Automatic color scheme picker for document templates based on image analysis and dual problem

Pere Obrador
HP Laboratories Palo Alto
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This paper presents two complementary methods to help in the area of document creation where the document includes color templates (banners, clipart, logos, etc.) as well as photographs. The problems that are being addressed are:

- given a photograph that a document needs to be built around, extract a good palette of colors that harmonize with the selected photograph, which may be used to generate the color template; The images are segmented with a color based morphological approach, which identifies regions with a dominant color. Based on the morphology of such "color" regions, and the other color objects in the template the scheme will pick a set of possible color harmonies (affine, complementary, split complementary, triadic) for such color elements within the document based on the combined morphology image-document. If the image is changed in the future the color scheme could be changed automatically.

- given a document color template, identify from a collection of images the best set that will harmonize with it. The document color template is analyzed in the same way as above, and the results are used to query an image database in order to pick a set of images that will harmonize the best with such a color scheme.

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Pere Obrador

Hewlett-Packard Laboratories
Palo Alto, CA, USA
pere.obrador@hp.com

ABSTRACT

This paper presents two complementary methods to help in the area of document creation where the document includes color templates (banners, clipart, logos, etc.) as well as photographs. The problems that are being addressed are:

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1. INTRODUCTION

Color harmony sets guidelines on how to create effective color combinations. Many attempts have been made, through many historical periods, to create recipes for color harmony. It is, however, not possible to make a list of rules to describe the harmonious or disharmonious visual image. Complementary contrast, whatever the subject, is not a requirement for a harmonious color image. "Ton-sur-ton" or analogous color scheme (where all colors are related to one color hue in slightly different shades or tints) color use doesn't guarantee harmony either. Only the human eye can judge the final artistic result[1].

The color schemes used the most in harmonization are[1]:
Analogous scheme: uses any three consecutive hues or any of their tints and shades on the color wheel
Complementary scheme: uses direct opposites on the color wheel
Clash scheme: combines a color with the hue to the right or left of its complement on the color wheel
Monochromatic scheme: uses one hue in combination with any or all of its tints and shades
Split complementary scheme: consists of a hue and the two hues on either side of its complement

The algorithms presented in this paper try to help in the generation of color documents that include banners, logos and photographs. The images and documents are analyzed in order to suggest possible color palettes or images that will harmonize well with the existing document/photograph.

In order to develop an algorithm that will help in color harmonization it is of critical importance to identify areas with a homogenous dominant color in which there is little color activity, and also of high importance is to identify smaller regions with high color activity (i.e., even if the color region is very small within that high color activity region, it may still be of high importance at harmonization time if the chroma of such region is significantly different from the rest of regions' chroma). Such an algorithm was developed in [3], and it will be briefly described in the following section below.

Since this paper is 100% color-related, I would encourage you to check the color version at the HP-Labs web-site (http://www.hpl.hp.com/techreports/).

2. ALGORITHM DESCRIPTION

This paper describes the color patch extraction algorithm[3], as well as a few algorithms for color harmonization: a) starting from a photograph suggest a color palette to go with it; b) starting with a document, retrieve the best images from a database that will harmonize with it.

2.1. COLOR PATCH EXTRACTION

The image, either the document or the photograph, will be converted to an abstract representation that will ease the task of harmonization as shown in figures 4 and 6. This representation includes a reduced number of color patches, their centroid location on the page/photograph, the size of each patch (in number of pixels), and the connection of each patch with any of the four borders of the image.

The image is first quantized to a set of color bins (which may be generated from the image itself for best results). The quantized image is then manipulated in order to obtain a reduced number of regions that can be used for harmonization purposes. The fewer patches and the larger they are the best for harmonization purposes, since the human visual system is most sensitive to large areas of color. These large regions are the ones that will be taken into close consideration in the algorithms below in the next two sections.

No perfect scene object segmentation[4,5], is intended in the color patch extraction process, since different objects may be quantized to the same color, the result may be a merged color patch.

(a) (b)

Figure 1. Examples of color patches (from the sample image "girl" in figure 2) and their underlying color patches, a) at a low resolutiolarger scale, b) at a lower scale.

