Comp Eng 4TN4
Project 2: Restoration of Backlit Images

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<u>Degradation due to Backlighting</u>

Study the problem of image quality degradation due to backlighting, identify its root cause, and search on the internet for hardware and software solutions, and compare these solutions in terms of their advantages and disadvantages.

The problem of backlit images shows that poor quality images are taken when the background of the image is too bright and the foreground therefore does not get enough light, which results in the background being over-exposed and the foreground being underexposed. There are a few solutions available for restoring the image quality of backlit images.

Some techniques involve the hardware of the actual camera used for taking the pictures. Adjusting the metering of the camera is one way to adjust for backlit images. Metering is the way the camera evaluates how much light is in a scene. By default, most cameras meter the entire scene, however it is possible to change the metering to meter the foreground rather than the whole scene.

Some software techniques for image processing of backlit images include algorithms that take into consideration the human visual system. One such algorithm enhances backlit images by boosting the luminance of image areas below the perceptual threshold while preserving the contrast of the other image areas.

The image below shows an example of a backlit image that produces undesirable results in terms of the contrast between the foreground and background. This project explores techniques used to restore these images using Optimal Contrast Tone Mapping and image segmentation.

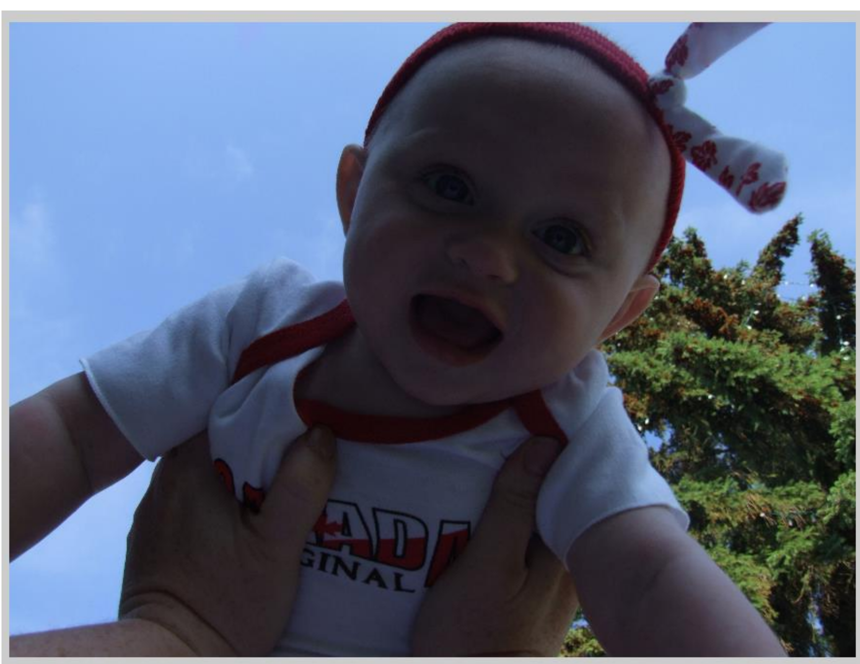


Figure 1: Example of backlit image – colour

Figure 2: Backlit image – gray-scale

