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Data Visualization and Responsive Design Principles applied to Industry 4.0: the Mentor Project Case Study

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ABSTRACT

Industries and the manufacturing sector are among the contexts that can enjoy great benefits from adopting digital technologies improvement. In this sense, Industry 4.0 has represented a clear revolution, having already improved production and performance, and it is still providing its potential in terms of sustainability, quality of activities for workers, business and company awareness, etc. In this context, the use of data visualization strategies, responsive design, and customization for user interface and interaction mechanisms can provide great benefits, improving the exploitation of the data, equipping the personnel with indispensable information about the status of machinery, productions, plants, and factories, etc, to different users who could be equipped with different devices. In this paper, we present a work-in-progress investigation, based on an Industry 4.0 real case study, where we have adopted data visualization and responsive design strategies, customizing a user interface and related interaction mechanisms, on the basis of different devices. The paper discusses some preliminary results, while validations with target users are planned and not yet conducted.

CCS CONCEPTS

• **Human-centered computing → Information visualization**; **Empirical studies in visualization**; • **Applied computing → Command and control**.

KEYWORDS

Data Visualization, Responsive Design, Industry 4.0, Interaction Design, Human Computer Interaction

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1 INTRODUCTION

The widespread diffusion and adoption of digital technologies (including those ones related to the availability of the Internet connection and of sensors and open hardware platforms) have improved possible services and functionalities in many and different scenarios ([20], [13]). Internet of Things and Smart Objects ([17], [9]) adopted in Smart city and Smart environment contexts (ranging from smart home [19] to smart campus [6], from smart gardening [11] to smart shire [12], just to cite a few of them) can play a strategic role in this sense, collecting plenty of data, monitoring trends and evolution of many and different elements, including those data and information coming from the users in a crowdsourcing and crowdsensing fashion ([4], [22]), by taking advantages of the pervasive diffusion of mobile devices ([7], [1]). The availability of all these data, characterized by a significant quantity and diversity, opens the door at the adoption of innovative technologies, with the aim of classifying them and predicting new trends, thanks to the use of big data strategies and machine learning and artificial intelligence techniques ([10], [3]). In this context, data visualization techniques can play an interesting role, since they could be exploited so as to make the gathered information more understandable and meaningful to users, better supporting them in decisions and policy-making activities [6]. In this sense, the Industry 4.0 scenario is particularly challenging: the adoption of digital technologies has represented a revolution, improving productions and performances [8], and it still reserving us lots of potentialities also in terms of sustainability [15], workers' wellness and quality of life in daily activities [16], business and company awareness [21], etc. Moreover, the customization of user interfaces and interaction mechanisms has to be adequately designed and developed in this context, enhancing users in their interaction with a suitable dashboard, on the basis of the user's role and profile and on the basis of the device in use during the exploitation of the data [5], since this represents an useful and strategic way to provide indispensable information about the status of machinery, productions, plants and factories, etc, to different users who could be equipped with different devices.

The work presented in this paper investigates the main issues that should be faced during the design of an interactive and responsive dashboard in an Industry 4.0 context, enriched with data visualization strategies. As the case study for this paper the choice fell on the Mentor Project: a cloud-based suite of applications created by Bucci Industries, a multinational firm particularly active in the Industry 4.0 and automation sectors. The main objective of the Mentor Project is to monitor and give useful information and insights about their machinery, which could be located in different places around the world. This is done by presenting to the end-users the data in such a way that it makes them fully comprehend the present and past status of the machinery even without being physically present [14]. This is done in order to know useful information like its health, its productivity rate, or if and when preventive maintenance is needed. For the case study of this paper, only a few pages from a couple of applications will be examined from the many that the Mentor Projects offers: more specifically, this paper will cover some pages from the "Alarm Help" and "Production & Statistics" applications. After a confrontation with the personnel responsible for the Mentor Project, a structure for the work to be done on the platform was agreed upon. First of all, there was an initial phase of research and analysis on the Mentor Project itself in order to better comprehend its functions, limits, and goals and to outline the best methods of data visualization to apply. After that, there was a design phase of the possible solutions for each element, done by creating a mockup of the mobile page, with many alternatives being made for each page, depending on what kind of data needed to be highlighted. Then it was followed by a confrontation and selection of those designs, made together with the personnel responsible for the Mentor Project, which was primarily based on the needs of the users for each specific page and visualization. Lastly, the final phase occurred, which consisted in implementing these changes right on the code of the Mentor Project. Since the work on this case study is yet to be fully completed, it was not possible to evaluate the end results by gathering feedback from the actual users, as it will be one of the next steps for future work on the project. To replace that, there will be a brief evaluation of the new interfaces, to prove that their benefits are tangible, and a short summary of all the innovative aspects that they bring in respect to the state of the art. The rest of the paper is organized as follows. Section 2 presents main design issues faced while designing an Industry 4.0 dashboard equipped with data visualization strategies with responsible design principles in mind, taking advantages of our case study characteristics. Section 3 describes a preliminary solution we have proposed, while Section 4 concludes the paper with a short discussion.

