Dead and Beautiful: The Analysis of Colors by Means of Contrasts in Neo-Zombie Movies

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The analysis of color in movies is a topic of increasing interest in the still-young research field known as digital film analysis or *cinemetrics*. The thesis of Brodbeck (2011) is one of the early examples which have been discussed broadly. Brodbeck created a donut plot for each movie in which dominant colors of scenes are represented by colored slices within the plot. Similar approaches were taken by (Baker 2015) and (Burghardt, Kao, and Wolff 2016). Both approaches identify dominant colors of all frames in a movie and represent these colors as lines in a barcode-like visualization. In the first and the third project dominant colors are created by means of a clustering-algorithm, more precisely *k-means*. This algorithm is one of the most common approaches in *color quantization* and is also delivered for such tasks in well-known computer vision libraries like OpenCV.

However, there are several issues with using k-means for color quantization in digital film analysis which are rarely discussed within the community. One of the more obvious problems is that k-means (and other non-hierarchical cluster algorithms) require pre-definition of the number of clusters to be found. Thus, an automated analysis of around 180,000 frames in a movie does not respect the fact that there are frames which are more complex in color than others. A more sophisticated procedure exists in which the k-means algorithm is used in a loop with different numbers of cluster. In this approach the best fitting number of clusters is defined and evaluated by the *silhouette coefficient* which is applied to the result of each loop. However, Figure 1 demonstrates that the best-fit in terms of clustering is definitely not the best-fit for the interpretation of colors in film analysis.

Figure 1: Cluster analysis of dominant colors in a frame image of *The Walking Dead.* According to the silhouette coefficient the number of two clusters produces the best clustering result.

Colors which seem to be important even before any interpretation has taken place disappear in the clustering process because they are 'eaten' by other clusters. Figure 2 offers a very impressive example for this phenomenon. The red girl from *Schindler's List* – the most exciting thing that happens in the movie in terms of color– is not represented within the clusters transparently. The reason is that k-means has a tendency towards equally sized clusters and that the color difference is not big enough to survive this tendency.

Figure 2: Cluster analysis of color in a scene from 'Schindler's List'

Another problem is that k-means produces slightly different results each time it runs. Hence, sometimes a color which would be perceived as different by humans is present in the result and sometimes it is not. The results differ most in between three and five clusters as predefined cluster values. However, this is exactly the span which is most often used for color quantization in digital film analysis. Finally, the k-means algorithm produces different results in correspondence with the color space in which a frame is represented. For instance, the HSV color space produces better results than the RGB color space.

All of these problems call for a theoretical evaluation of what dominance means for dominant colors in digital film analysis. Unfortunately, the previously mentioned projects have not presented such evaluations. Furthermore, these projects also did not systematically interpret the results they have produced. For this reason, it is not transparent which semantics can be found in the patterns.

All this being said, a different approach for the computational analysis of colors in movies seems necessary. This approach needs to introduce a starting point which is technologically less arguable and which offers concepts for the interpretation of results. The approach that will be presented builds upon the theory of *seven color-contrasts* developed by Johannes Itten (Itten 1961, 36–109). Itten claims that the effect of colors is not absolute but depends on the surrounding color environment. Colors interact with each other and there are seven contrasts in which this interaction can be analyzed. These contrasts are:

- hue
- saturation
- light-dark
- cold-warm
- complementary
- simultaneous
- extension

Each contrast has certain capabilities to structure and create effects in the narrative and aesthetic design of a movie. They can be used: to guide the attention of viewers, to create spatial ambiance, to create orientation or confusion, to support the symbolic layer or to create associations as well as emotions. Although these effects are not generalizable the approach of color-contrasts has more to provide to interpret color in movies than the analysis of single colors. This holds true especially where the dynamics of multiple contrasts are related with each other and begin to form a language of color. For instance, a movie might have a stable opposition between cold and warm colors but more progressive color dynamics (Wulff 1988) between light and dark colors. The results of such an analysis can be related to narrative aspects, characters, leitmotifs or the *Mise en Scène* in a movie or a corpus of movies.

The technological implementation of this approach depends on the type of contrast that will be analyzed. Data for the first three contrasts can be obtained by converting movie frames to the HSV or HSB color space. The conversion between the YUV color space (in which many movie files are represented) into HSV is lossless in most cases (Ford and Roberts 1998). Each channel in HSV represents one such contrast. Usage of the CIE L*a*b* color space can be considered to comply with certain issues of color awareness that are not tackled by HSV and others. Other contrasts require further processing. For instance, to obtain cold and warm color values, each value in the hue channel can be associated with a value that represents how warm or cold it is. In general, values of red and yellow are conceived as warm. However, this effect is very much influenced by cultural and psychological aspects (Küppers 2000). Therefore, the association of color values with values of warmth is a task that requires decision-making. In contrast, the presence of complementary and simultaneous colors is a mathematical relationship and can be computed within a certain color space consistently.

There are also several ways in which contrast data can be analyzed. Figures 3 and 4 visualize two of such strategies. In both cases a histogram of one contrast was computed for every second of the movie. In Figure 3 the leftmost and rightmost peaks in each histogram was calculated. These peaks constitute the min- and max-bound of the contrast span in each frame. The x-axis represents the time-axis of the movie while the y-axis shows the value of each min- and max-bound.

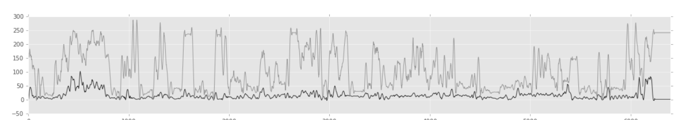

Figure 3: Slightly interpolated boundaries of light-dark contrast in '28 Days Later'

In Figure 4 the contrast of a spectrum was reduced to 16 bins and each contrast value that was produced by a critical number of pixels was plotted as a point. The size of the point represents the number of pixels in a frame for each bin.

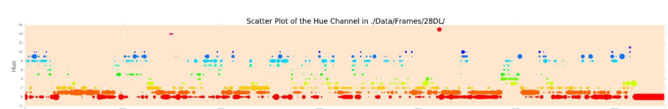

Figure 4: The appearance of hue values above a certain threshold in '28 Days Later'

The movie which underlies both visualizations is *28 Days Later*. Figure 3 represents the light-dark-contrast. It shows two sequences in which light and dark colors go up simultaneously for a certain amount of time. One sequence is between the 200th and the 800th frame the other between the 6000th and the beginning of the credits. In the first sequence the protagonist Jim awakes from coma and realizes that the world fell apart. In the second sequence the main group of persons reach the final save place. Thus, a similar pattern in one contrast frames the actual storyline. However, the color-itself-contrast represented in Figure 4 is extremely different in these scenes. The first scene has a narrow spectrum while the spectrum of the second scene is broad. The narrow spectrum provokes disorientation because it tones down differences. The color segment is literally dazzling. In contrast, the spectrum and coverage of colors at the end mediate clarity, stability and order.

This presentation will outline the problems of k-means for color quantification in digital film analysis. It will describe the theory of seven color-contrasts and give examples how such theory can be adopted computationally. Each step will be illustrated by an analysis of a corpus of three neo-zombie-movies, more precisely *28 Days Later*, '[REC]' *and World War Z*.

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