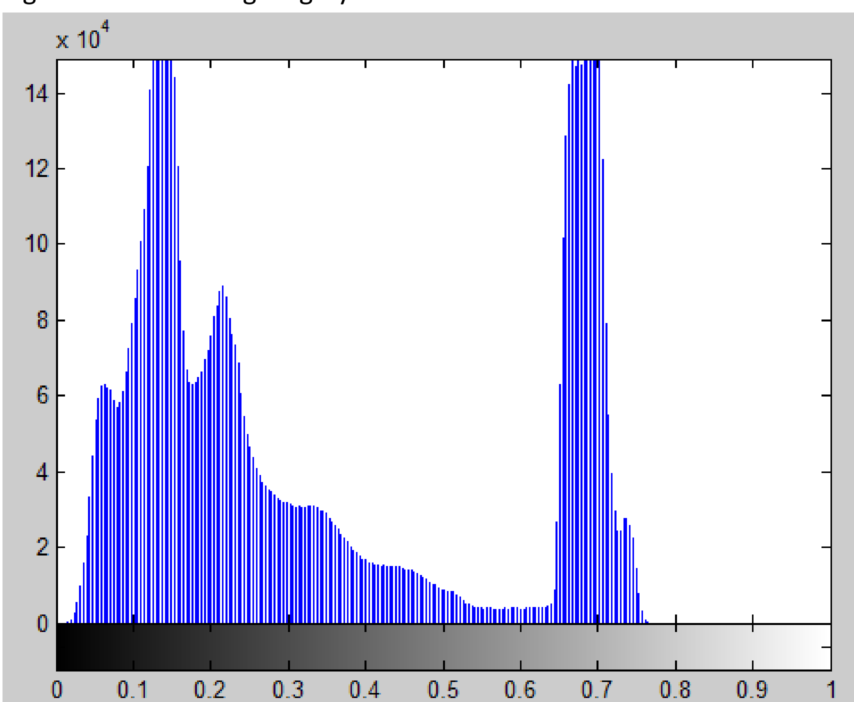


Figure 3: Histogram of original backlit image

Restoration of Backlit Images

A simple way of mitigating the backlit problem is to apply a transfer function that stretches the dynamic range of the dark end of the histogram. Histogram equalization is another possibility. Implement these techniques and comment on the limitations and weaknesses of these techniques, if any?

There are a few simple techniques that can be used to help enhance images that are backlit. Two such techniques include histogram equalization and applying a custom transfer function that can help to brighten the dark portions of the image.

Histogram equalization is an image enhancement technique that helps evenly distribute image intensities to enhance contrast. The output of the histogram equalization is shown below, as well as the histogram of the output.

As seen below, the use of histogram equalization for the purpose of restoring backlit images does not provide ideal results. While the image appears to have greater contrast, parts of the image appear to be over-exposed. The colour produced does not seem to be as natural and appears to be distorted, especially when the difference between the foreground and background is large.

Figure 4: Histogram equalization output image – gray-scale

Figure 5: Histogram equalization output image – colour

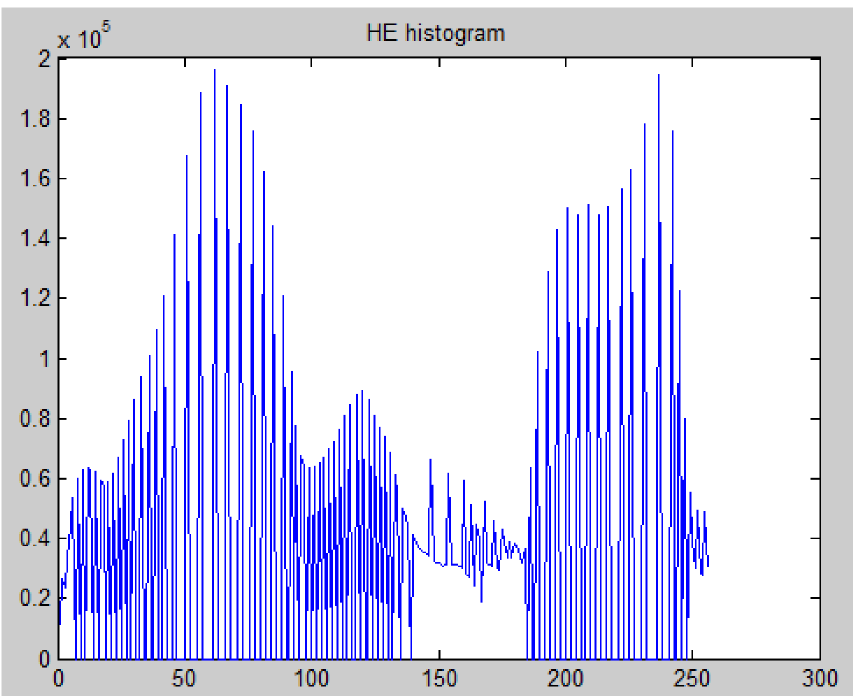


Figure 6: Histogram equalization – histogram of output

Another approach to solve this problem is to implement a custom transfer function to re-map the gray-scale values of the histogram. The example used for restoring backlit images is shown as the S-curve transfer function below. The idea is to make the darker portions of the image brighter (foreground) and reduce the brightness of the bright portions of the image (background).