2 DESIGN ISSUES AND GOALS

Given the Mentor platform and the problem to face with its responsive interface, which were both addressed in the previous part, the goal of this section is to introduce the specific pages where the problem will be faced, more specifically what kind of data and information are meant to show, how do these pages appear on a desktop and mobile view, and then what kind of solutions were designed in order to improve their data visualization on mobile.

2.1 Desktop views

2.1.1 Alarm Help. The goal of the "Alarm Help" application of the Mentor platform is to visualize in a graphical way the status and statistics of the various alarms and alerts, both from the past and from the present, that are set off on certain machinery. This multiple-line graph (Figure 1) is part of the "Analytics" page and is meant to show the number of occurrences that happened over each day for each of the main events, which are highlighted with a different color as shown in the chart legend. It is also possible with the button in the top-right corner to change the graph in order to make it show, instead of the number of occurrences, the total time of duration of the event for that day.

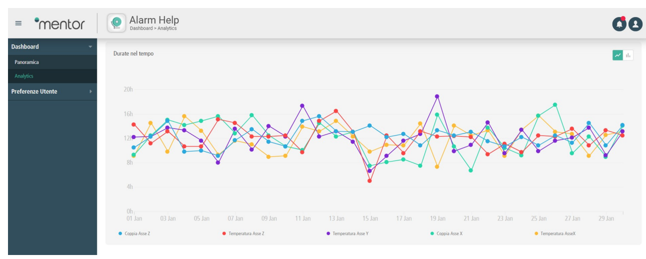

Figure 1: Line graph of the activation time of the events for "Alarm Help".

2.1.2 Production & Statistics. The "Production & Statistics" application is used to give a visualization of the information and statistics of the production data and efficiency for certain machinery, often using visual tools such as graphs. This timeline graph (Figure 2) has the purpose to inform the user on how the various statuses and shifts of the machinery alter over a certain time period. This period can be 24 hours long, such as in this case with the timeline graph, or longer (like various days or weeks), and in that case, another type of graph is used.

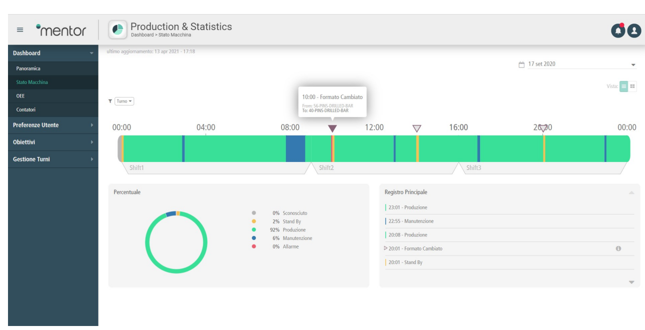

Figure 2: Timeline graph of the state of given machinery during a 24 hours period for "Production & Statistics".

2.2 Previous Mobile views

Since the problem focus is to improve the responsive visualization of these pages and graphs, especially on mobile devices, it is important to take the already existing responsive interface of the Mentor platform and analyze it, in order to identify its weaknesses and problems and try to create a better interface that solves them. Since the mobile visualization is one of the key points of Mentor's usage, it is crucial to also exploit the features that are unique for the mobile devices, such as the bigger range of interactivity that the touch screen gives, and also not to limit the visualization to be just a simple transition of the desktop page to a different screen format [2] [18].

2.2.1 Alarm Help. The graph (Figure 3) is drawn in a space that is too restricted if compared to the amount of information it wants to communicate: the result is that this version of the graph can manage to give a brief idea of the general trend for the various events, but overall it remains very difficult to read in a deeper way, and almost impossible to try to look for specific data.

