Color Harmonization for Augmented Reality

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ABSTRACT

In this paper we discuss color harmonization for Augmented Reality. Color harmonization is a technique used to adjust the combination of colors in order to follow aesthetic guidelines. We implemented a system which is able to harmonize the combination of the colors in video based AR systems. The presented approach is able to re-color virtual and real-world items, achieving overall more visually pleasant results. In order to allow preservation of certain colors in an AR composition, we furthermore introduce the concept of constraint color harmonization.

1 INTRODUCTION

In Augmented Reality (AR) oftentimes virtual objects must be generated without any knowledge about the real world environment in which they are going to be deployed. This is particularly relevant for outdoor AR applications (*e. g.*, Layar[4]), where neither the application developer nor the content creator have reasonable control over the real world background, which will be blended with the virtual content. Even if the knowledge about the visual properties of the real world surroundings is available, the dynamics of the real world environment in all but the most constrained laboratory conditions make it at least very difficult to ensure that virtual content will always fit into its real world environment. It is therefore desirable to investigate online composition algorithms that can adjust the virtual and real image components to yield a better visual match.

Among the known properties of appealing images, the combination of colors is accepted as one of the most influential factors. Specific combinations of colors are known to yield pleasing visualizations [1], while others are commonly considered displeasing. Since furthermore the aesthetic of a design is known to improve its usability [2], we present an approach to automatically harmonize color combinations for AR.

We discuss color harmonized AR environments as a first step towards aesthetic Augmented Reality environments. Our system is based on the work of [1]. However, in order to segment the input frame in real time, we use the approach presented in [3]. To be able to apply color harmonization techniques within an interactive AR environment, we have to furthermore address three previously not considered problems.

1. The AR application has to support rendering in real time.
2. Since the color of real world objects may be used to recognize important scene objects, such objects or colors must be precluded from color shifts.
3. Temporally coherent color changes have to be implemented to avoid flickering artifacts.

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2 REAL-TIME COLOR SHIFTING

To achieve real-time performance, we implemented the color shifting on the GPU using pre-computed look-up tables. We identify and execute the necessary color shifts on a per pixel basis. Our algorithm consists of the following steps:

1. Pre-compute color shift for all templates and orientations and store in a look-up table (off-line)
2. Select harmonization template T and its orientation θ, according to [1]
3. Select split border between template sectors, according to [3]
4. Shift the hue value of every pixel, using a pixel shader

For each color template T, we compute a single look-up table before the application is started. This color template look-up table (CT-LUT) holds the results of each possible color shift, for each hue value. We set the granularity to 1 degree of arc (0 to 359), resulting in a texture dimension of 360 by 360 texel. Each texel encodes the mapping result for a single hue in a single orientation of the template. The different mapping directions for a single hue have been assigned to different color channels of the texture. At runtime, a template and an orientation and its mapping direction is chosen for an image according to [1]. Finally, a simple texture lookup defines the new color per pixel.

3 FRAME COHERENT COLOR SHIFTING

Frame coherent color harmonization for AR differs strongly from offline frame coherent color shifting as discussed by Sawant et al. [3]. Firstly, in an interactive system it is impossible to process upcoming frames and secondly, AR systems have to deal with the effects caused by the camera system. For example, noisy images of two successive frames easily may result in a selection of two different harmonization templates. Consequently, unstable camera images may have a strong impact on the hue after shifting has been applied.

To cope with unstable light conditions or strong camera noise will result in unpleasant color flickering due to a frequently changing color template or template orientation. To avoid such jumps back and forth between different templates and orientations, we delay changes to the current harmonization template and its orientation. By keeping these parameter fixed over time, the resulting color shifting remains the same for a single hue and is thus more stable over time.

Our implementation computes the best template and an orientation by counting the number of occurrences a template would have had in the last n frames. The template with the most occurrences will be selected, while no changes to the template will be allowed for the next n frames.

4 CONSTRAINED COLOR HARMONIZATION

Color harmonization is a powerful tool, which is able to increase the effectiveness of AR visualizations. However, since real word environments may consist of objects, which commonly appear in a meaningful color, the AR display cannot heedlessly change the color of every object in the environment, as otherwise the visualization will fail to communicate inherent object semantics.