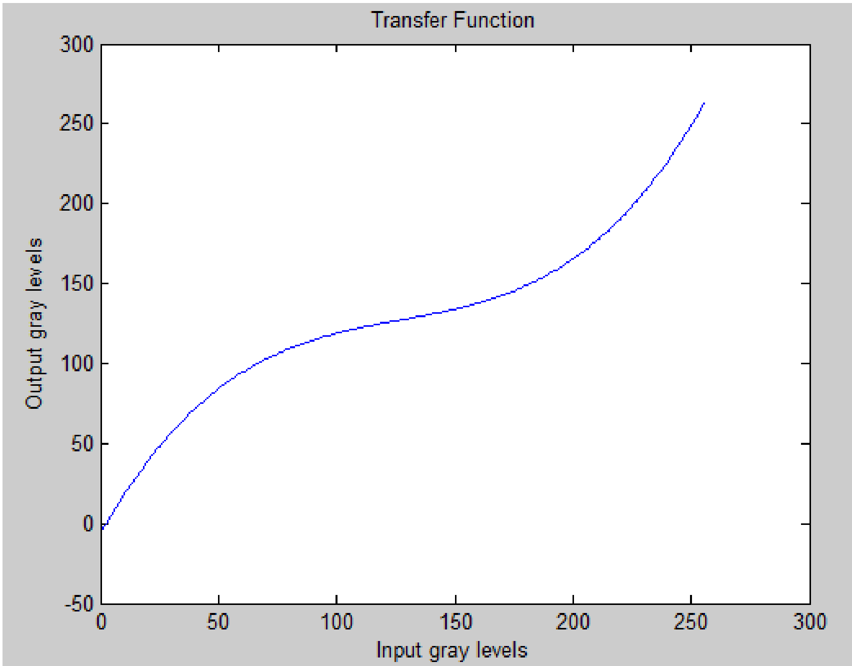


Figure 7: Transfer function

The following images show the results of using this transfer function for backlit images, as well as the histogram of the output. It can be seen that while the output that is produced is better than that of histogram equalization and is an improvement on the original image, there is still room for improvement in terms of increasing the brightness and contrast of the foreground in the image.

