Edge-driven color constancy

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Citation for published version (APA):
Gijsenij, A. (2010). Edge-driven color constancy

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Chapter 7

Summary and Conclusions

7.1 Summary

In this thesis, methods are explored to obtain color constancy, exploiting spatial relations in addition to pixel values alone. The results obtained in the thesis are discussed per chapter in the following paragraphs:

Chapter 2: Edge-based Color Constancy. In this chapter, we have investigated a first attempt to incorporate spatial relations between pixel values, rather than pixel values alone. We propose a new hypothesis for color constancy, called the Grey-Edge hypothesis, which assumes that the average edge difference in a scene is achromatic. Based on this hypothesis, we propose an algorithm for color constancy, which is based on the higher order structure of images. Furthermore, a framework of color constancy based on low-level image features is proposed, which includes the known algorithms (Grey-World, White-Patch, Shades-of-Grey) as well as the newly proposed Grey-Edge and higher-order Grey-Edge algorithms. The quality of the various instantiations of the framework is tested on two data sets of images recording objects under a large number of different light sources. The experimental results show that the newly proposed simple color constancy algorithms obtain similar results as more complex state-of-the-art color constancy methods. Furthermore, the results show that color constancy based on the Grey-Edge hypothesis obtains better results than those obtained with the Grey-World method for real-world images.

Chapter 3: Generalized Gamut Mapping using Image Derivative Structures. This chapter extends the more sophisticated gamut mapping algorithm to include the statistical nature of images. We show that the proposed gamut mapping framework is able to include any linear filter output. The main focus in this chapter is on the local n-jet describing the derivative structure of an image. It is shown that derivatives have the advantage over pixel values to be invariant to disturbing effects (i.e. deviations of the diagonal model) such as saturated colors and diffuse light. Further, as the n-jet based gamut mapping has the ability to use more information than pixel values alone, the combination of these algorithms are more stable than the regular gamut mapping algorithm. Different methods of combining are proposed. Based on theoretical and experimental results conducted on large scale data sets of hyper spectral, laboratory and real-world scenes, it can be derived that (1) in case of deviations of the diagonal model, the derivative-based approach outperforms the pixel-based gamut mapping, (2) state-of-the-art algorithms are outperformed by the n-jet based gamut mapping, (3) the combination of the different n-jet based gamut mappings provide more stable solutions, and (4) the fusion strategy based on the intersection of feasible sets provides better color constancy results than the union of the feasible sets.

Chapter 4: Improving Color Constancy using Photometric Edge Classification. The edge-based color constancy methods that have been discussed so far does not distinguish between different edge types. In real-world images, different edge types exist such as material, shadow and highlight edges. These different edge types may have a distinctive influence on the performance of the illuminant estimation. Therefore, in this chapter, an extensive analysis is
provided of different edge types on the performance of edge-based color constancy methods. First, an edge-based taxonomy is presented classifying edge types based on their photometric properties (e.g. material, shadow-geometry and highlights). Then, a performance evaluation of edge-based color constancy is provided using these different edge types. From this performance evaluation it is derived that specular and shadow edge types are more valuable than material edges for the estimation of the illuminant. To this end, the weighted Grey-Edge algorithm is proposed in which these edge types are more emphasized for the estimation of the illuminant. From the experimental results, it is shown that the proposed weighted Grey-Edge algorithm based on highlights, when applied to linear images, results in an improvement varying from 14% to 41% with respect to the regular Grey-Edge. However, the detection of specular edges, in contrast to the detection of shadow edges, is negatively affected by gamma-correction. Therefore, for non-linear images, all current state-of-the-art methods, including pixel-based and edge-based methods, are outperformed by the proposed weighted Grey-Edge algorithm using shadow edges, resulting in an improvement of 9% with respect to the current best-performing algorithm.

