Pixel-Based Analysis of Information Dashboard Attributes

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Abstract. This paper focuses on pixel-based usability guidelines and their use for an information dashboard user interface. The first part of the paper examines existing usability design advices, presents existing pixel-based metrics and make suggestions of new ones. The second part presents results of pixel-based analyses performed on two groups of well-designed dashboards and randomly chosen dashboards. Results of these two groups are compared and their differences are discussed.

Keywords: information dashboard, pixel-based analysis, usability guidelines, user interface

1 Introduction

An information dashboard, as a presentation layer of an information system, is a tool whose goal is to visualize concrete information which is important for an accomplishment of particular tasks. It usually presents analytical data and key performance indicators of some processes which are used for further decisions. An information dashboard (*dashboard*) should help make these decisions. Thus, it should be well-designed to help users get quickly familiarized with its meaning and displayed content. Visual aspect of a dashboard should be in accordance with design principles of user interfaces used for a data visualization.

As described in [3], most of the existing dashboards contain some design problems. In some cases, these problems represent little aesthetic imperfections, but sometimes, these problems may lead to serious usability problems. Possible way how to detect these problems is to let users or design experts perform this task (e.g. *usability testing* or *heuristic evaluation* [13]). It can be effective but expensive and time consuming. In our research, we are working on system which can do these usability evaluation automatically without presence of users or design experts. For this purpose we designed framework described in [5].

Goal of this paper is to collect pixel-based metrics which can be used for computing attributes suitable for differentiation between well designed dashboards (according to advices described in [3]) and the others. We expect that correctly designed dashboards can be numerically distinguished by specific values of particular attributes. We explore this assumption by comparisons of computed attributes for well design dashboards and randomly picked ones.

2 Usability Evaluation Based on Guidelines

A definition of a dashboard was established by Stephen Few [3] as:

Definition 1. *A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance.*

To design such dashboard, [3] recommends several advices and demonstrates frequently made mistakes. Example of such advice can be seen in Figure 1. Similar advices can be found in a lot of literature [4, 8, 13, 18, 20].

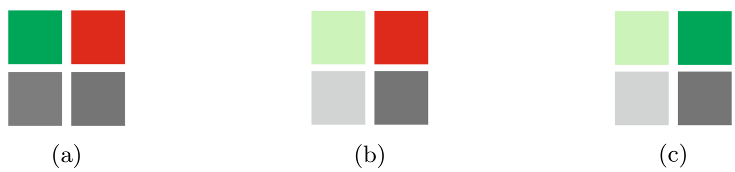


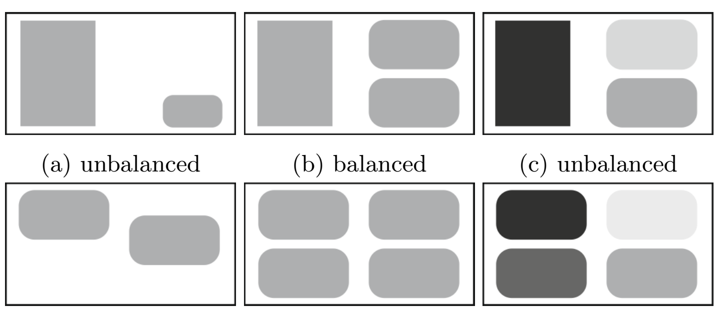
Fig. 1: Example of the design principle which recommends to encode a different meaning by color intensity (1b, 1c) rather than only by color hue (1a) because it can be missed by someone who is color-blind.

In this research, we focus on quantitative advices (*usability guidelines*) which can numerically measure some values and thus they can be simply transformed into a runnable code. They are usually simpler than qualitative advices. Therefore, lower rate of usability problems and higher rate of false positive usability problems are detected. However, they are not intended to replace evaluation based on qualitative advices (e. g. heuristic evaluation). Their goal is to automatize some time-consuming processes.

The role of usability guidelines has been rising with the evolution of user interfaces. In the 80s, guidelines was designed for textual user interfaces [17]. In the 90s, guidelines were integrated in several systems used for graphical user interfaces development – e. g. [2, 11, 9], which are also evaluated by [6]. In the early 2000s, the evolution of the Internet and web pages played crucial role in a development of a usability evaluation [7]. Researchers were looking for new techniques which would increase attractiveness of web pages. Terms like an *aesthetics* which specifies a rate of webpage beauty became more important [10]. Several guidelines suitable for increasing of aesthetics were found [12, 14, 16, 15, 22]. Today, smartphones, tablet devices and *internet of things* are becoming more important. Thus, further progress of user interface design regarding these areas could be expected.

