural and climate differences among countries [10]. Collect all these factors and include them in a model to estimate indoor thermal sensation is very complex and not too easy to apply.

In order to make it as simple as possible, the proposed model didn't collect those additional data to estimate indoor thermal sensation. Instead, it requests that people send their subjective thermal sensation as proposed by the thermal comfort judgement scales of ISO 10551 [11]. Then, and in addition to the temperature and humidity sensors, the developed devices have three voting buttons ("hot", "nice" and "cold") to allow people to express their subjective thermal sensation. Figure 1 shows some photos of the device and highlight the key elements present.

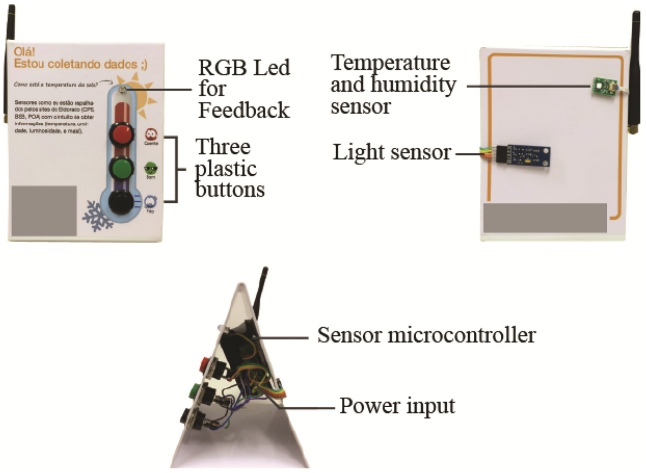


Fig. 1. IoE device.

All data collected through the sensors and the voting buttons of the devices are presented in a Web portal (Figs. 2 and 3), as well as information about the usage of the meeting rooms in the building, especially the scheduled and occupied times, which are not always the same.

Fig. 2. Home page.

Fig. 3. Temperature and humidity graph of a specified room.

Like many other IoE systems nowadays, the proposed solution does not have a smart, automatic analyzer that can discover and resolve real-time numerical and descriptive sensing and take rational actions based on them [2]. Therefore, a human analysis is still required.

3 Usability Review: Initial Version

As previously mentioned, the proposed IoE system, both the devices and the Web portal, were initially designed and developed by software engineers without any experience with user-centered design. Usability researchers joined the team only after a few months of the first release of the project and, since the first contacts with the devices and with the portal, their feelings were that a redesign would be required.

Given that feelings, usability researchers decided to get a fast feedback from people who had been used the devices and the Web portal. To do so, informal interviews were applied and reinforced that the hypothesis of poor usability may be real. However, a more precise usability study was required to understand the issues and discover potential user demands not yet covered by the device and the Web Portal. Thus, a user survey was performed to evaluate the devices, whose major results were also described on [12], whereas, to evaluate the Web portal, a usability review assisted by the DECIDE framework [13] was done and will be described in the remaining parts of this paper.

Guided by the DECIDE framework, the selected high-level goals of the Web portal evaluation were to discover the major users' concerns and avoid them in a redesigned version of the Web portal. An invitation was sent to workers of the building who had little or no experience with the Web portal and 17 were selected as participants of the usability review. Before proceeding with the usability review, each participant had to fill and sign an agreement form and, also, it was explained that the object of the study

was only the usability of the Web portal, not the participant, and that his/her identity and any personal data would be anonymously handled.

Then, each participant was requested to freely explore the Web portal and check key areas of it: Home page, Map and Dashboard. And, at the end, all participants answered a questionnaire with both open and Likert-scale questions to collect their opinions and suggestions. The summarized results for each of the key areas are presented next.

Home page

"What should I find here?", 70.5% of participants mentioned the lack of information on the Home page, having no idea about the purpose of the Web portal.

Map

"What is the meaning of that symbol?", 41.1% of users mentioned that symbols in the map were unrepresentative. Colors in charts did not have enough contrast for 29.5% of the users.

Dashboard

"I understand nothing about this chart", charts were unclear, especially the X axis, for 29.4% of users, who also complained about tight space among columns and about information overhead. Colors in charts and the "ideal temperature average" indicator were also problematic.

Figures 4, 5 and 6 present bar charts with the consolidate data of some of the Likert-scale questions. From these charts, it is possible to notice that most of the participants easily found the information they wanted in the Web portal, the overall look and feel was appealing for less than 50% of the participants and the charts and graphs present on the Web portal were easy to read and understand for a little more than 50% of the participants.