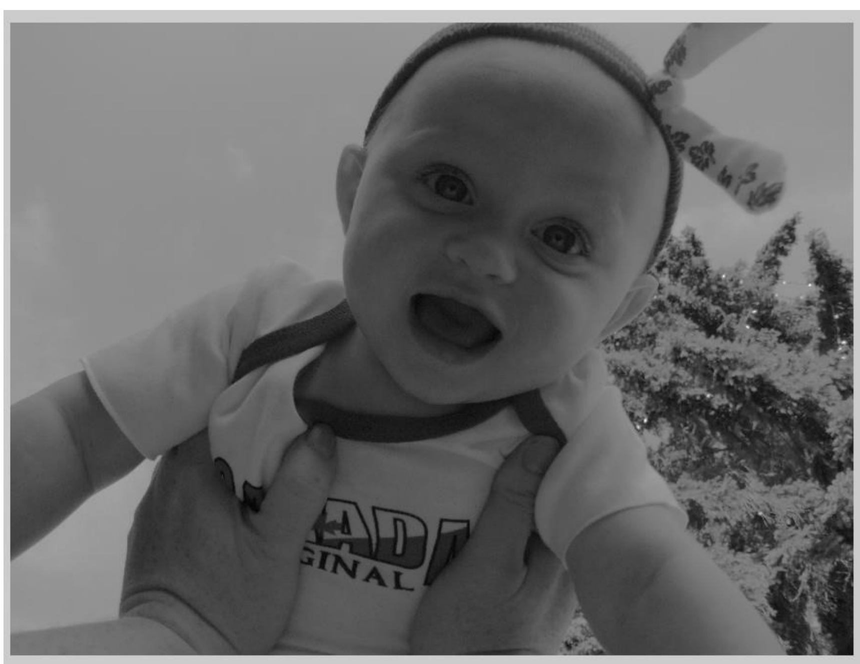


Figure 8: Transfer function enhanced image – gray-scale

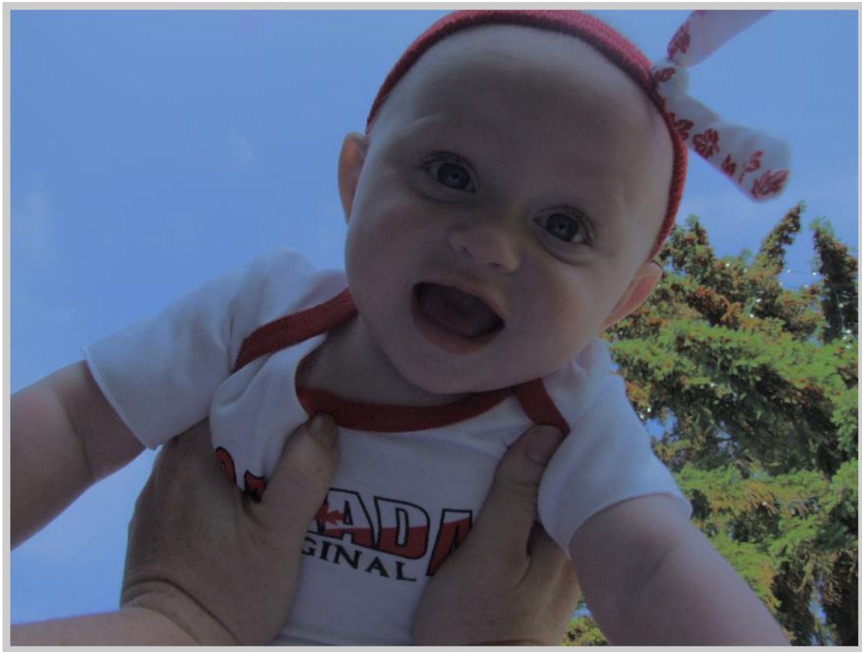


Figure 9: Transfer function enhanced image – colour

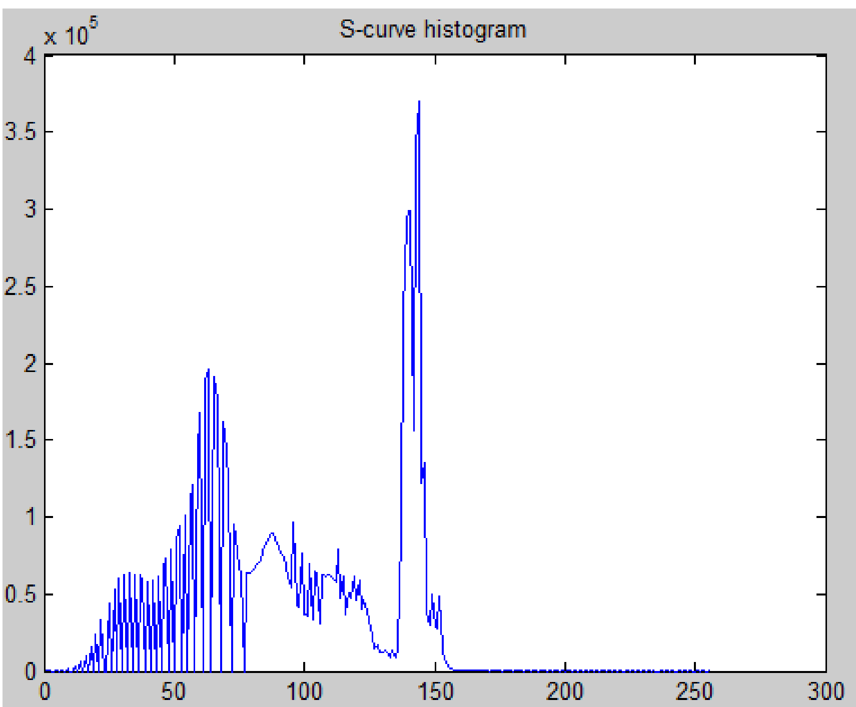


Figure 10: Histogram of transfer function enhanced image

Backlit Image Restoration using Image Segmentation and OCTM

You are required to design and implement your own algorithm(s) for backlit image restoration. Your design goal is to beat histogram equalization and simple transfer functions in image quality robustness. Your algorithm needs to restore colour backlit images.