Following list presents selected guidelines based on color pixel-based metrics which measure usage of individual color values, or a distribution of those values in a dashboard image raster:

– **Colorfulness:** This attribute represents a diversity of used colors. According to [3], it should be low in dashboard. To monitor such attribute, dashboard raster representation need to be converted into color space which better corresponds with a human perception (like *HSB* [3] or *CIE Lab* [20, 22]). For instance, [21, 16] consideres colorfulness as a saturation in CIE Lab color space where saturation is computed as *chroma* divided by *lightness*.
– **Amount and share of color values:** According to [3], dasboard should contain low amount of dominant color values. To measure such attributes, raster can be transformed to RGB color space. Color values of this color space are usually stored as 24 bit numbers (more than 16.77 million of distinct color values), thus *posterization* [15] or conversions to 8 bit Gray Scale (representing color intensity) and 1 bit Black-White (*thresholding* [1]) color spaces are advised.
– **Distribution of colors:** We focused on two design attributes – *balance* and *symmetry*, illustrated in Figure 2. Balance is a metric which calculates a distribution of an optical weight in a picture along a vertical or horizontal axis [14, 19]. Symmetry is a metric, which calculates a rate of axial duplication of a visual image of graphical elements along horizontal and vertical axes (*axial symmetry*) or the diagonal axes (*radial symmetry*) [14, 22]. Higher balance and symmetry can make user interface less disordered which can lead to simpler perception of these interfaces. To compute these attributes, we used formulas presented by [9, 14] and extended them for pixel-based purposes (color intensity of pixels was also considered – Figure 2c, 2c).



(a) unbalanced (b) balanced (c) unbalanced

(d) asymmetric (e) symmetric (f) asymmetric

Fig. 2: Example of balanced and unbalanced (symmetric and asymmetric) screens. Balance and symmetry based on color intensity (2c, 2f) has been also considered in this research.

3 Experiment Description

The goal of our experiment was to find out, if there exist metrics which can be used to distinguish between a group of dashboards designed according to expert advices and a group of dashboards which were designed without these rules. We applied selected metrics on the two following groups:

- **Group 1:** a group of 10 dashboards which were designed by experts according to rules defined by [3].
- **Group 2:** a group of 120 randomly picked dashboards which were collected from the Internet. No information about usability of these dashboards was considered.

Each dashboard was stored as a bitmap in 24 bit RGB color space. For purposes of particular analyses, further transformations to other color spaces were done. The dashboards of Group 1 were transformed to other 3 sizes (75%, 66%, 50% of the original size[3]) to take a lower resolution impact into consideration. Therefore, the size of Group 1 was increased from 10 to 40 samples.

Table 1: List of metrics used in each analyzed dashboard (B&W = Black-and-White)

Metric/Set of Metrics	Color Space
colorfulness: average hue, saturation, brightness	HSB
colorfulness: average lightness, chroma, hue, saturation	CIE Lab, CIE Lch
amount of distinct color values	RGB, Gray-Scale
...with share higher than 0.1%, 0,5%, 1%, 5%, 10%	Gray-Scale
share of the 1st and 1st+2nd most used color values	RGB, Gray-Scale
share of black color value	B&W
balance, symmetry	Gray-Scale, B&W

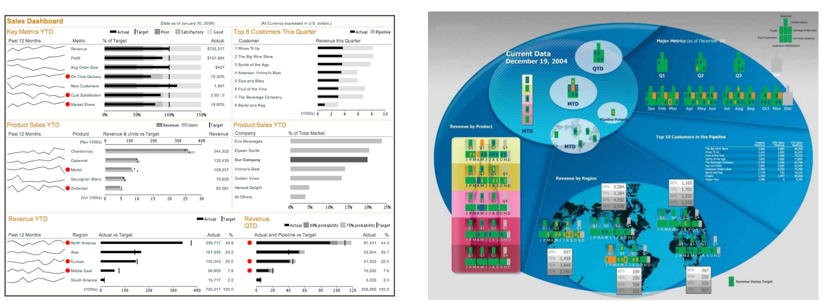
The experiment procedure was the following. First, we computed values of a selected metric for each dashboard of Group 1 and 2. Then, we took these values and calculated arithmetic mean μ and standard deviation σ for Group 1 and Group 2 separately. We repeated this procedure for each metric listed in Table 1. Finally, we compared results of Group 1 with results of Group 2. We were also looking for metrics with low standard deviation in Group 1 to find typical characteristics of well-designed dashboards.

[3] The smallest width was 175px and the smallest height was 130px. There was no reason to include dashboards with smaller resolution, because they were readable with difficulties. The experiment was focused only on dashboard with sufficient resolution.

4 Results

First dashboard attribute, that was examined, was colorfulness. We used formula based on sum of mean saturation and its standard deviation described by [21]. As we expected, the dashboards of Group 1 are less colorful than those from Group 2 (see Table 2). This is satisfied for both examined color spaces – HSB a CIE Lab. Thus, these metrics seems to be suitable for further application in dashboard categorizations. As described in section 3, we also applied the same formula with other channels of mentioned color spaces (like hue or brightness), yet the results were not so interesting.