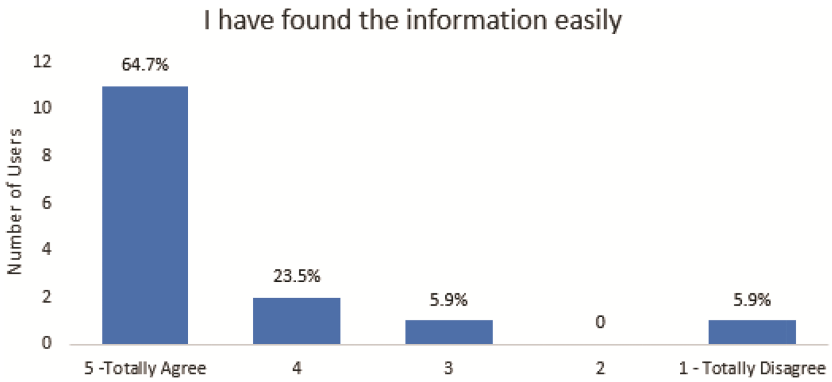


Fig. 4. Ease to find information.

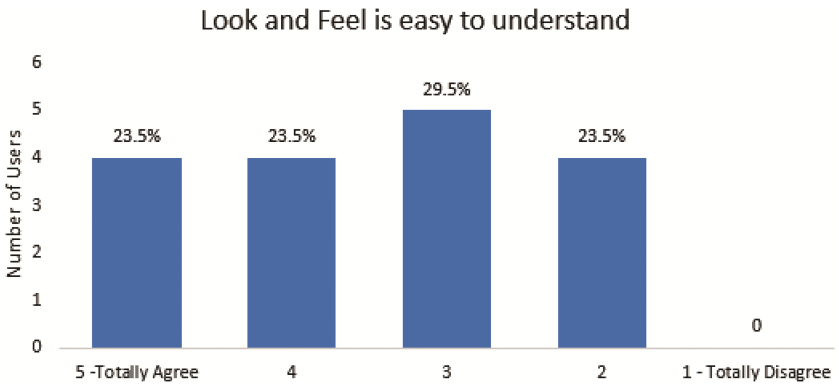


Fig. 5. Overall look and feel evaluation.

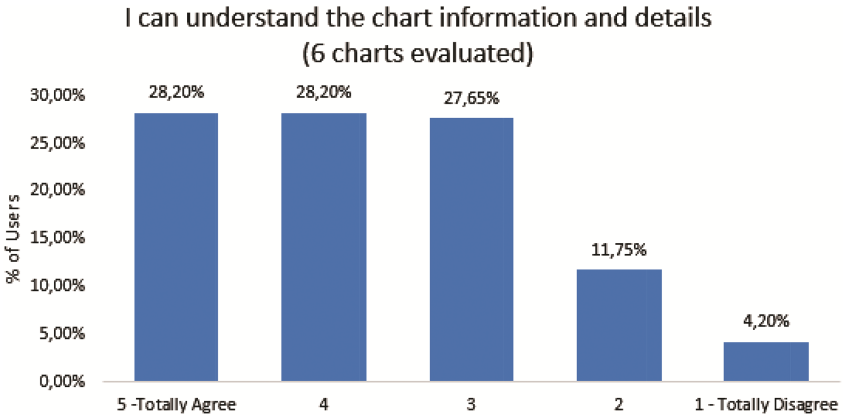


Fig. 6. Charts.

The word cloud present on Fig. 7 shows the most frequent terms present in the answers of the open questions. Most of the words are related to things that users didn't find too easy to do on the Web portal and suggestions to enhance their experience using the Web portal.

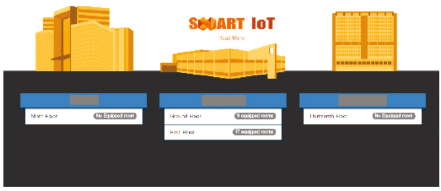
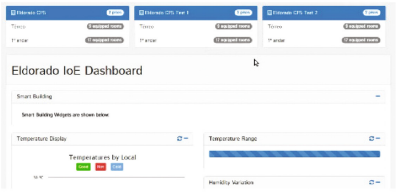
Fig. 7. Tag cloud.

4 Proposed Redesign

Taking into account the findings of the usability review, usability specialists proposed a redesigned version of the Web portal, trying to fix the issues reported by the users and fulfill their expectations. Table 1 presents a comparison between the initial version of the key areas of the Web portal (Home Page, Map and Dashboard) and the redesigned version of them.

This redesigned version of Web portal was then implemented, published and re-evaluated using the same procedure as mentioned in the previous section. The details of this usability review are presented in the next section.

Table 1. Before and after comparison.

Before	After
Home Page	
	
Map	
	
Dashboard	
	

5 Usability Review: Redesigned Version

In the usability review of the redesigned version of the Web portal, 15 people volunteered and had to perform the same explorations of the key areas (Home page, Map and Dashboard) as the first usability review and answered a similar survey at the end. The major results for each key area are summarized below.

