Tailles et couleurs des objets voisins pour une séparabilité visuelle

About Object Size and Colors for Visual Separability

Éric Languenou

Abstract—This summary presents an ongoing reflection on the estimation of the separability limits between neighboring geometric objects according to their colors, sizes, the observation conditions, and the media used. The assignment of colors to categories in unordered categorical visualizations is crucial for the readability of charts. Data scientists often apply *rainbow* color palettes in order to guarantee identification and separability, producing thus visualizations with degraded aesthetics. Reducing the hue range (while losing the identification property) improves aesthetics but requires the use of labels and the selection of a finely optimized color-category assignment [3]. Finding the limits of separability according to the conditions of observation, the colors of the categories, the smallest visual angles of the neighboring categories objects then appears essential. Many difficulties (observer, media, color calibration, environment, etc.) justify that we have not yet started this study in the case of data visualization (to the knowledge of the author). The following reflection proposes a protocol to attempt to clear up this aspect and two foreseen applications of the results.

1 Introduction

One type of data commonly visualized concerns unordered categories (see figure 1). Here, the choice of the color palette and the assignment of the latter colors to the categories is crucial both for the readability of the diagram and for the aesthetics of the result. The need for category identification by color recognition implies a strong contrast between the colors of the palette. In order to optimize these contrasts, it is common to choose a so-called "*rainbow*" palette, which often leads to diagrams with questionable aesthetics.

One possibility then lies in abandoning the identification property by adding labels to the graphic objects making up the diagram. Therefore, a palette based on a narrower range of hues is applicable, provided that the colored graphic objects are still visually separable. Indeed, when two neighboring objects have colors that are too close and depending on their sizes, the brain and the eye of the observer can reduce the two objects to a single object of the same color (*spreading* effect). We recently published an approach that optimizes the assignment of colors to categories and applied it to streamgraphs and chord-diagrams [3]. This method is based on the expression of a need for a colored contrast between the n categories by using the geometry of the graphic objects representing the categories. The user provides a color palette containing n colors and the genetic algorithm generates a color-class assignment, maximizing the contrast between the n categories. Note that the visual separability between two neighboring objects of different colors is independent of the length of their common border but dependent on their thicknesses [4]. The thinner the graphic object, the greater the risk of confusion. Note also that the above-mentioned assignment optimization method is only based on the data of the diagram, as well as the construction rules of the diagram type. Neither the final publication size of the diagram, nor the observation distance are considered during the optimization, yet the eye is sensitive to visual angles[1]. Thus, the selection of a color palette with a reduced range of hues may, despite the optimization, result in an unreadable diagram for certain scales of presentation.

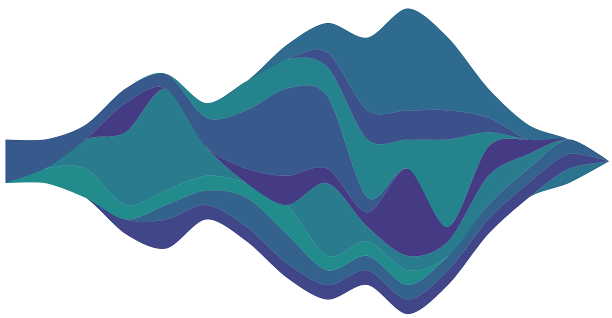

Fig. 1. Unordered categorial visualization using a reduced viridis colormap

2 Goal

To guarantee the readability of the diagrams without using palettes of the *rainbow* type, it is thus necessary

• LS2N, Nantes Université
E-mail: eric.languenou@univ-nantes.fr

1. l'*angular thickness*

to carry out colored objects visual separation tests. It is, for example, possible to present a user with pairs of patterns of various sizes and of different colors in order to estimate the readability limits.

Many difficulties are inherent to this aim and clearly justify the lack of research carried out on this specific subject:

- large color space (even though categorical visualization imposes constraints on color palettes);
- variations of perception among observers. Color blindness and many types of color blindness (10% of the male population)
- lack of calibration of the media that will broadcast the diagram, resolution;
- difficulty of calibration when carrying out user tests;
- difficulty in considering the visual environment of the observer.
- influence of objects geometry (frontier orientation) on the separability

The importance of these difficulties should not prevent the beginning of such research, which could eventually lead to values which would be sufficient for most screens or paper broadcasts. Note that producers of books, magazines, or newspapers have calibrated printing methods. The purpose of this research is thus twofold: first, to allow a visualization specialist to estimate, for a given color palette and media, the limits of visual separation in terms of visual angle. This generated data can then help to optimize the assignment of colors to categories for that color palette and various visualizations. The second goal is to identify possibly general limits of pattern separability in categorical visualizations by carrying out a controlled study.