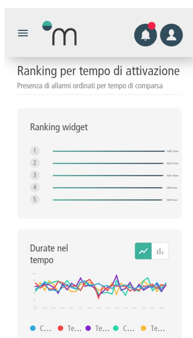

Figure 3: Mobile view of the line graph for "Analytics".

2.2.2 Production & Statistics. Since the timeline graph (Figure 4) is a horizontal-oriented graph, it feels very difficult to read when displayed on a mobile device, which has a vertical-oriented screen. Given also the huge amount of data that the graph wants to communicate, such as shifts, events, and various times, the graph ultimately feels hard to read on a deeper level.

2.3 Design Propositions

Once analyzed the already existing mobile view of the pages and its problems, the following phase was focused on the design of various solutions for these problems, by creating different mockups for each page. Their creation was led by the need to design the mockup around the type of usage expected on mobile for that page, with various versions that could be made for each type of usage, each one highlighting different aspects of the data with their visualization.

2.3.1 Alarm Help. For the line graph 3 possible solutions were found (Figure 5). The first one consists in keeping the graph as it was, but displaying it with bigger dimensions and using horizontal scrolling in order to make it fully readable on a mobile device. This decision was made because the graph represents a continuous time series on its x-axis, and the horizontal scrolling helps in giving

Figure 4: Mobile view of the timeline graph for "Production & Statistics".

a sense of temporal continuity to the visualization. The second possible solution focuses on flipping the graph, by drawing the event lines vertically and putting the days on the y-axis and the values on the x-axis, making the graph fully readable with vertical scrolling. The main point that led to the creation of this mockup is that a vertical-oriented graph could take full advantage of the vertical-oriented screen of the mobile phones, but the downside to that is that by choosing an unusual way to display the data the graph might feel too difficult to read at a first glance. The third solution that was found consists of isolating each of the single lines by drawing them into separate graphs, with each of them being much smaller and simpler than the original, and then putting all of these new graphs next to each other. This solution manages to give a very intuitive and fast comparison between the trend of each of the elements, but on the other side, it sacrifices a lot of the precision in the values that it communicates.

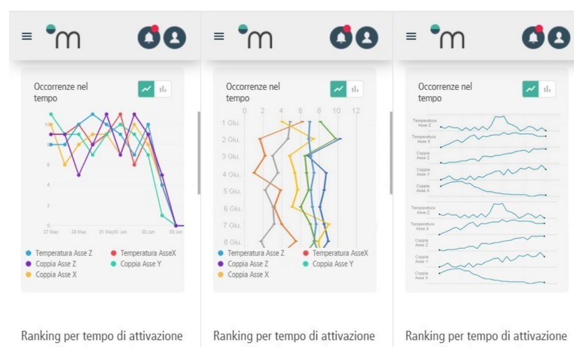

Figure 5: Mockups proposed for the line graph for "Analytics".

2.3.2 Production & Statistics. Also for the timeline graph 3 different solutions were found (Figure 6). The first one consists in converting the bar into 2 "donut charts", each of them representing half of the day, in a structure that resembles a clock. This option could be expanded with additional texts and labels for indicating in a more precise way times and turns because its main weakness is that it sacrifices various details present in the original one. The second mockup consists in maintaining the bar, but flipping it vertically and dividing it into two, with each of these pieces representing half a day, in order to not make it take up too much of the vertical space present on the screen. This solution manages to give a good visualization into the deeper data present on the page, with its only downside in being more complicated to read at a first glance because of the vertical alignment of the timeline. The third alternative is similar to the previous one, but keeps the horizontal layout of the bar and breaks it not based on a fixed amount of time but based on the turns sequence and then visualizes each of the fragments one on top of the other. This mockup manages to keep the same information as the one from before but tries to be more easily accessible, thanks also to the fact that usually, the number of different turns for the machinery in a single day aren't more than 4.

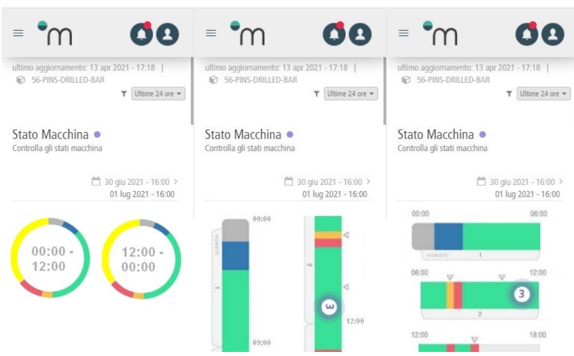

Figure 6: Mockups proposed for the line graph for "Production & Statistics".