In the algorithm that was designed for the purpose of restoring backlit images, the image was first segmented and then a contrast enhancement algorithm was applied. The image was segmented by assuming that backlit images are the superposition of two Gaussian distributions representing the foreground and the background of the image. Using this assumption, the threshold for segmentation can be obtained by finding the point at which the two Gaussian distributions intersect. Once the image is segmented, an optimal contrast tone mapping (OCTM) algorithm was applied separately to the two image segments. This ensures that the optimal parameters are chosen for the two segments that would allow for the best enhancement results.

The following images show the results of applying the image segmentation technique discussed in the separation of the background from the foreground.

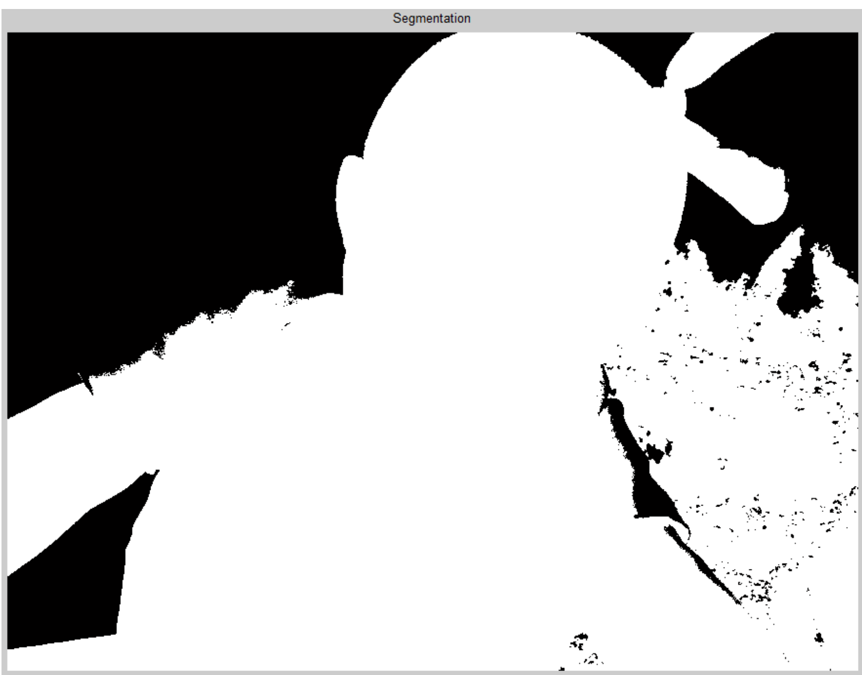


Figure 11: Binary representation of the segmentation

Figure 12: Over-exposed segment

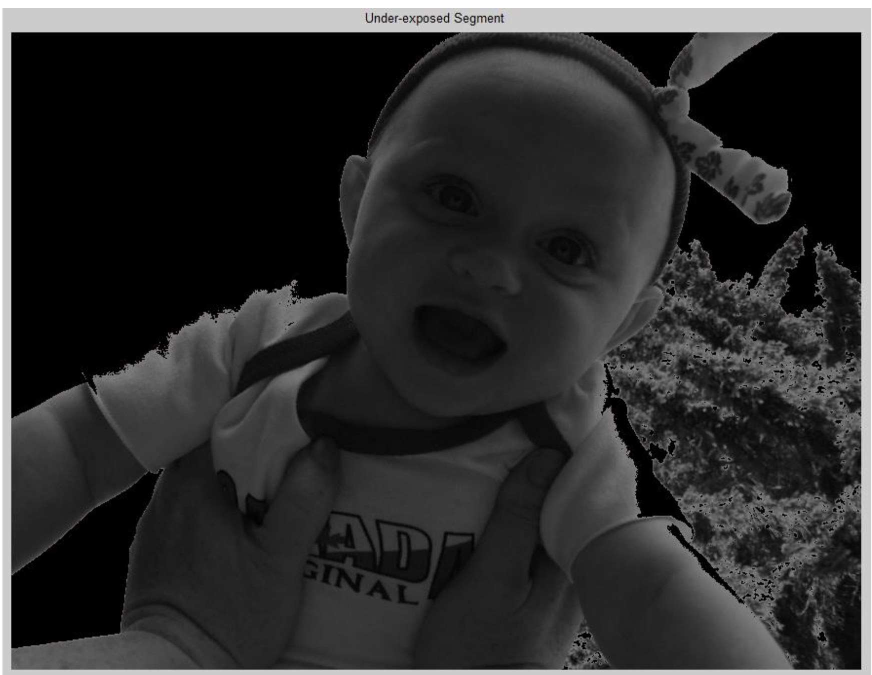


Figure 13: Under-exposed segment

Once the image appeared to have been segmented correctly, OCTM can be applied to the separate segments. This allows for the choice of the best parameters for the two segments since they have different properties in terms of their contrast. The following images show the OCTM enhanced image after appropriate parameters were chosen. The OCTM algorithm used was the same as that used in Project 1.