3 State of the Art

Researchers have well studied the diffusion of color around a colored figure on a contrasting background [5]. They have also explored the limitations of pixel-based visualizations, glyph identification, and associated visual angles [2]. Maureen Stone studied the consequences of object size on the color diffusion effect and the distinction during the generation of color palettes in the "tableau" software [8]. About scatter plots, there is a state-of-the art on visual class separation measures [1] and a taxonomy [6]. The researchers also designed the concept of *just perceptible difference* (JND) [7] to study colors that are objectively perceived to be the same.

In biology research domain, there are a lot of publications about the eye response in cells, cones and rods, about image comprehension processing stages. Unfortunately, none of the findings in these publications relate directly to our cases.

4 The Proposed Approach

It would be relevant to deal with different media for the distribution of diagrams, computer monitors, but also tablets and *smart-phones* (*smart-watches*?) on the one hand and paper media on the other hand, books, magazines, newspapers, brochures.

The number of color pairs to compare for a palette of n colors is equal to $n(n-1)/2$ because the risk of *spreading* is symmetric, which gives, for a color palette made of 10 colors (cf. figure 2), 45 pairs. But, depending on the chosen palette and how its hues are spread, one can quickly reduce this number.

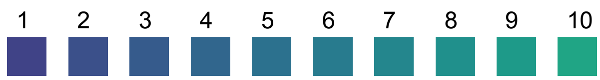

Fig. 2. A 10 colors Viridis reduced colormap

After acquiring the size of the observed page and the viewing distance, the protocol would be based on two typical pages:

- a first page serving for a rapid elimination of easily distinguishable color pairs displayed on thin adjacent objects;
- a second to determine a limit thickness of separation for a pair of colors.

We must adapt these test pages to the media being examined. The spatial organization of the patterns (grid or random positions) and the option of presenting them successively rather than all at once on a single page remain to be determined during preliminary tests. It is also true for the background color (black, white or a color depending on the color palette). Luckily, with categorical color palette, brightness is usually constant, and in this first attempt, we do not consider objects interface orientation even if the human eye response depends on orientation.

4.1 A first Filtering of Color Pairs

On this test page, visible in figure 3, the user clicks on color pairs that are visually inseparable and we saved the indexes pairs for later use in the second test page. On the paper version, a text field may be available to write down the concerned pairs indexes.

4.2 Selection of the limit thickness by pair of colors

For each pair of colors identified in the first test page, a second sample page (see figure 4) shows a selection of patterns displaying adjacent rectangles of varying thicknesses. The user clicks on the pair that he/she considers readable. For the paper version, the test pages are printed and the user enters the readable pattern index. A triple $(color1, color2, visualAngle)$ for example $(color\#4, color\#6, 10^{-4})$ is then saved.

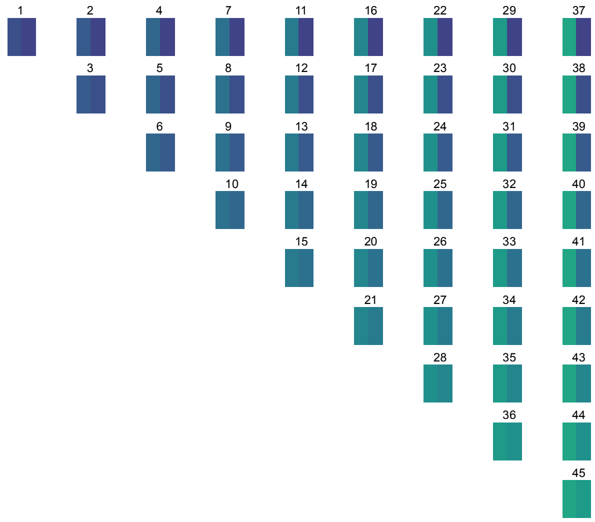

Fig. 3. First Screen for filtering problematic color pairs

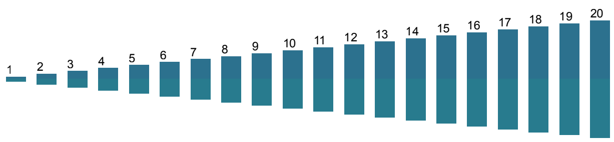

Fig. 4. Second Screen: selecting discriminable thickness, color pair #14 (colors #4,#6)

