Habilitation Thesis: **Image Enhancing Techniques Based on Fusion**

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Abstract:

The present habilitation thesis summarizes the research contributions of the candidate obtained between 2011 (when the candidate obtained the PhD) to this date.

The most significant research activity and the obtained results are presented structured in several parts that represent original contributions in the field of image processing and computational photography: image dehazing (day-time single image dehazing, night-time single image dehazing, dehazing evaluation dataset), underwater images enhancement, image decolorisation and single scale fusion technique for effectively merging images.

I. Image dehazing deals with the problem of enhancing the visibility in terms of color and details for images degraded by haze. In outdoor environments, haze phenomena appears when the light reflected from object surfaces is scattered due to the impurities of the aerosol, or due to the presence of fog and haze. The yielding hazy images are characterized by poor contrast, lower saturation and additional noise.

a.Day-time image dehazing. Firstly, we describe a novel single image strategy that demonstrates to accurately dehaze images by only taking as input the original degraded information. Our approach is built on a fusion strategy and derives two inputs from the original image. These inputs are weighted by three normalized weight maps and finally blended in a multi-scale fashion that avoids introducing artifacts. The method is fast being straightforward to implement and shows to outperform the related operators. Our approach performs an effective per-pixel computation, that reduces the amount of artifacts compared with the patch-based methods.

b.Night-time image dehazing. To deal with the problem of night-time hazy scenes, we introduce a novel modality to compute the airlight component while accounting for the non-uniform illumination presents in nighttime scenes. Unlike the day-time dehazing strategies that estimates a constant atmospheric light over the entire image, we estimate this by accounting the local values and patches of varying sizes. Our work combines the advantages of using the physical model and uses noise and artifacts reduction ability by employing the fusion strategy.

c.Image dehazing evaluation dataset. We proposed a dataset that contains 1400+ pairs of images with ground truth reference images and hazy images of the same scene. Our dataset, called D-HAZY, is built on the Middlebury and NYU Depth datasets that provide images of various scenes and their corresponding depth maps. Based on the depth information and using the physical model of a hazy medium we derive a corresponding hazy scene with high fidelity. Using D-HAZY dataset, we perform a comprehensive quantitative evaluation of the recent techniques.

II. Enhancing Underwater Images. We describe an effective technique that is able to enhance underwater images. Our strategy derives the inputs and the weight measures only from the degraded version of the image. In order to overcome the limitations of the underwater medium we define two inputs that represent color corrected and contrast enhanced versions of the original underwater image/frame, but also four weight maps that aim to increase the visibility of the distant objects degraded due to the medium scattering and absorption. The enhanced images and videos are characterized by reduced noise level, better exposedness of the dark regions, improved global contrast while the finest details and edges are enhanced significantly. In addition, the utility of our enhancing technique is proved for several challenging applications (image matching, segmentation, etc.).

Moreover, for highly scattered underwater scenes, we introduce a novel approach. Following the optical underwater model, we first compute the back-scattered light by searching for the brightest location along each image patch. By simply applying the optical model using our local estimate of the back-scattered light, we are able to obtain a good degree of visual restoration, even on in extreme underwater scenes. Our results demonstrates that our proposed solution can deal with the difficult situations where most of the existing enhancing underwater approaches fail, such as when using artificial illumination at higher depths and high turbidity.

III. Image decolorization (color-to-grayscale) deals with the problem of converting a color image (with three-RGB-channels) into a single channel image version. Often, the standard decolorization conversion is simply employed as the luminance channel of different color spaces. However, this simple global mapping disregards important chromatic information and therefore, in many cases, the output does not preserve the original appearance. Our grayscale transformation, designed in RGB color space and takes as individual inputs the three color channels (R, G, B). Our technique is guided by two weight maps that transfer in the final result the most significant information of each derived input (RGB color channels). In order to minimize artifacts introduced by the weight maps, our approach is designed in a multi-scale fashion.

IV. Single scale image fusion. Image fusion plays an important role in a wide range of imaging applications. One of the main problem for all the fusion algorithms is related with the ability to use it for real-time applications. In our recent work we introduced a single-scale fusion strategy that is more computational effective for blending multiple-sources images and produces similar results in comparison with the traditional multi-scale image fusion technique (MSF). Interestingly, our single-scale expression obtained from the multi-scale approximation also provides insightful cues regarding how the MSF process manipulates weights and image features to compute a visually pleasant outcome. The impact is significant, since this approach facilitates to process high resolution images more effectively.