A Novel Sensor to Visually Track Fading of Printed Material

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Abstract

As printed papers, banners, packages are pervasive, so is the recognition that they will fade over time due to exposure to light, pollutants and handling. However, few people can easily quantify the degree of fading that has already occurred until it is well-advanced and often irreversible. An assurance of the accuracy / validity of color samples is especially important in the commercial realm. For example, a user of a Pantone book or an alternative set of printed reference color samples needs to know that the sample colors are still accurate and valid. The only currently used marker is a printed date. We propose the use of a simple visual reference marker that is based on a side-by-side color comparison. We used our understanding of the fading process of printed material to create a novel type of fade sensors. These sensors are based on the concept that inks fade non-linearly and at different rates. Selecting the right combination of inks enables us to display visual cues or messages at various stages of the fading process. In our first experiment, we accumulated empirical fade data for several combinations of HP original ink and media and 3rd party company refill ink and media. We developed algorithms and visualization programs to analyze a dataset of 536 colors per ink and media sets through 80 years of fading and reduced the pool of marker color candidates to 20-40. In this initial phase, the final selection was done manually to account for the directionality of the color difference (luminance, chrominance, or hue) and to incorporate previous research on text readability. In the future we are planning to automate the final selection process. Adding our sensor to a set of reference color samples would visually communicate that the colors samples are not valid anymore and that the set needs to be replaced.

Keywords

Color fading, visual marker

Introduction

Printed paper has been used for a millennium to communicate, enjoy and archive information. It has endured time and new technology mainly due its robustness and visual nature. However, as any fixed physical medium it degrades over time due to exposure to light, pollutants and handling. Most people are familiar with the sight of a faded picture, packaging material or marketing poster that has been exposed for a bit too long. A lot of research has been conducted in improving the light fastness characteristics of printing resources (ink, media). For simplicity, printing and supply companies, professional photographers and art galleries only communicate the final expected longevity of a printed document using standard metrics that were defined to mimic specific environmental conditions. Those numbers are based on the time when the density changes of a small set of color patches reach certain thresholds in an accelerated fading environment that simulates a specific real world situation (a specific light exposure, UV content, etc.). Naturally, those test environments do not always represent the real life conditions and use. Moreover, although humans can tell when an image is faded, they can not accurately quantize the degree of fading. This results in waiting until the damage is well advanced and often irreversible. There are many applications where a user can benefit by having a simple visual measure to assess the degree of deterioration of a printed artifact: In the commercial realm, a user of a Pantone book or alternative set of printed reference color samples will know that the sample colors are still accurate and valid. Fading depends on the light exposure. A color reference book left open near the window will fade faster than one stored in the dark inside a drawer. We don't want to measure time, but how much fading caused by environment exposure has occurred. In the professional world, such a fade measurement tool can be used for "color branding management", or in a consumer environment, a customer will know when it is time to reprint his pictures, album, or archival album [1].

Our Solution

Our goal is to enable the user to easily and visually quantify the degree of fading. We propose to use our understanding of the fading process to our advantage and develop several fade sensors.

Two possible implementations are shown in *Figure 1*. They are based on side by side comparison for simplicity and can be grouped into two categories: The first set consists of custom "patches" that are printed alongside the picture or document using the same ink as being used for the reproduction of the document. As shown below, this solution will track the fading of a document during its everyday use (indoor, outdoor, protected or non protected, pages left open, varying sunlight amounts, etc.); something that is not possible today. Currently available light fastness numbers provide a single number indicating when the change in colors reaches a certain threshold under the assumption that the printed artifact is stored in specific conditions and require the recording of the time of printing.

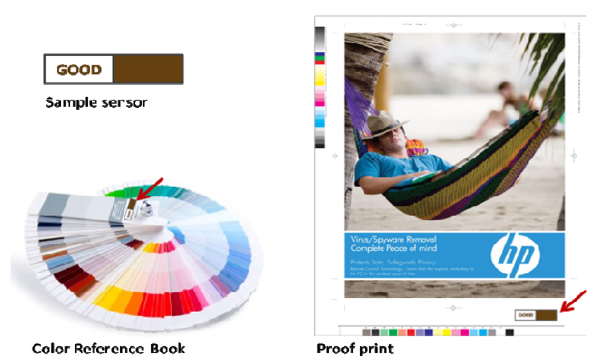

***Figure 1**. Examples of fade sensors embedded in a) a Color Reference Book and b) into a Hard-Copy Proof.*

The envisioned fade sensors in this group track and communicate color modifications due to real world environmental conditions instead of assumed ones and do so continuously even before the threshold is reached.