Chapter 5: Color Constancy using Natural Image Statistics and Scene Semantics. Existing color constancy methods are all based on specific assumptions such as the spatial and spectral characteristics of images. As a consequence, no algorithm can be considered as universal. However, with the large variety of available methods, the question is how to select the method that performs best for a specific image. To achieve selection and combining of color constancy algorithms, in this chapter, natural image statistics are used to identify the most important characteristics of color images. Then, based on these image characteristics, the proper color constancy algorithm (or best combination of algorithms) is selected for a specific image. To capture the image characteristics, the Weibull parameterization (e.g. grain size and contrast) is used. It is shown that the Weibull parameterization is related to the image attributes to which the used color constancy methods are sensitive to. A MoG-classifier is used to learn the correlation and weighting between the Weibull-parameters and the image attributes (number of edges, amount of texture and SNR). The output of the classifier is the selection of the best performing color constancy method for a certain image. Experimental results show a large improvement over state-of-the-art single algorithms. On a data set consisting of more than 11,000 images, an increase in color constancy performance up to 20% (median angular error) can be obtained compared to the best-performing single algorithm. Further, it is shown that for certain scene categories, one specific color constancy algorithm can be used instead of the classifier considering several algorithms.

Chapter 6: A Perceptual Analysis of Distance Measures for Color Constancy Algorithms. The main goal of this chapter is to analyze the correlation between several performance measures and the quality, obtained using psychophysical experiments, of the output images generated by various color constancy algorithms. As color constancy algorithms are often evaluated using a distance measure that is based on mathematical principles, like the angular error, it is unknown whether these distance measures correlate to human vision. From the results that are obtained in this chapter, it can be concluded that the often used angular error correlates with human perception to a large degree, but still leaves room for improvement. Subsequent issues that have been addressed in this chapter are the distribution of performance measures, suggesting additional and alternative information that can be provided to summarize the performance of a large set of images, and the perceptual significance of obtained improvements, i.e. the improvement that should be obtained before the difference becomes noticeable to a human observer.

7.2 Conclusions

In this thesis we have proposed methods and techniques to improve the accuracy of color constancy algorithms. The first objective of this thesis is improve existing color constancy algorithms by using spatial relations between pixels rather than absolute pixel values. To this end, the Grey-Edge algorithm is proposed, as well as the generalized gamut mapping using derivative structures. These algorithms use spatial information by processing derivatives of images. We have shown that the derivative-based approaches can outperform the traditional techniques in some situations,
while pixel-based methods are favored in others. Furthermore, edges have the advantage over pixel values that they can automatically be classified into different edge types without prior knowledge about the scene. Therefore, we have analyzed the effect of different edge types on the performance of edge based color constancy. We can conclude that using specular and shadow edges, if detected accurately, can significantly improve the performance of edge-based color constancy.

The second objective of this thesis is to analyze color constancy methods, with the intention to combine the algorithms dynamically, based on image content. It was shown in chapters 2–4 that edge-based algorithms are preferred in some situations, while pixel-based methods perform better on other images. In chapter 5 we have shown that the performance of color constancy algorithms can be predicted by observing natural image statistics in the form of edge distributions. The Weibull-parameters of an image are indicative for the type of information that is present in an image, and consequently, they are indicative for the performance that can be obtained using an specific type of color constancy algorithm (e.g. pixel-based or edge-based). A new algorithm was designed that is able to determine the optimal color constancy algorithm for a specific type of image, and this algorithm was shown to outperform any existing algorithm.

Finally, the third objective of this thesis is to evaluate color constancy performance using a performance measure that correlates with human vision as much as possible. We have shown that the often used angular error has a high correlation with human perception. However, a disadvantage of this measure is the fact that it does not take the direction of the error into account. A higher correlation can be obtained by weighting the deviations in the separate color channels differently. The optimal weighting coefficients are dependent on the images that are used to evaluate the color constancy methods on. Further, we have shown that an improvement lower than approximately 5 – 6% is not perceived as improvement by human observers.