Another aspect that should be noted is the multi-resolution nature of such a problem. Underlying color patches at different scales may look very different indeed. i.e., what may look as an underlying color patch at a very small scale, might just look as a non-underlying color at a very large scale (see figure 1a, where the vertical white stripe, reflection on nose in figure 2b, is removed at the larger scale in favor of the underlying color; on the other hand, at a smaller scale it is definitely an underlying color within its region as seen in figure 2c). And the other way around, large enough regions (given the scale/resolution) with high color activity will not have a clear underlying color patch and should be left alone.

Having these requirements in mind, a technique was developed[3], in order to extract the underlying color patches in an image, quantized with a predetermined quantization table (palette): a parallel symmetrical a*lternating sequential filter* scheme which allows for color patch extraction, while maintaining edges and detail regions, and also, a maximum likelihood scheme to fix edge jitter[6,7], in color morphological filters applied to sparsely quantized images. This algorithm is multi-resolution by nature, and it can be devised having in mind the scale of the color patches that need be preserved. This filter is implemented in stages (*alternating sequential*), starting with the smaller scale, and ending with the larger scale. 4 stages give good results for the color harmonization application.

(a) (b) (c)

Figure 2. a) original "girl" image, b) quantized to 25 color bins, c) 4-stages color patch extraction

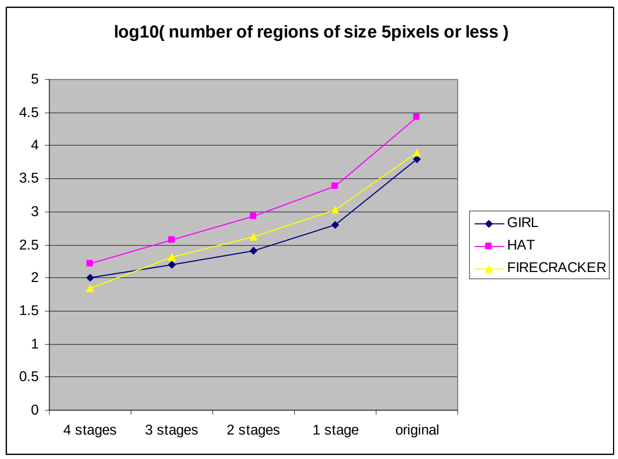
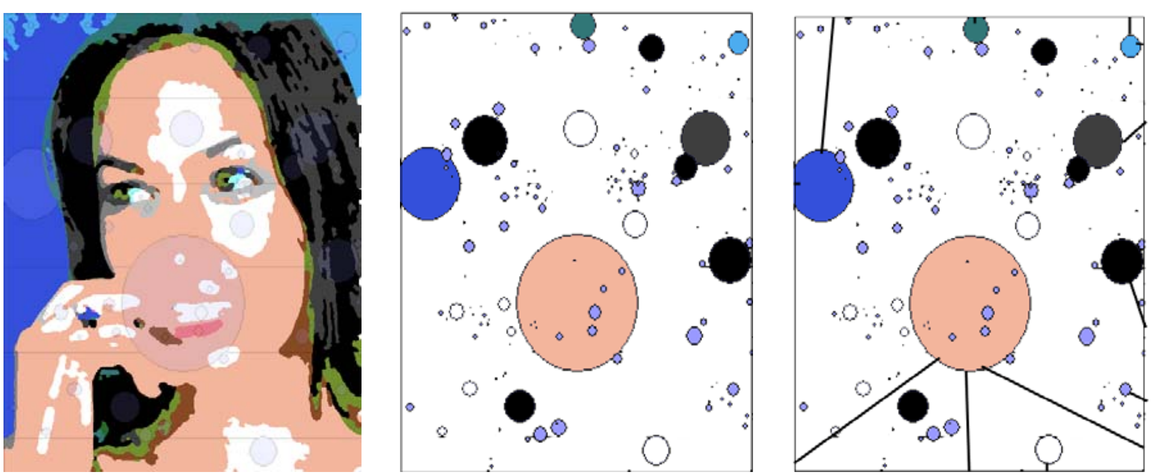


Figure 3. overall number of color patches of size 5pixels or less after processing on the image in figure 2, and 2 other images[3]



(a) (b) (c)

Figure 4. a) "girl" image with superimposed color patch abstraction, b) "girl" color patch abstraction, c) larger patches touching borders abstraction.