For a specific printing system (printing technology, paper & ink) the various color combinations will fade non-linearly and at different rates. We are taking advantage of those differences! The color samples that are used are optimized for that particular printing system and are selected to be different immediately after printing and to become indistinguishable after a certain amount of light exposure which corresponds to an unacceptable amount of fading. The selected colors for the patches are dependent on the combination of inks and media; however this information is already gathered when printing companies establish the light fastness for that specific set of inks and paper. An example for that type of a fade sensor is illustrated in *Figure 1b*.

Figure 1a shows an alternative implementation: Fade-Sensors can be produced separately at the print shop and then applied like stickers to the products during the production of the color reference book. It is similar to producing book covers on different presses than the core of the books. The advantage of this approach is the higher flexibility: Inks can be designed and used that have specific fading characteristics and again pairs of colors can be selected that communicate that a specific amount of light exposure has been reached.

During the development of HP's Fade Simulator [2,3] we accumulated empirical fade data for several combinations of ink/paper for HP original and refilled ink provided by 3rd party companies. Specifically, color charts sampling the printer color gamut were printed and measured. The charts were than subjected to an accelerated fading process (using a fadometer) which changes the reflectance properties of the patches. To monitor the behavior of the fading process the charts were re-measured in regular intervals, typically once a day for several months. The collected data set was then used to calculate reflectance data corresponding to a discrete set of time intervals. That data set was then used together with the initial device-dependent color values to create a set of ICC fade simulation profiles for a specific original HP ink and media set and for a 3rd party refill ink and media. Those Fade Simulation profiles can be used to generate previews (on either a monitor or a printer) of how an image will look like after a certain amount of time assuming a particular light exposure per day.

As previously mentioned, for the specific application described in this paper we are not interested in time, but we want to measure when a certain fading stage which is determined by the amount of light exposure, pollutants, and humidity has been reached. We don't care in which time frame that occurred. It is also important to note that simply measuring the amount of light exposure wouldn't be enough as there are other factors that influence the degree of fading as mentioned above.

As the refilled ink has in general a lower light fastness than HP's supplies we used that data set to illustrate the ideas of this paper. Figure 2 visualizes the fading path of a few selected color patches printed with refilled ink over a time frame of 80 years in the CIELab color space. As expected, there is a general trend of color change from fairly saturated at the beginning to generally more de-saturated and lighter after 80 years. However, it is notable that the path taken is not linear. Less visible in this figure is the fact that the amount, speed, and path direction varies among the colors.

We developed algorithms and visualization programs in the Python programming language to analyze a dataset of 536 colors through 80 years of fading. The original colors were selected to represent an even sampling of the Lab color space (16 hue angles). To find potential color candidates for our application, we compared pairs of colors using the ΔE76 color difference and set specific rules and thresholds depending on the application. This enabled us to sort through the thousands of possible combinations and reduce the pool of candidate pairs to 20-40. In this initial phase, the final selection was done manually by visually looking at the pairs of color patches. In the next implementation, we are planning to refine our selection process to enable a fully automated system. This will require us to take into account the directionality of the difference (luminance, chrominance, or hue) and to incorporate previous research on text readability [4].

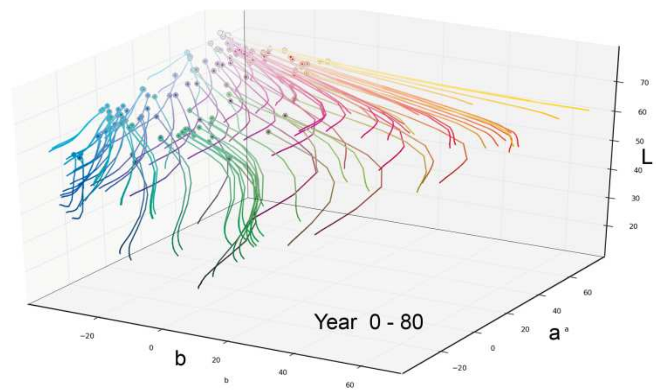

Figure 2. *Graph of the paths of color fading from 0-80yrs in Lab color space.*

Results

Using our first dataset, we have selected pairs of colors to meet different embodiments for this specific paper/ink set. The changes of the color differences (ΔE76) occurring for a few example pairs due to fading are shown in *Figure 3*. Pair 1, 2, 3 correspond to the black, red, purple patch-pairs in the second row of Figure 4. As can be seen, Pair 3 reaches a small ΔE early in the fading cycle meaning that it the patch colors are becoming indistinguishable from each others. The 2 colors in Pair 2 are distinct at the beginning, but gradually become less distinct as the years passes to also become indistinguishable by the end. However, while the ΔE of Pair 3 decrease slightly, it stays large enough that at the end of the test, the colors are still distinct visually.