3 PRELIMINARY RESULTS

This section will focus on illustrating the choice made between the mockups for each page and its motivation, showing directly the final result as implemented on the actual Mentor application, as well as its innovative aspects in respect to the actual state of the art.

3.1 Implementation and Results

After a confrontation phase with some of the key figures behind the Mentor project, in which the mockups seen above were presented, a selection was made based on the necessity of the mobile visualization for each page.

3.1.1 Alarm Help. The choice made here was to select the graph with the horizontal scrolling (Figure 7), in order to enhance the temporal continuity while also offering a complete visualization. The main points were to keep the data intact and to give a visualization that is easily readable at a first glance, but still enough complex to be able to develop a deeper analysis, and not be an over-simplified version of the desktop one. The vertical graph solution missed the first point, as it was not intuitive to read because of the unusual disposition of data. The multiple graphs solution instead passed on that point but missed the second one, as it lacked depth in the quantity of the information that is conveyed. The selection that was made provided to be a solid mix between the two main points, exploiting also the interactivity typical of the mobile devices. This solution, while not taking much more overall space than the previous one, manages to make the graph more readable by using the horizontal scrolling, while also giving to the end user the possibility to read more deeper into the data and the trends of the various alarms.

Figure 7: Line chart with the horizontal scrolling, which was chosen for "Analytics".

Figure 8: Horizontal fragmented timeline chart, which was chosen for "Production & Statistics".

3.1.2 Production & Statistics. The choice made here was to use the mockup with the graph divided into many horizontal fragments, based on the turns of the machinery (Figure 8). This option was chosen thanks to the fact that it maintains every data intact since it's just the same graph divided into many parts but still manages to remain intuitive and simple to read. The first mockup, the one with the double "donut chart", was discarded since it did not have enough depth in the data shown, such as missing the turns and the event, while also not being particularly intuitive to read, especially if compared to the other ones. The vertical double bar solution instead was able to maintain all the data intact but was ultimately discarded since the vertical orientation made it less intuitive to read, in a similar way to the vertical graph of the Alarm Help section. The winning solution managed to keep all the data intact while also being the most easily accessible of the three, and providing a clear and deep visualization of the data. This solution gives the graph much more space to display itself than before and this represents a great benefit for the overall readability of it, which now is significantly improved and allows the end user to understand better the various states and alarms of the machine through the day.

3.2 Innovation in respect to the state of the art.

This last part will focus on the innovation emerged from the interfaces shown, in respect to the actual state of the art of the subject.

3.2.1 Alarm Help. Since the graph is kept almost the same as the original, here the only true innovative aspect lies in the introduction of the horizontal scrolling, which gives the whole visualization a new dimension, unique only to the mobile environment, while also following the trend to focus more on the interactivity within mobile interfaces. [2] [18]

3.2.2 Production & Statistics. This visualization too is very similar from the original one, and here the innovative aspect is to be searched in the way the same graph is drawn differently to adapt itself to the mobile screen. In fact, by splitting the timeline into multiple bars, it is possible to turn quite effectively an horizontal graph into a vertical one without the need to completely change the graph structure, allowing then to create a visualization which suits better the vertical oriented screen of the mobile devices.

4 DISCUSSION AND CONCLUSIONS

By analyzing the end result, which overall is in line with what was stated in the introduction, it is possible to notice a clear improvement over the previous mobile interface. In particular, the interface became much more intuitive and simple on mobile devices, showcasing a clear improvement in readability and visualization of the data, which now is optimized for mobile devices, making this version on par with the desktop one, and not inferior anymore. As for the possible future developments on this work, the first one that comes naturally is to expand it to also other applications and pages of the Mentor Project, in order to enhance the mobile visualization of the platform on a broader scale. Since the work behind this paper is still not final, as stated by the name of the previous section ("Preliminary Results"), another possible development could be getting information and validation from the direct users of the platform since all the feedback analyzed in this paper came from the Mentor Project design and development team, including the personnel responsible for it: while not being an easy process, this research would find important data to then guide a process with the aim of validating the work done so far or even doing perfective software maintenance on the responsive interface. Lastly, one more potential development for this work would consist in trying to increase the interactivity of the graphs on mobile devices, in order to exploit even more the unique tools, such as the touch screen, that the mobile environment offers.

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