Advances in Digital Imaging and Computer Vision

Review Paper on Histogram Matching / Histogram Specification

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# Abstract

Enough research in the Image Processing Literature on Intensity Normalization focuses on matching histograms and other histogram mapping methods, with some emphasis on normalizing images to provide biologically interpretable units. During the processing of MRI, various scanners or criteria will be used for scanning various subjects, or the same subject at a different time, which could result in broad differences in intensity. This variability in intensity would substantially impair the efficiency of subsequent MRI processing and population analysis, such as imaging segmentation and calculation of tissue volume. Over the years, the histogram specification has been widely used in optical image processing. Primarily used as an image enhancement tool, techniques such as histogram equalization (HE) can create a strong contrast with approximately no effort in terms of inputs to the algorithm or computational time needed.

# Introduction

In image processing histogram matching, or histogram specification is the modification of an image such that its histogram suits the given histogram. The recognized histogram equalization technique is a unique case in which the defined histogram is uniformly distributed. Potentially, someone can use histogram matching for controlling detector reactions, as a relative calibration detector technique. It may be used to normalize two images, where the images were captured at the same local lighting at the same location but by different sensors, ambient conditions or global lighting. Histogram equalization is a widely used worldwide grayscale image enhancement process, where the grayscale value is uniformly spread on the basis of the histogram's accumulated density function [1][2][3].

Histogram equalization and histogram normalization methods can also be used to change the average brightness of the images. These types of techniques primarily extend the spectrum of the gray value in the histogram without changing its intensity. Techniques like this not only boost the overall image and increase its clarity, but the comparison among tumors and other tissues is not dramatically improved. The histogram specification (HS) will alter the frequency of the grayscale variables and improve the local brightness, but mostly changes the local brightness as per the frame of reference. Mainly the frame of reference is selected by a radiologist, but because it is time consuming there have been attempts for automating it[1][2][3].

# State of the art

An unplaced problem, the exact histogram specification, is solved according to F. Balado et al [1]. This approach is based on the concept of an ordering relationship, which induces nearly strict ordering on pixels of images. Theoretical and experimental, findings are given regarding the nature of the strict ordering. If ordering is accomplished, pixels are automatically divided into classes and allocated to the gray level desired. The proposed strict ordering is consistent with the natural one and is therefore usually maintained for the information quality of the pictures.

The immediate implementation of the new methodology shall replace the classical histogram equalization and specification. The proposed approach enables for example, direct verification of image enhancement, by the definition of the histogram specification of human visual models. The exact histogram specification enables very precise normalization of the image, which is of general interest to processing images.

The proposed definition of order is general. This is not limited to a single filter bank or set of gray levels. Gaussian filters or combinations of Gaussians and Laplacians, for example, it may produce an order that is best suited to the human visual system. Using a bank of gradient or Laplacian filters, allows for the ordering of possible contour pixels and thus, a new class of edge detectors.

To conclude, apart from the exact histogram specification, the strict ordering proposed here is a fruitful idea which will see many interesting applications once it is available to the image processing community[1].

A. Bevilacqua and P. Azzari et al [2] developed an algorithm to follow the requirements of the histogram specification, namely the creation of an image whose histogram exactly matches the target histogram, regardless of the source image. The algorithm describes a novel process for doing accurate histogram equalization by creating a flat histogram.

Typically mapping between the initial histogram and the flattened target is carried out by means of functions that may include 1-d features (gray levels) or n-d features, where various metrics (e.g. neighborhood average) make the discrepancy between pixels with the same values for the remaining (n1)-d features. The method removes the idea of mapping function and replaces it with the theory of one-to-many mapping. This helps one to assign pixels with the same value for one attribute in the source histogram to different gray level values. Established indicators were used to assess the time and efficiency of our process. They tried to use only 1-d of the source histogram function.

This makes their algorithms one of the fastest and strongest, as opposed to other algorithm that has been the reference in literature so far. Therefore, they have developed a method that always achieves a flat histogram where other methods fail to do so [2].

X. Sun *et al* [3] has exhibited the efficacy of the histogram normalization approach through multiscanner MRI data in the presence of different magnetic field strengths. He investigated the influence of intensity normalization on the conduct of tissue pressure in T1 MRIs. Their brain MRI histogram normalization algorithm will normalize scans of the same weighting but obtained on different scanners or with different acquisition parameters. Compared to other such techniques he improved consistency and homogeneous intensities for MR brain scans following normalization.