Figure 2 shows an original image, the quantization, and the color patch extraction result. In the color patch image it can be observed that the detail is well preserved in areas of high color activity (i.e., eyes, ring), and at the same, the overall number of patches (regions) has been reduced considerably (see figure 3 to see how the number of color patches is reduced with the number of processing stages).

Once the color patches are extracted, the abstract representation of figure 4 can be built. The centroids, as well as the average color (in Lab color space) for each patch, and the morphology of the image with respect to the borders (number of pixels of each patch touching which border) are stored in such representation. The importance of such representation will become apparent in the sections below.

2.2. COLOR SCHEME PICKER BASED ON PHOTOGRAPH

This algorithm allows to automatically generate a palette of colors from a photograph, which the graphic artist or designer can use directly knowing that it will harmonize with said photograph.

By extracting the Lab color averages of each of the color patches the palette for logos/banners/text can be easily generated. It can also be done by a weighted average of the color in all the regions from the same color bin, or a combination of the two. This is quite straight forward from the abstract representation presented in section 2.1 (see figure 7a.

One important thing to keep in mind is text readability, since not all color combinations are easily read. Once the palette is generated, the text possible colors are reduced as presented in [8], based on the background color that is selected.

If the graphic artist would like to place the photograph on a full-bleed background for instance, this means that all the photograph will be immersed in that background color[1,2] (i.e., all borders of the photograph will be touching that color), with strong implications to the color harmony of the result. In such situations, the color palette for such background is also reduced by the following algorithms (in fact after obtaining the image abstraction as in figure 4, any of the color schemes presented in the introduction could be used to select a background color):

Analogous background #1 (largest):

- pick the non-gray color bin in which all regions are barely touching the borders (*sizeFactor* >=minSizeFactor)
- pick the largest (in number of pixels) such color bin
- the background hue will be the hue of the average of such color bin

Analogous background #2 (unusual):

- pick the non-gray color bin in which all regions are barely touching the borders (*sizeFactor* >= minSizeFactor)
- pick the colorimetrically most different (**Lab** space, **ab** distance) such color bin
- the background hue will be the hue of the average of such color bin

Complementary background:

- pick the non-gray color bin in which all regions are mostly touching the borders (*sizeFactor*< minSizeFactor)
- pick the largest (in number of pixels) such color bin
- the background hue will be the complementary hue of the average of such color bin

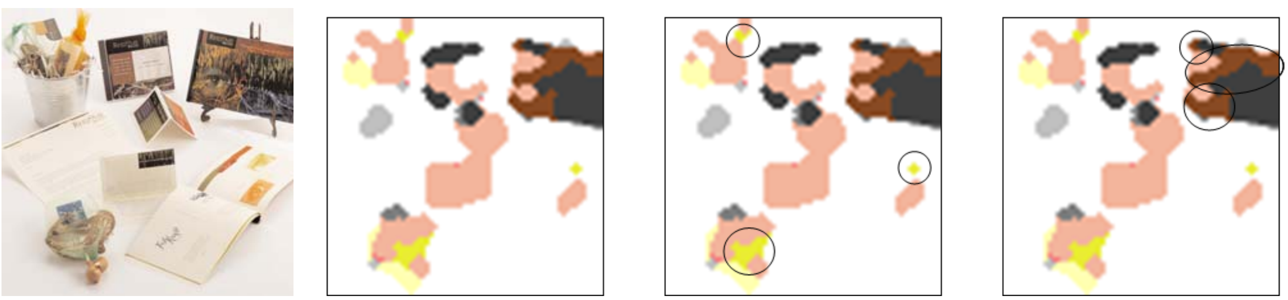
The algorithm is not considering gray-scale color bins, since these colors harmonize well with any color, and for this reason are not considered in this study.

Where *sizeFactor* is calculated for each color bin as:

$$\text{sizeFactor}_i = \frac{\sqrt{\sum_{j\ patch \in patch_i} totalPixels_j}}{1 + \sum_{j\ patch \in patch_i} borderPixels_j} \qquad \textbf{equation } 1.$$

And gives a good estimation of the relation between the size of a patch and how much it is in contact with the border. The more pixels touching the border, the smaller *sizeFactor* becomes, and will not be chosen in the analogous algorithms above, which makes sense, because the background color should not merge with any part of the photograph so that it stands out. If the color is touching the border (and it is the largest such patch), a complementary background will bring out the photograph.