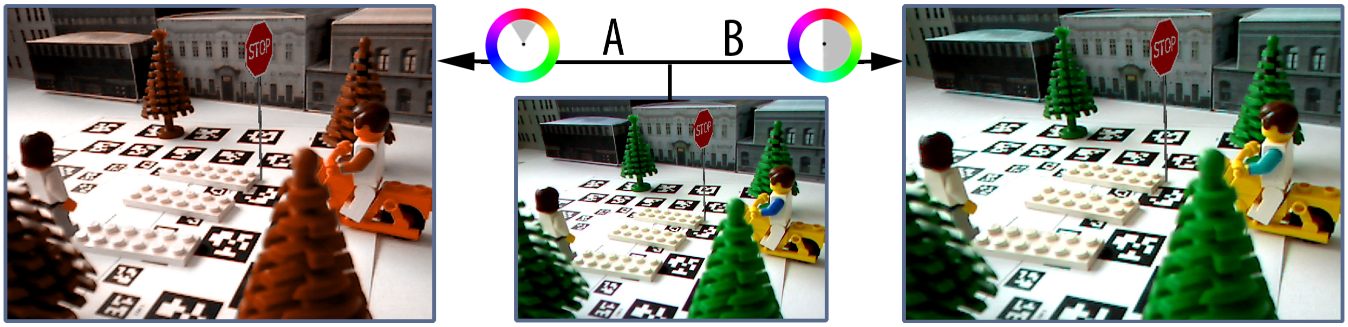

Figure 1. Histogram scaling versus template search restriction. (A) Restricting the template search to only constrained elements may heavily change the appearance of the entire visualization. The environment in this example consists of a single constrained object (the red stop sign) which appears in a single color. By restricting the template search to only the hue values of the stop sign, the hue values of the entire environment will shift towards red. (B) By scaling the histogram at hue values of constrained pixels we are able to compute the template and its orientation taking into account the remaining part of the imagery. This technique is able to harmonize the environment using fewer modifications. Notice the slight changes of hue values on the formerly blue arm of the LEGO figure riding the motor-bike.

This will lead to an increased cognitive load, making the AR application less valuable to the user.

4.1 Color constraints

In AR visualizations, we can identify four different types of color-to-object assignments. If no semantic meaning is encoded in an object's color, we are free to change its hue during harmonization. However, other objects have to be presented in exactly a given color. In the remainder we refer to these color constraints as *hard constraints*.

Besides *hard-* and *non-constrained* colorizations of the objects within an AR environment, we find objects, which can be presented using any color within a given interval. For example, trees appear in different colors, ranging from a green over brown to a red. However, blue or purple trees do not exist in real environments, restricting the AR display to colorize trees using only hue values out of a pre-defined range. Since we are not allowed to use all possible colors, but are still free to choose from a range of colors, we refer to these color assignments as *continuous soft constraints*.

A variation of continuous soft constrained pixels can be found on objects, which appear in a few different colors. For such objects, only a few pre-defined hues are allowed, instead of a continuous range of colors. Such *discrete soft constraint* are often used in AR advertisement applications. For example, an AR application may present a virtual prototype of a car within a real world environment. Since such an advertisement in AR attaches great importance to the original design and consequently the original color of the car, the AR display is not allowed to change the colors of the presented virtual car. However, cars are often designed in different color-schemes, which allow a few other designs, from which the AR application can choose during harmonization of the visualization.

4.2 Constrained color harmonization

By restricting the input of the template selection, we are able to harmonize unconstrained colors towards constrained ones, rather than globally harmonizing the colors. However, heavy modifications may be introduced in order to adapt the colors of the unconstrained parts of the environment. This is especially problematic if only a few different colors appear on constrained objects. For example, the red stop sign shown in Figure 1 is the only constrained element. Since the stop sign appears in only a single color, the selected harmonization template will cause the entire environment to shift its colors towards the red of the stop sign (Figure 1A).

In order to balance the amount of changes needed to adapt unconstrained colors and the impact of constrained elements, we allow computing the template from the entire imagery with an emphasis on the constrained parts (Figure 1B). To realize this, we introduced a parameter, which weights the hue values of constrained pixels in the hue histogram. Since the hue histogram is used to compute the harmonization template and its orientations, the weighting allows adjusting the importance of constrained elements to the final rendering. A high weight will select a template, which covers the hue values of the constrained portions of the scene, while a low weight respects unconstrained scene content more.

5 Future Work

We believe that color harmonization is an important component of any AR visualizations and thus should be considered by any AR rendering framework. In the future, we will look into measuring the actual impact of our image modifications to the user. Since we believe that the impact of a color harmonized AR environment is highly dependent on the goal of the AR application, we will evaluate its importance within different AR scenarios with different ratios between important and unimportant color assignments.

In addition, future work on harmonizing color combinations within AR environments should include more automatic segmentations as well as object labeling. This will reduce the effort to prepare virtual and real world content and will allow a robust harmonization even in completely unknown environments.

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