In *Figure 4*, the resulting selected pairs are displayed in three possible embodiments at three stages of the fading process. The first column (a) represents the beginning stage, the middle column (b) represents a midpoint warning that fading is occurring and care should be taken. In the third and last column (c), fading is excessive and the printed reference material should not be used. In the first row, three patches of color look distinctly different at the beginning but the distinction diminishes as fading occurs. In the second column, the two right most patches have faded to the same color, and in the third column, the three patches are undistinguishable and the printed reference material should not be used.

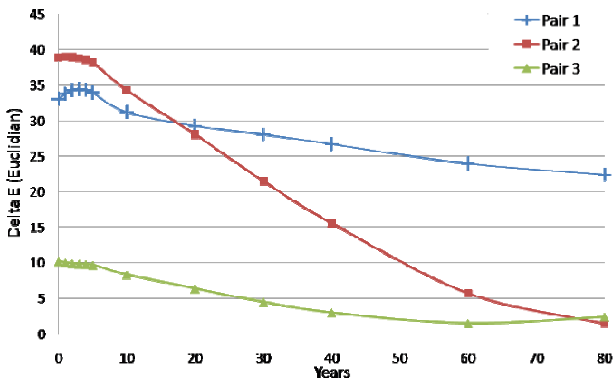

Figure 3. Diagram to show the selection process and resulting patches.

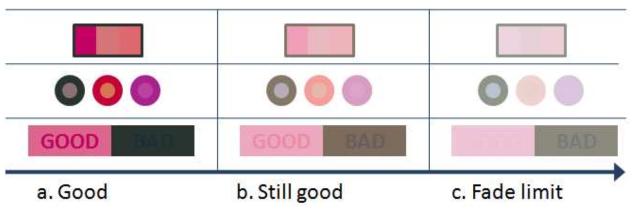

***Figure 4**. Examples of color sensors.*

In row 2, a variation using patch-pairs is implemented to better show the fading as a rating system. While 3 out of 3 patch-pairs are good in the first column, only 2 are distinct in the second column. Finally only 1 patch-pair is remaining in the last column. In row 3, we show an example of displaying a descriptive message for the user that either appears or disappears over time. The text is useful in communicating the information in an efficient an unambiguous way.

A fair question to ask is the need for a visual based fade sensor and if there is an alternative to this solution. As pointed out before, companies like HP make a huge effort to increase the light fastness characteristics of our products and we also communicate those numbers to our customers. However, fading will inevitably occur and it is difficult if not impossible to predict the fading rate in advance as each user will use and store the reference book in so many “original ways”. There are specific niche applications where a customer cares about monitoring the fading process. A simple expiration date is not acceptable in those situations, as they will be mostly ignored by the user who is not realizing the degrees of fade that might have occurred. Brand managers in companies cannot be pleased if resellers are using faded marketing materials, and in the Graphic Arts industry companies like Pantone are concerned that after some time the color patches that are been used as reference colors change their appearance and are no longer useful for accurately communicating color information. Pantone addresses the issue by stating on the back of their books that the Guide (book of color samples) should be replaced annually. They have a number for the year printed next to a bar code, but it is not even clear whether that is the year when the booklet was printed or when it is supposed to be replaced. They could put a complete expiration data on their product. ISO technical working groups, responsible for the development of standards are considering a requirement to put expiration dates on hard-copy proofs. While this approach is simple, it has to make some assumptions about the use model. The actual conditions under which the reference set is used might not correspond with those assumptions and thus the fading might happen quicker than expected. If the number is too conservative the user is asked to replace the guide at a point when it would not have been necessary. This is neither cost effective for the end user nor beneficial to the environment. Another issue with using the date is that it disappears among all the other information on a product.

Currently, there are no simple methods to visually track the fading of printed artifacts. Adding our sensor to for example a set of reference color samples would visually communicate that the colors are not accurate anymore and that the set needs to be replaced. On the consumer side, owners of photos or photo album realize that the image is gradually fading, but since they do not know the amount nor the recommended limit, they wait until it is completely faded. Our solution might warn them that it is time to either reprint the image or scan and reconstruct the image before it is too late [1,4].

Conclusion

We have demonstrated that it is possible to take advantage of the fading process to create a feedback sensor for both professional and consumer applications. We expect that its simplicity and visual nature will make our customers aware of the gradual changes and trigger a corresponding action of either reprinting or restoring a document or replacing it in case of color reference material. The proposed sensor is an indicator and not an exact measurement device.

References

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