We also did an experiment and converted dashboards to 8 bit Gray-Scale color space and analyzed histograms of color intensities. As it can be seen in Figure 3, the histogram of the dashboard with a low rate of colorfulness (3a) contain one dominant intensity (background) and few other intensities with a low frequency of occurrence (data pixels). On the contrary, the histogram of the colorful dashboard (3b) contains a range of many color intensities with a relatively high frequency of occurrence. That makes the share of the dominant color intensity significantly lower.



(a) $C_a = 0.16211$ (b) $C_b = 0.91657$

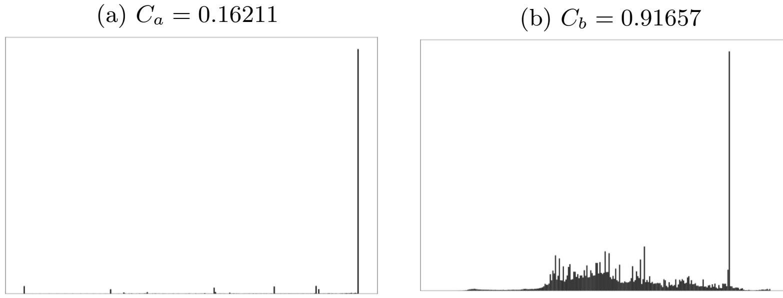


Fig. 3: Comparison of 2 Sales Dashboards used from [3] with histograms of their color intensities – from 0 (black) to 255 (white)[4]. Dashboard on the left is significantly less colorful than the one on the right side.

The reason of this difference is also the fact that dashboards of Group 2 often contain high amount of *non-data pixels* [18] whereas amount of these pixels is highly reduced in Group 1. This reduction causes increasing of background share which is represented by the most used color value in Group 1. The best color spaces to numerically evaluate share of major colors are according to our results 12 bit posterized RGB, 4 bit Gray-Scale and 1 bit thresholded Black&White (see Table 2). Thresholding was done adaptively according to [1].

Table 2: Selection of the most interesting results which were gathered by application of measures on 2 groups of dashboards described in section 3.

Metric	μ_1	σ_1	μ_2	σ_2
HSB, CIE Lab/Lch				
HSB saturation	0.1094	0.0459	0.3841	0.2081
CIE Lab/Lch saturation	0.2170	0.1823	0.6835	0.5770
12 bit RGB ($2^{12} = 4096$ color values)				
Amount of distinct color values	375	435	670	464
Share of the 1st most used color value	79.94%	7.67%	54.44%	21.08%
Share of the 1st+2nd most used color values	84.60%	4.71%	66.37%	18.95%
4 bit Gray-Scale ($2^4 = 16$ color values)				
Amount of colors with share > 5%	1.35	0.53	3.36	1.65
Amount of colors with share > 10%	1.00	0.00	2.06	0.99
Share of the 1st most used color value	82.94%	4.87%	57.06%	19.57%
Share of the 1st+2nd most used color value	87.10%	3.51%	72.54%	17.96%
Color distribution: balance	0.914	0.041	0.764	0.138
Color distribution: symmetry	0.921	0.021	0.852	0.061
1 bit Black-and-White (2 color values)				
Share of black color value	13.98%	3.33%	28.80%	15.77%

As regards color distribution analysis, dashboards of both examined groups have high rate of balance and also relatively high rate of symmetry in the all three color spaces. The best results were computed in 4 bit Gray Scale color space (presented in Table 2). It can be seen that balance and symmetry values are slightly higher in Group 1, which was expected. However, the difference between Group 1 and 2 is not so significant. We assume that this fact is caused by human need to see things balanced and symmetric and thus designers usually provide these attributes without an explicit intention. These metrics seem to be good to evaluate dashboard usability but they don't seem to be the best at differentiation between Groups 1 and 2.

[4] Labels presenting values of vertical axis are ignored. They are not so important in this case because they depend on actual size of a dashboard and our intention was to emphasize ratios of color intensities.

5 Summary

The goal of this research was to analyze pixel-based attributes of dashboards. For this purpose we specified the set of the measures which were used in 3 particular analyses examining colorfulness, color usage and color distribution. We analyzed the group of well-designed dashboards and compared the results with the set of randomly chosen dashboards with no explicit information about their usability. As result, we identified metrics which are suitable for classification algorithms which will be able to distinguish well-designed dashboards (Table 2).

5.1 Limitations and Future Work

In this research, only some of pixel-based attributes were examined. In the future, we would like to add attributes which relate with representation based on graphical elements. Also, we would like to apply our framework in some real design tool which is used for dashboard creation. For now, our training set is based on dashboards recommended by [3]. In the future, we would like to use proposed metrics to calculate dashboard attributes which will be used as features in machine learning algorithms. Then, other training sets based on other design principles could be used.

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