Home page. "Can I change the language?", the Web portal was written in English, but all the participants (and, in fact, most of the workers of the office building) were Brazilians. Therefore, some participants requested an option to switch from English to Portuguese.

Also, in order to provide more information about the IoE environment and its objectives, an "About" page was created and included inside the Web portal, but it was not accessible through the Home page, which caused some complaints from some participants, who would like to have that kind of information on the first page they accessed. Figure 8 shows this new "About" page.

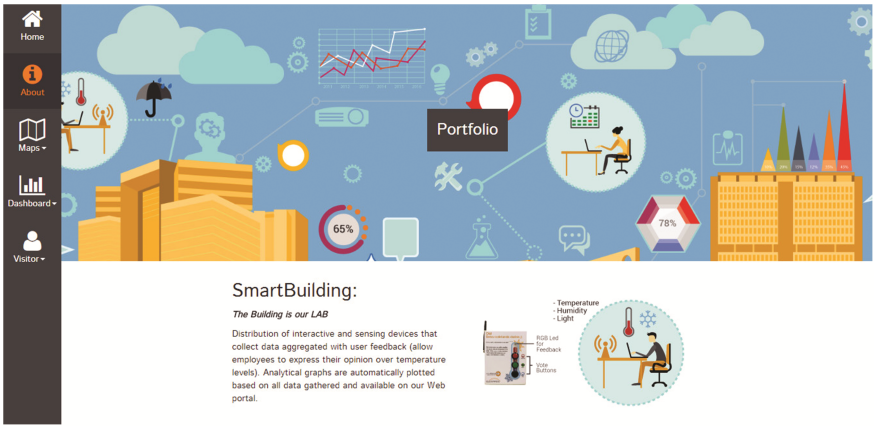


Fig. 8. New page "About" page.

Also, 20% of the participants complained about the "Smart IoT" logo shown at the top of the Home page, arguing that the logo looks like "SNART" or "SOART", not "SMART". Actually, the idea was to resemble an infinite symbol (∞) in the middle of the logo. Figure 9 shows the new logo.

Fig. 9. New logo for the "Smart IoT Portal".

Map. "Maps are realistic and I found my location quickly", this was a common comment from the participants about the redesigned Map section of the Web Portal. However, a few issues were yet found: 26.7% of the participants reported that mouse hover event was not working properly due to the position of the icons to represent the humidity, as shown on Fig. 10 (the highlighted cactus and the umbrella icons). Thus, the pop up dialog to present detailed information of the rooms was not opening if the mouse was hovering at the top of these icons – but it was working as expected if mouse hovering any other places.

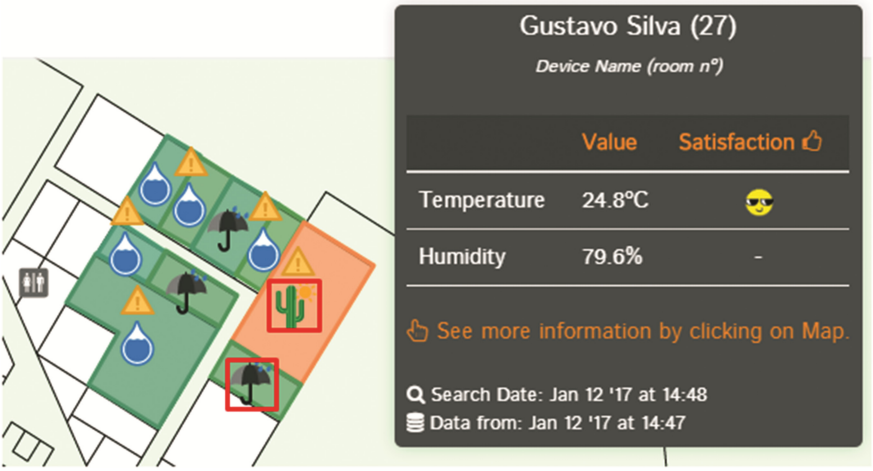


Fig. 10. Humidity indicator icons (cactus and umbrella) conflicted with the mouse hover event. (Color figure online)

Another interesting issue found in the Map section was about the adopted colors to represent nice thermal sensation (green) and hot (orange). One of the participants was color-blind and commented that it was difficult to distinguish these colors.

Dashboard. In Dashboard, participants reported that it was difficult to identify the rooms by their numbers – although this issue had already been there since the previous version, it was only identified in the redesigned version of the Web portal. Another issue that was also present in the previous version but only found in the redesigned version was the lack of a "loading" feedback while the graphs are not yet shown on the page.

