Fusion of Visual and Near Infrared Images in Embedded Platforms
ECE496 Senior Thesis
Literature Review

Gustavo Fonseca, gvf3@illinois.edu

1 Introduction

This report summaries the main papers that attempt to fuse Visual (VIS) and and Near Infrared (NIR) images for various purposes. See the problem statement for further clarification about what I plan to use this research for.

2 Literature Review

2.1 Enhancing Photographs with Near Infrared Images, Zhang, 2008 [1]

The authors in [1] proposed an algorithm to fuse VIS and NIR images using the Haar Wavelet to extract texture and contrast from the images to enhance clarity of the output image.

It is worth noting that they produced their own images using a hot mirror, a mirror that only reflects IR light and lets all visual light pass through. Thus, they were able to get a grayscale NIR image with the exact same orientation and alignment as the VIS Image.

When extracting the contrast of both images, the authors experimented with global histogram matching and gradient techniques. It is worth noting that the results may be improved with local histogram matching with the tradeoff of computational complexity.

When extracting the texture of the images, the authors used the Haar wavelet, which inherently preserve texture information.

Regarding results, the paper does not provide any objective measures to compare their results, nor do they use a common dataset with their algorithm. Regardless, the samples provided did show a significant increase in visual clarity in darker regions of the VIS image.

2.2 Color outdoor image enhancement by V-NIR fusion and weighted luminance, Herrera, 2019 [2]

The main approach used by the authors in [2] to fuse VIS and NIR images is a pixel-by-pixel technique. More specifically, the new image is a weighted average of the VIS and NIR images. The authors use several transforms between RGB and $l\alpha\beta$ color spaces to determine the weights for each pixel. The main goal of this technique is to enhance the areas of the VIS image that lack information in the color space, such as shadows or fog.

It is worth noting that the authors assumed that the images were perfectly aligned and had the same dimensions.

The authors evaluated the algorithms performance with 2 metrics: Restore Edges and Colorfulness, comparing this method with other approaches such as [1] and [3]. To do this, they used the dataset [4].

2.3 RGB-NIR Scene Dataset [4]

Researchers from EPFL have created a dataset of VIS and NIR images. There are 477 images in 9 categories, including indoor and outdoor photos. The images are perfectly aligned and have the same dimensions (1024×768). This database is open source and is available to use free of charge.

It is worth noting that the images were taken with 2 professional cameras: one that only takes in VIS images, and the other capable of capturing the whole specturm up to the NIR band. To isolate the NIR band, they used a 750 nm cutoff filter on the NIR images.

2.4 Near-Infrared Guided Color Image Dehazing, Feng, 2013 [5]

The authors in [5] focuses on the problem of dehazing an image, which is different than providing more information to darker areas of an image like in [1].

The authors use a model to estimate the hazing within an image based on the "transmission", which is a value per pixel from 0 to 1, that represents the mixture of the original image and airlight, such as fog or clouds. To estimate airlight color, the authors proposed to explore the correlation within local patches of the image, using NIR images to select the best local patch.

The authors then used an optimization and Bayesian approach to estimate the transmission per pixel.

The authors only did qualitative evaluation of their proposed model, only comparing a few images with other dehazing methods.

2.5 A novel approach for image dehazing combining visible-NIR images, Vanmali, 2015 [5]

Similar to [5], the authors in [3] focuses on the problem of dehazing an image. They also use the same transmission and airlight model as [5].

This paper uses 8 images from [4] to do their evaluation, comparing against various other methods such as [1].

Unlike [5], they used 3 quantitative methods: quality assessment model proposed by [6], Anisotropic Quality Index (AQI) proposed by [7], and a new method created by the authors themselves that looks at the average local entropy of the image.

2.6 Color image dehazing using the near-infrared, Schaul, 2009 [8]

The authors in [8] also consider the problem of using VIS and NIR images to dehaze a scene. The authors used a mutliresolution analysis, called Weighted Least Squared (WLS). This method is similar to wavelets, as it decomposes the image into various layers of different resolutions. As noted by the authors, this method contains redundant information that wavelets would not contain.

The authors only provided qualitative results in a handful of images.

It is important to note that this is one of the first papers to attempt to fuse VIS and NIR Images.

2.7 Automatic and accurate shadow detection using near-infrared information, Rufenacht, 2013 [9]

The authors in [9] use VIS and NIR image fusion to try to detect shadows within a scene. This paper does a pixel-by-pixel approach of comparison between the two images. NIR images are helpful for shadow detection as the color of objects is less pronounced, thus, it is easier to differentiate dark objects from shadows.

This paper illustrates some of the different use cases for the fusion of VIS and NIR images, other than dehazing or image enhancement.

2.8 Reflection removal with NIR and RGB image feature fusion, Hong, 2023 [10]

The authors in [10] used VIS and NIR images to train a Deep Learning Neural network to remove reflections from visual images.

The authors highlight that reflections are mostly absent from NIR images. On the other hand, NIR images may lack texture information if not enough NIR light was reflected from the object. The authors call this problem, "Vanishing Texture".

The authors also made use of active NIR while collecting training data. Active NIR refers to using an external Infrared light source such as an LED to provide infrared light when the sun is not present. This is very helpful during indoor scenarios, as not much sunlight is present.

References

[1] X. Zhang, T. Sim, and X. Miao, "Enhancing photographs with near infrared images," in *2008 IEEE conference on computer vision and pattern recognition*. IEEE, 2008, pp. 1–8.

[2] M. A. Herrera-Arellano, H. Peregrina-Barreto, and I. Terol-Villalobos, "Color outdoor image enhancement by v-nir fusion and weighted luminance," in *2019 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC)*. IEEE, 2019, pp. 1–6.

[3] A. V. Vanmali, S. G. Kelkar, and V. M. Gadre, "A novel approach for image dehazing combining visible-nir images," in *2015 Fifth national conference on computer vision, pattern recognition, image processing and graphics (NCVPRIPG)*. IEEE, 2015, pp. 1–4.

[4] E. IVRL, "RGB-NIR Scene Dataset," https://www.epfl.ch/labs/ivrl/research/downloads/rgb-nir-scene-dataset/, accessed: 2024-10-10.

[5] C. Feng, S. Zhuo, X. Zhang, L. Shen, and S. Süsstrunk, "Near-infrared guided color image dehazing," in *2013 IEEE international conference on image processing*. IEEE, 2013, pp. 2363–2367.

[6] Z. Wang, H. R. Sheikh, and A. C. Bovik, "No-reference perceptual quality assessment of jpeg compressed images," in *Proceedings. International conference on image processing*, vol. 1. IEEE, 2002, pp. I–I.

[7] S. Gabarda and G. Cristóbal, "Blind image quality assessment through anisotropy," *JOSA A*, vol. 24, no. 12, pp. B42–B51, 2007.

[8] L. Schaul, C. Fredembach, and S. Süsstrunk, "Color image dehazing using the near-infrared," in *2009 16th IEEE International Conference on Image Processing (ICIP)*. IEEE, 2009, pp. 1629–1632.

[9] D. Rüfenacht, C. Fredembach, and S. Süsstrunk, "Automatic and accurate shadow detection using near-infrared information," *IEEE transactions on pattern analysis and machine intelligence*, vol. 36, no. 8, pp. 1672–1678, 2013.

[10] Y. Hong, Y. Lyu, S. Li, G. Cao, and B. Shi, "Reflection removal with nir and rgb image feature fusion," *IEEE Transactions on Multimedia*, vol. 25, pp. 7101–7112, 2023.