The ability of the normalization protocol to adjust global intensity variation was shown by three evaluation techniques. During MR image processing, various devices or configurations will be used for scanning different subjects, or the same subject at a different time, which may result in broad differences in intensity between scans. With this method he always ensure a high-resolution image, that will act as a reference image to keep the accuracy of the uniform images high. The histogram normalization process can be used in a number of MRI sequences and imaging components.

Normalization has been applied to the development of a brain prototype for young Chinese adults. These findings showed, that the normalization of the intensity could achieve improved performance of the image analysis, without spatial registration. Pressure standardization is a crucial step in the process of building a population prototype and has a positive effect on the final sample outcome [3].

# Methodology – Implementation

After our research in the state-of-the-art chapter, but also in the literature that exists in various databases, we tried to implement some techniques. The first we tried was F. Balado [1] methodology, where we also found the coorisponding code on github. We made a few changes, not to the effectivness of it, but its overall stracture. Therfore, we applied it to some data that was given to us and the results will be demonstrated in the Result-Discusion chapter. In this implementation you will not only see the results of the Exact Histogram Specification, but we can also see a Default Specification that we where taught in the classroom. That way we can refere to other results and compare them to each other. We explaind briefly what F. Balado did in his paper in the previous chapter, now the code we apply for it, is taking the histogram of the reference image and after through a method, it also takes the target image and aplies the exact histogram match. There are also two possibilities, incase the image is at grey values or its colorful.

To accomplish this assignment,we started a search through the internet, and we found several different techniques for histogram matching, or histogram specification and we decided to use one of them. But we made some changes to its internal code, so it would meet our needs. Thus, this implementation is for histogram matching and we can further compare the results with the previous implementation. This method computes the histogram and the Cumulative Distribution Function or CDF of the images and afterwards we proceed with a algorithm to match those variables and compose our new image and its histogram.

# Results – Discussion

In this chapter we will present some results of the two techniques that we used. The data was given to us for this assignment and we applied some of them to our methodologies. In Figure 1 we can see the results that from some data by having some similar images. We can see our target image and the reference image, also we can see the exact histogram specification that was made and the default histogram matching along with their matching histograms. In Figure 2 we can view the results of our other implementation which shows as our original image the refence image with their histograms and their CDF’s and the image that is matched to the reference histogram with its histogram.

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| Figure 1 Exact HS & Default HM | Figure 2 ΗΜ |

In figures 3,4,5,6 we can also see some other implementations with different data. In all these cases the image of the target is quite similar to the reference one. In most cases the results are obvious enough and we can tell what’s the difference and how much the implementations have been successful.

Exact HS & Default HM

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| Figure 3 Exact HS & Default HM | Figure 4 HM |
| Figure 5 Exact HS & Default HM | Figure 6 HM |

In figures 7,8,9,10 we can see that the target image (or original image) and the reference image are different between them. In figure 7 and figure 8 we can see that the results of the exact Histogram Specification and the Histogram Matching are dissimilar and that they produced different results.

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| Figure 7 Exact HS & Default HM | Figure 8 ΗΜ |

In Figure 9 & 10 below we can see that that the Exact HS has made the image white, so the specification didn’t go so well in contrast with the default and the HM of figure 10.

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| Figure 9 Exact HS & Default HM | Figure 10 ΗΜ |

So, to conclude we have different results from all three variations, the exact histogram specification the default histogram matching that was taught to as at a lecture and the histogram matching that we applied with some changes to a code we found. Sometimes we have similar results to the same data, other times there differences by having either better or not so good results.

# References

[1] F. Balado, “Exact Histogram Specification,” *ICASSP, IEEE Int. Conf. Acoust. Speech Signal Process. - Proc.*, vol. 2018-April, no. 5, pp. 1413–1417, 2018, doi: 10.1109/ICASSP.2018.8462242.

[2] A. Bevilacqua and P. Azzari, “A High Performance Exact Histogram Specification Algorithm Alessandro,” *Proc. - 14th Int. Conf. Image Anal. Process. ICIAP 2007*, no. October, pp. 623–628, 2007, doi: 10.1109/ICIAP.2007.4362846.

[3] X. Sun *et al.*, “Histogram-based normalization technique on human brain magnetic resonance images from different acquisitions,” *Biomed. Eng. Online*, vol. 14, no. 1, pp. 1–17, 2015, doi: 10.1186/s12938-015-0064-y.