So all color bins with *sizeFactor* >=minSizeFactor (barely or not touching border) are considered for analogous schemes, and color bins with *sizeFactor*< minSizeFactor (mostly touching border), are considered for complementary color schemes. See figure 7b for an example of analogous #1 (largest), where the full bleed background has been generated automatically, after the average hue of the circled regions presented below in figure 5c.



(a) (b) (c) (d)

Figure 5. Image in figure I with a) original "stationary" image, b) color patches being extracted, c) regions belonging to the largest color bin with *sizeFactor*>=minSizeFactor, d) regions belonging to the largest color bin with *sizeFactor*>=minSizeFactor, for bottom and left borders only

On more level of complexity arises if the graphic artist is willing to add new color objects that are intersecting the photograph. For instance, it could be intersecting the photograph on the left and bottom borders (as shown in figure 7c). In this situation the algorithm can still be the same as the described above in this section, but modifying the formula for *sizeFactor,* where only the borders that will be intersected are considered as borders in equation 1. Figure 5d shows how the result for the analogous #1 (largest) has changed to another color bin (larger than the selected in figure 5c) which is touching the right border. One last consideration is that this new color object should harmonize with the background of the image (figure 7c shows that in this case the result is harmonious); in the case it would not harmonize, the algorithm could fall back to the following (smaller) analogous color bin, and so on.

2.3. PHOTOGRAPH RETRIEVAL BASED ON DOCUMENT QUERY

In this section the dual problem from the one presented in the section above is presented. In this case, given a document with space for a photograph, the system queries a database retrieving the best suited images for such document based on the morphology of document and photograph, and an analogous color scheme. Other color schemes are obviously possible, as the ones presented in the introduction, for instance.

The main idea is to generate abstract representations both for the document and the image to be tested for similarity. The morphology of each of them will be used to see how close in space the color patches are to each other. The color similarity and the size of the patches.

Figure 6 shows an example of all the process in order to obtain such abstract representation. The original image (Figure 6a), is quantized with the same color bins as the images in the data base, resulting in figure 6b. This is further processed by the 4-stage color patch extraction algorithm resulting in figure 6c, and the abstract representation of figure 6d. Up to here, it is exactly the same process as described in section 2.1.

One of the important things to keep in mind when processing color documents is that anti-aliasing borders usually map to intermediate color bins, resulting in color artifacts when trying to detect color similarity.
After heavy experimentation, for better results it is important to keep the document abstraction to a few color bins only. In the presented algorithm the largest color bins covering at least a certain percentage (*areaPercentage*) of the color (non-gray) areas are kept in the abstract representation (figure 6e).

Now, both document and images in the database have the abstract representation (document: figure 6e, sample image: Figure 4b). Such representations can be used in order to calculate how well the document and sample images fit in a color harmonious way.

The approach to calculating how well the document and image fit was initially investigated as a modified gravitational function, in which the *harmony measure* between two color patches would be directly proportional to the product of color patch areas, and inversely proportional to the square of their distance, both euclidean in document space, and also euclidean colorimetric in Lab space. In this specific rendition of the algorithm the closer the color patches are (from sample image to document) the higher the *harmony measure*, but this could be changed at will, and could actually be left to the graphic artist to determine the layout of the photograph with respect to the document.

After psycho-visual tests, the formula was modified to equation 2, where the influence of the color distance was greatly increased. The size of the areas influence has been reduced to the square root of the product of the areas, the euclidean distance in document space has also been reduced to the distance itself (non-sqared), and the euclidean distance in Lab color space was augmented to be the distance to the fourth power.

$$harmony\_measure_{ij} = bin\_factor * \frac{\sqrt{patchSize_i * patchSize_j}}{\left(1 + centroidDist_{ij}\right) * \left(1 + \left(colorDist_{ij}\right)^4\right)} \qquad \textbf{equation } 2.$$

with

$$centroidDist_{ij} = \sqrt{\left(centroidX_i - centroidX_j\right)^2 + \left(centroidY_i - centroidY_j\right)^2}$$

and

$$colorDist_{ij} = \sqrt{\left(averageL_i - averageL_j\right)^2 + \left(averageA_i - averageA_j\right)^2 + \left(averageB_i - averageB_j\right)^2}$$