Figure 14: OCTM applied to over-exposed segment

Figure 15: OCTM applied to under-exposed segment

Figure 16: OCTM enhanced image including both segments – gray-scale

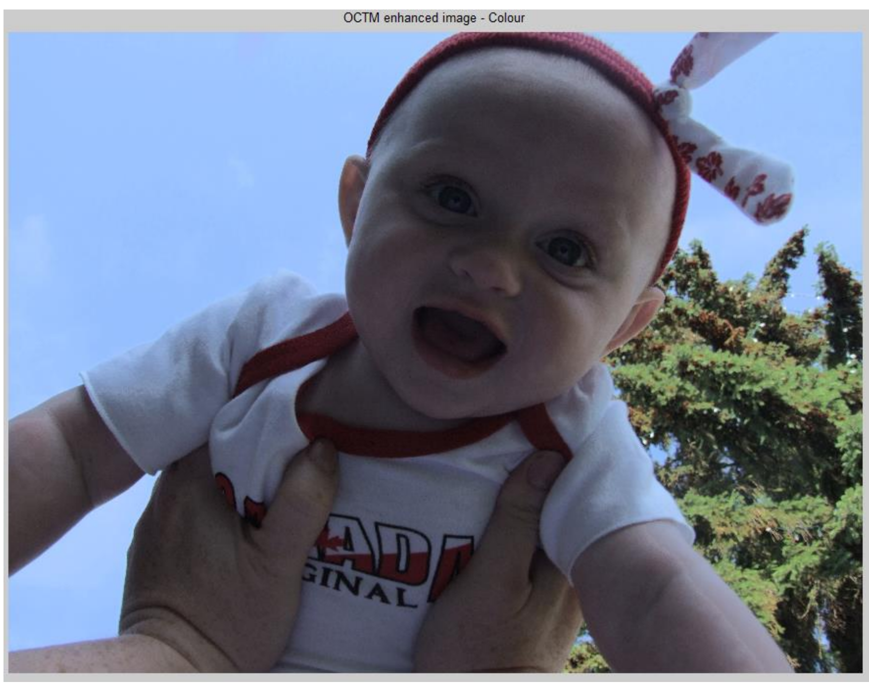


Figure 17: OCTM enhanced image including both segments – colour

Figure 17 shows the final output of the OCTM enhanced image for the backlit image. The results of this image show that there is good contrast in the foreground and background segments. This shows significant improvement from the original and some improvement in contrast compared to histogram equalization and the S-curve transfer function. However, it can be seen that there are some problems with using this technique, particularly in the segmentation. The algorithm may not be able to exactly separate the foreground from the background, as can be seen on the arm of the child in the image. This may be caused by the fact that the two Gaussian distributions of the foreground and background overlap and will therefore cause errors in the segmentation. Also, problems may arise when the histogram of the two segments do not look exactly like Gaussian distributions, which was the assumption that was made.

The following figures show a comparison between the different techniques that were used to be able to determine which technique produces the best results. The transfer functions and histograms of the images were also plotted below.