5 Use of results

The test pages would produce, for a color palette C, a list of triplets $L_C = \{(C_i, C_j, visualAngle_{i,j})\}$ that could be used in two ways:

- A software could validate a previously designed diagram that already has a color-category assignment. Depending on the visual angle provided for the final reading of the figure, the software calculates a matrix of category pairs visual angles, (using the thicknesses of neighboring categories objects) as shown in figure 5. It contains for each pair of categories (i, j) the smallest visual angle encountered on the two neighboring categories graphical metaphors.
  Depending on the colors categories assignment, we thus compare each pair of categories visual angle to the list of triplets and thus the assignment is validated or invalidated or else a warning of *spreading* risk could be displayed.
- In the specific case where n colors are proposed for n categories, to the color-category assignments correspond permutations $p = (p_1, ..., p_n)$ with the value of p_i equal to the index of the color assigned to the category i.
  We can therefore use the list L_C during the category-color assignment optimization by eliminating the candidate permutations which do not pass the L_C filtering.

  For example, if the list includes the triple $(color\#4, color\#6, 10^{-4})$ and the visual angle matrix shows a value less than 10^{-4} for the pair of categories $(layer\#5, layer\#7)$, then assigning colors #4 and #6 to these two categories is not possible. As a result, the permutations where $p_5 = 4$ and $p_7 = 6$ or $p_5 = 6$ and $p_7 = 4$ will be rejected.

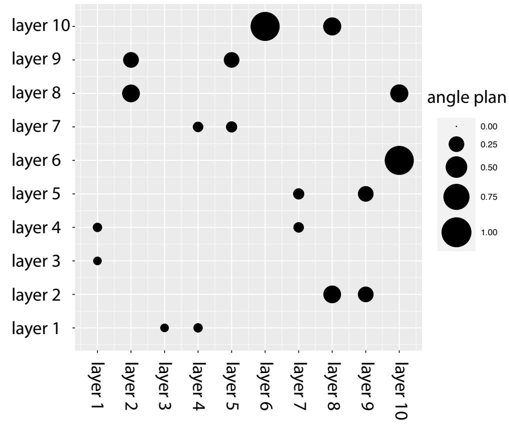

Fig. 5. Fictional example of visual angle matrix for a diagram

6 Conclusion

This summary proposes to start research on the separability of neighboring graphic objects according to the colors and their apparent sizes. This is a complicated area because of inherent difficulties, including media calibration, visual environment and media type. We describe a user testing protocol and propose two methods to apply the test results.

References

[1] M. Aupetit and M. Sedlmair. Sepme: 2002 new visual separation measures. In C. Hansen, I. Viola, and X. Yuan, editors, *2016 IEEE Pacific Visualization Symposium, PacificVis 2016, Taipei, Taiwan, April 19-22, 2016*, pages 1–8. IEEE Computer Society, 2016.

[2] C. G. Healey and A. P. Sawant. On the limits of resolution and visual angle in visualization. *ACM Trans. Appl. Percept.*, 9(4), oct 2012.

[3] E. Languenou. Contrast driven color-group assignment in categorical data visualization. In *proceedings of the IVAPP 2023 : 14th International Conference on Information Visualization Theory and Applications*, Lisboa, Portugal, 2023. Best Paper Award.

[4] S. M. Newhall. Width and area thresholds of discrimination of two colors. *Journal of General Psychology*, 52:247, 1955.

[5] B. Pinna, G. Brelstaff, and L. Spillmann. Surface color from boundaries: a new 'watercolor'illusion. *Vision research*, 41(20):2669–2676, 2001.

[6] M. Sedlmair, A. Tatu, T. Munzner, and M. Tory. A taxonomy of visual cluster separation factors. *Comput. Graph. Forum*, 31(3):1335–1344, 2012.

[7] G. Sharma, W. Wu, and E. N. Dalal. The ciede2000 color-difference formula : Implementation notes, supplementary test data, and mathematical observations. *Color Research and Application*, 30:21–30, 2005.

[8] M. Stone. In color perception, size matters. *IEEE Computer Graphics and Applications*, 32(2):8 – 13, 2012.