The way the system is implemented is by placing the sample image abstraction in the reserved space for the photograph on the document (figure 6f). For each color patch in the document, the *harmony measure* between this patch and each of the color patches in the sample image are calculated as shown in equation 2, and then added together resulting in the *final_harmony_measure* (equation 3).

$$final\_harmony\_measure_m = \sum_{i \in document} \sum_{j \in image} harmony\_measure_{i,j} \qquad \textbf{equation } 3.$$

Each image *m* in the database ends up with a *final_harmony_measure*. The larger this quantity, the better it will harmonize with the document, based on the rules stated above.

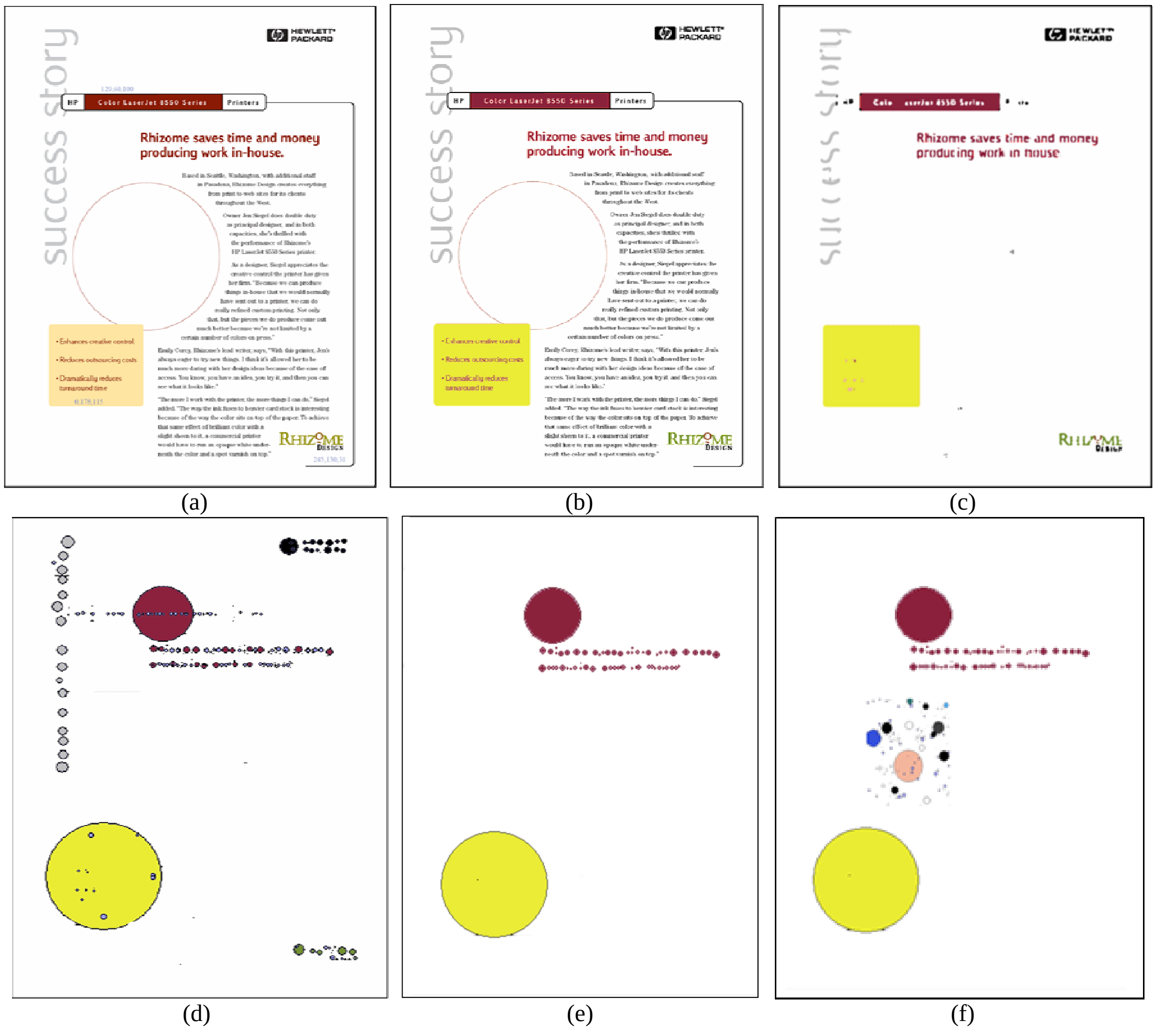


Figure 6. a) original document with a circular space for photograph, b) quantized to 25 color bin, used colors are the centroids of the color bin, c) color patch extraction, d) color patch abstraction, e) 90% of color area starting from larger color bin (avoiding color artifacts due to aliasing), f) color patch abstraction incorporating a sample image ("girl").

3. RESULTS

These algorithms have been tested with a color quantization scheme with 25 fixed bins (non image dependent). As mentioned above, it would be best to requantize based on each of the starting images for the color scheme picker base on a photograph, but it is unrealistic for the photograph retrieval based on document query, since all the images in the database would have to be re-processed for every change in the color scheme of the document.

The color patch extraction is performed with a 4 stage filter[3].

In order to optimize for speed, with reduced impact in the final results, the photo abstraction size was kept very small (64*48 pixels), while the document abstraction is kept pretty detailed (1024*800) due to the fine details in such images.

The *sizeFactor* is set to 4, which is equivalent to an area of 16 pixels not touching the border in a 64x48 pixels abstraction image representation.

The *areaPercentage* is set to *90%*.

Figure 7 shows, starting from the photograph on the left, an automatically generated analogous color palette (a), along with a analogous (largest) full bleed background automatic selection (b), and finally an extra rectangle added for design style which overlaps the photograph on the left and bottom borders, for which the color is also calculated automatically with an analogous (largest) color scheme. See section 2.2 for details.

Figure 7. a) Palette automatically extracted from the image, b) automatic background full bleed color, analogous #1 (largest) color scheme, c) adding a rectangle overlapping with image (color selected automatically with analogous #1 (largest) color scheme using only the bottom and left borders to check *sizeFactor*).

Figures 8 and 9 show an automatic retrieval of images from a 900 photograph database (images taken with a digital camera over a period of a few months with no prior selection whatsoever). The retrieved collections are ordered from highest *final_harmony_measure* to lowest (file name first 6 characters).