Figure 18: Comparison between all the different backlit image restoration techniques

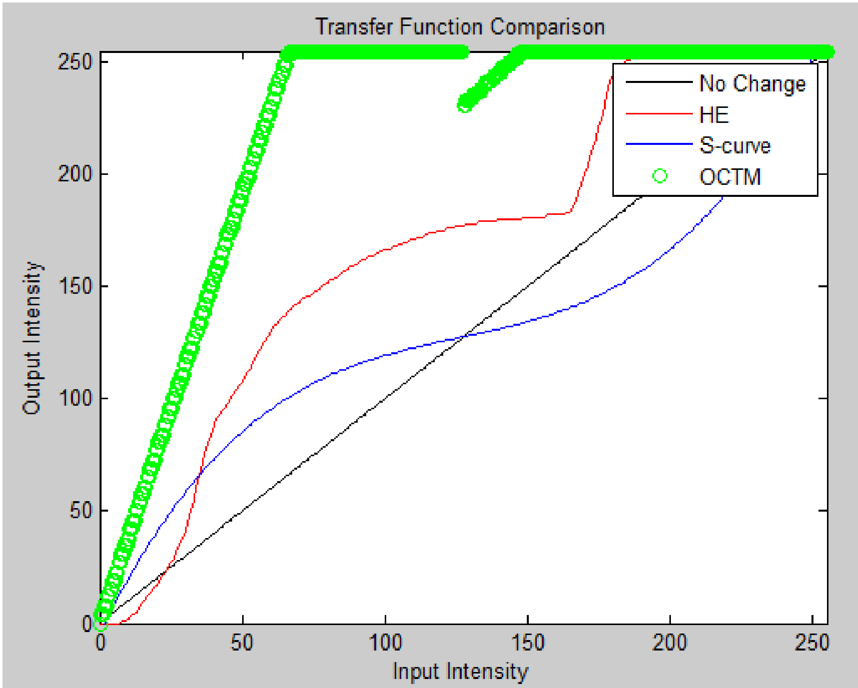