Figures 11, 12 and 13 present bar charts with the consolidate data of some of the Likert-scale questions and compare with the previous results. It is interesting to notice

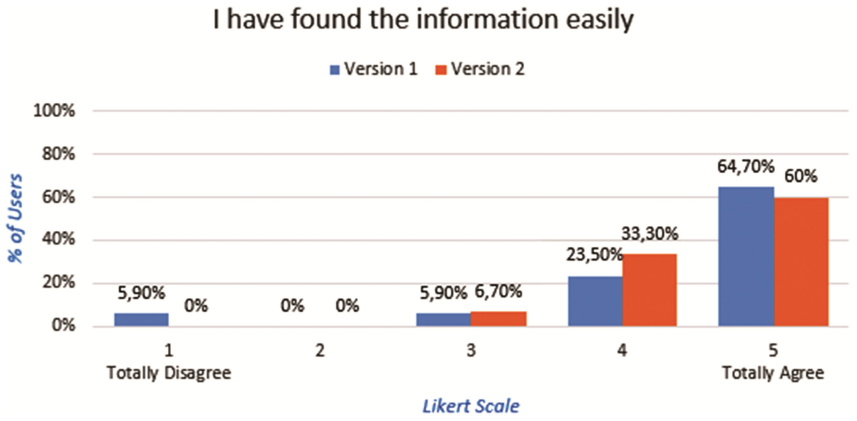


Fig. 11. Ease to find information.

that, for the "ease to find", the proportion of "Totally agree" answerers decreased, but the amount of positive answers (4 and 5 in the scale) increased from 88.2% to 93.3%. Additionally, answers for the questions the about overall look and feel and the chars were more positive for the redesigned version of the Web portal.

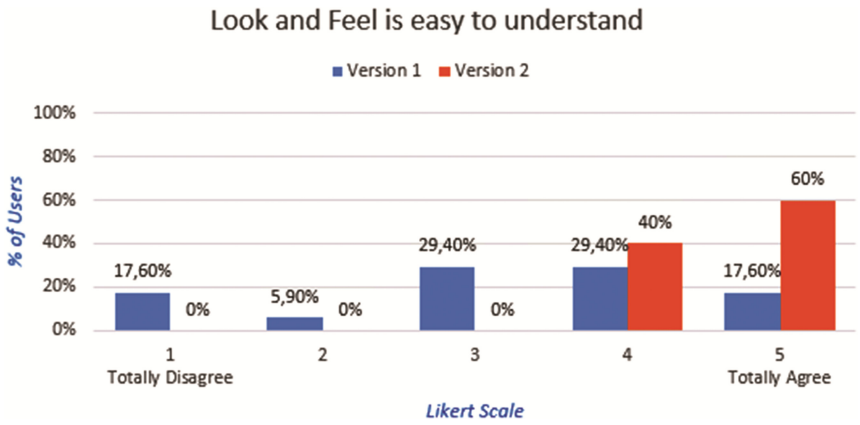


Fig. 12. Overall look and feel evaluation.

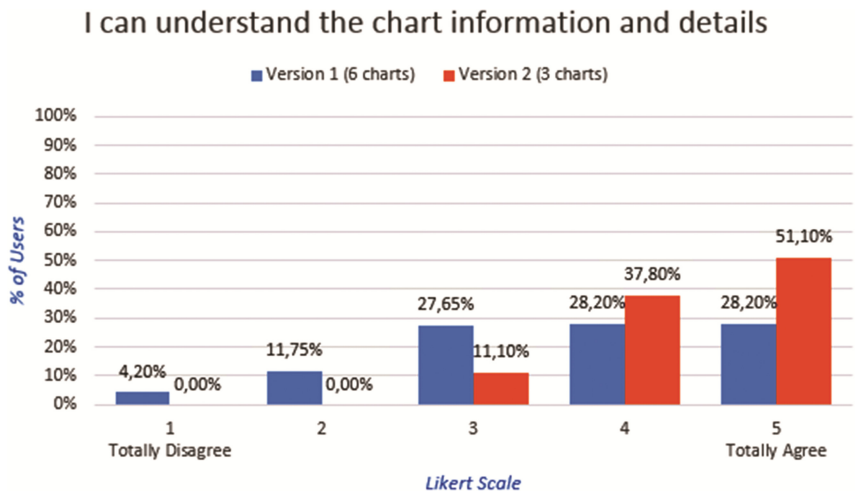


Fig. 13. Charts.

6 Concluding Remarks

The amount of different information on the IoE Web portal was huge and it was difficult to understand the state of each room or of the whole building, like many other IoE systems with poor usability. Thus, the portal was redesigned based on the results of a usability review, fixing the major issues found, and has received a more positive

feedback. However, new issues that compromise the user experience were found and require other enhancements and fixes that are planned to be implemented in the next versions of the Web portal.

Another future work that is being analyzed by the usability researchers is how to make the Web portal more appealing to users, so that they will access the Web portal and check the thermal sensation statuses more frequently.

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