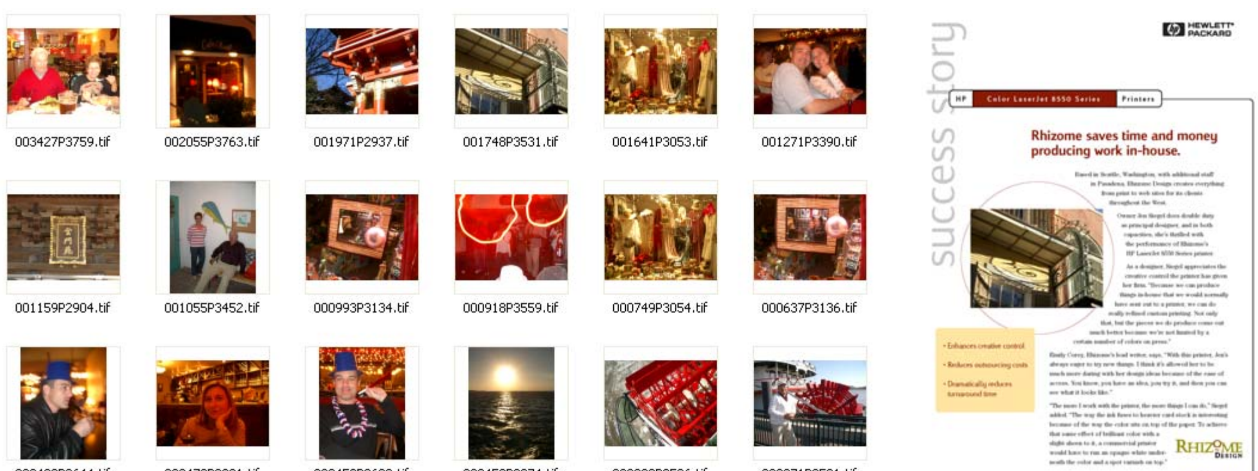
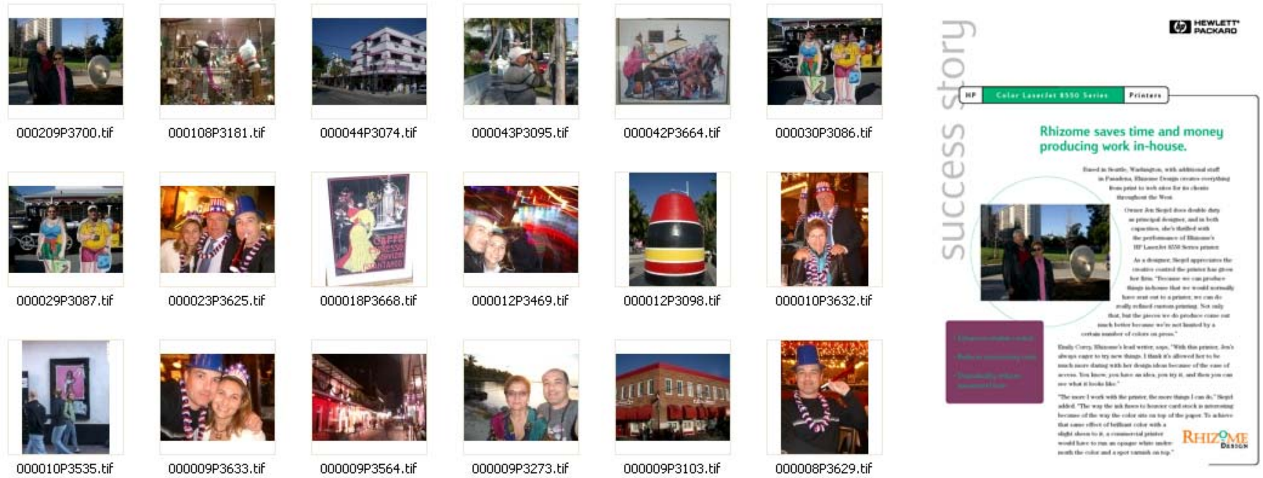


Figure 8. a) Results retrieved after querying the database with the document on the right (distance measure appears as first 6 digits in file name), b) example of the document with one relevant photograph from the retrieved list

Figure 8b shows a document template with red (top) and beige (bottom) banners. The results are psycho-visually very relevant from the color harmonization standpoint. The selected image in figure 8b (ranked 4th in the retrieval list) is very relevant, since it also has the red areas on the top-right, and the beige areas in the bottom-left. The graphic artist can safely select this image, since this is the harmonization rule embedded in the algorithm.

Figure 9b shows a document template with green (top) and violet (bottom) banners. This is a very unusual combination in the real world, but the algorithm still manages to retrieve very relevant results. The selected image in figure 9b (ranked 1st in the retrieval list) is quite relevant, since it also has the green areas on the top-right and middle of photograph, and the violet areas in the bottom. The graphic artist can safely select this image, since this is the harmonization rule embedded in the algorithm.



a) b)

Figure 9. a) Results retrieved after querying the database with the document on the right (distance measure appears as first 6 digits in file name), b) example of the document with one relevant photograph from the retrieved list

4. CONCLUSIONS AND FUTURE WORK

A color patch extraction algorithm has been introduced, which allows for color harmonization algorithms. Two of these have been presented.

a) color scheme picker based on photograph, where given a photograph a color palette and possible background colors are presented automatically following 3 color schemes (analogous largest, analogous unusual and complementary)

The logical way to extend this work is to try more sophisticated color schemes (not only analogous and complementary), as the ones presented in the introduction.

b) photography retrieval based on document query, where given a document with space for a photograph, it queries a database retrieving the best suited images for such document based on the morphology of document and photograph, and an analogous color scheme.

This algorithm can also be extended by trying more sophisticated color schemes (not only analogous), as the ones presented in the introduction. Also experimenting with new morphology relationships between the document and photographs, and also extending the theory of overlapping color objects with photographs presented in section 2.2 to this algorithm, which would allow retrieving photographs placed on non-white document regions.

Check the color version at the HP-Labs web-site (http://www.hpl.hp.com/techreports/).

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