Figure 19: Transfer functions of the different techniques

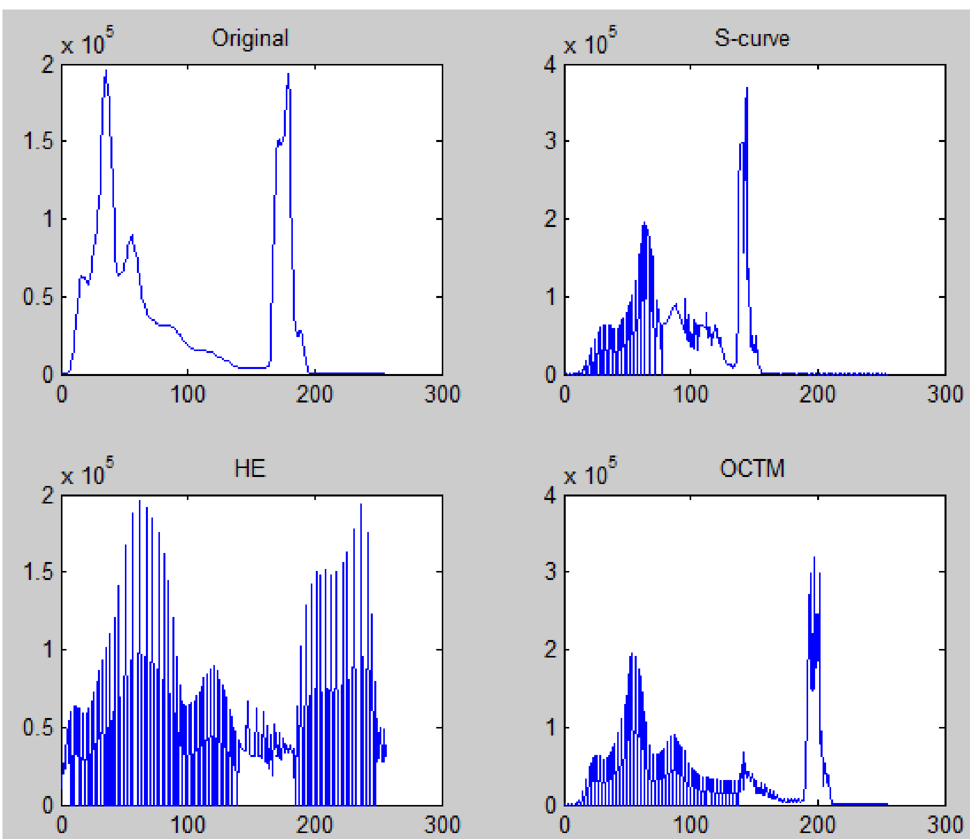
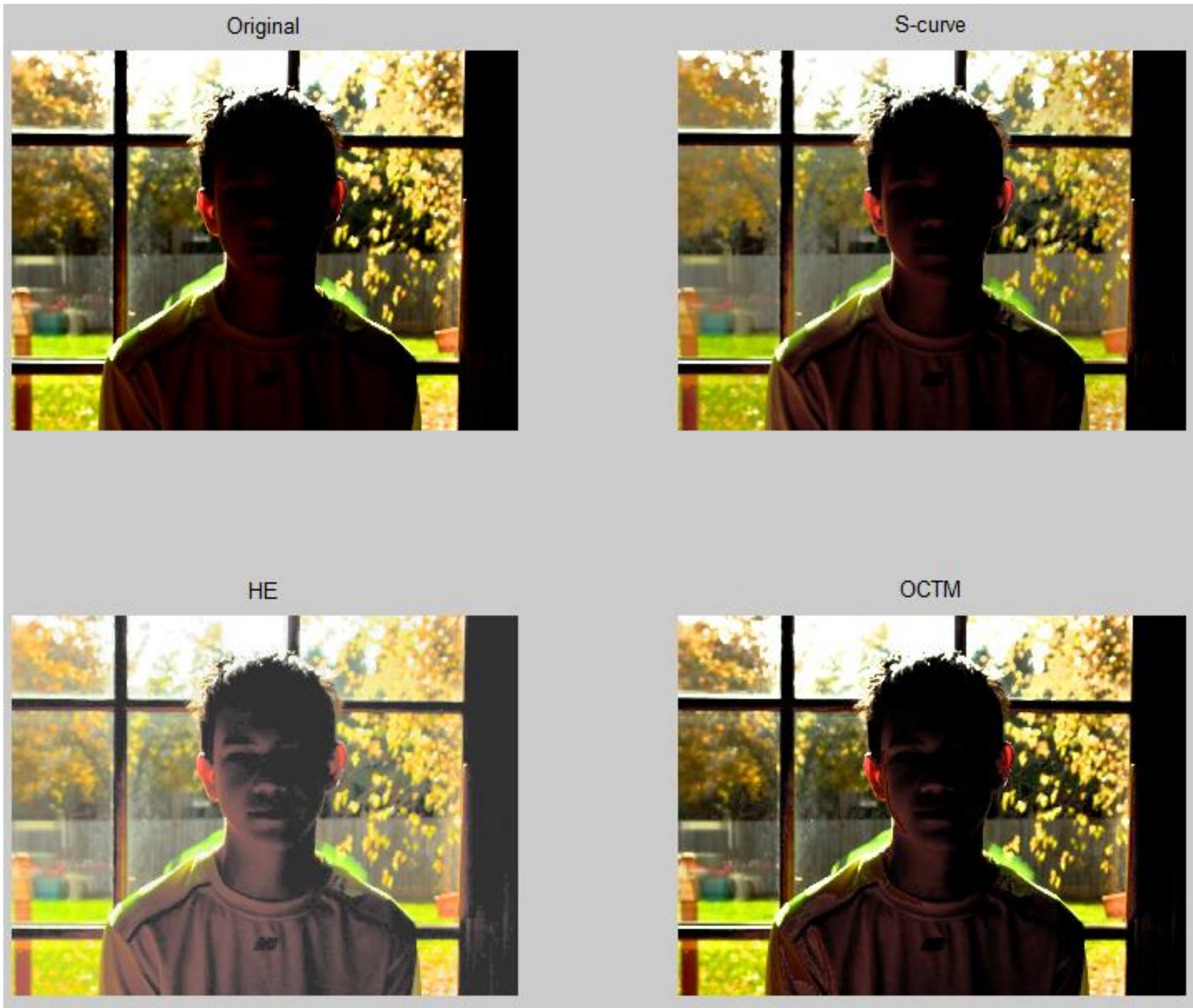
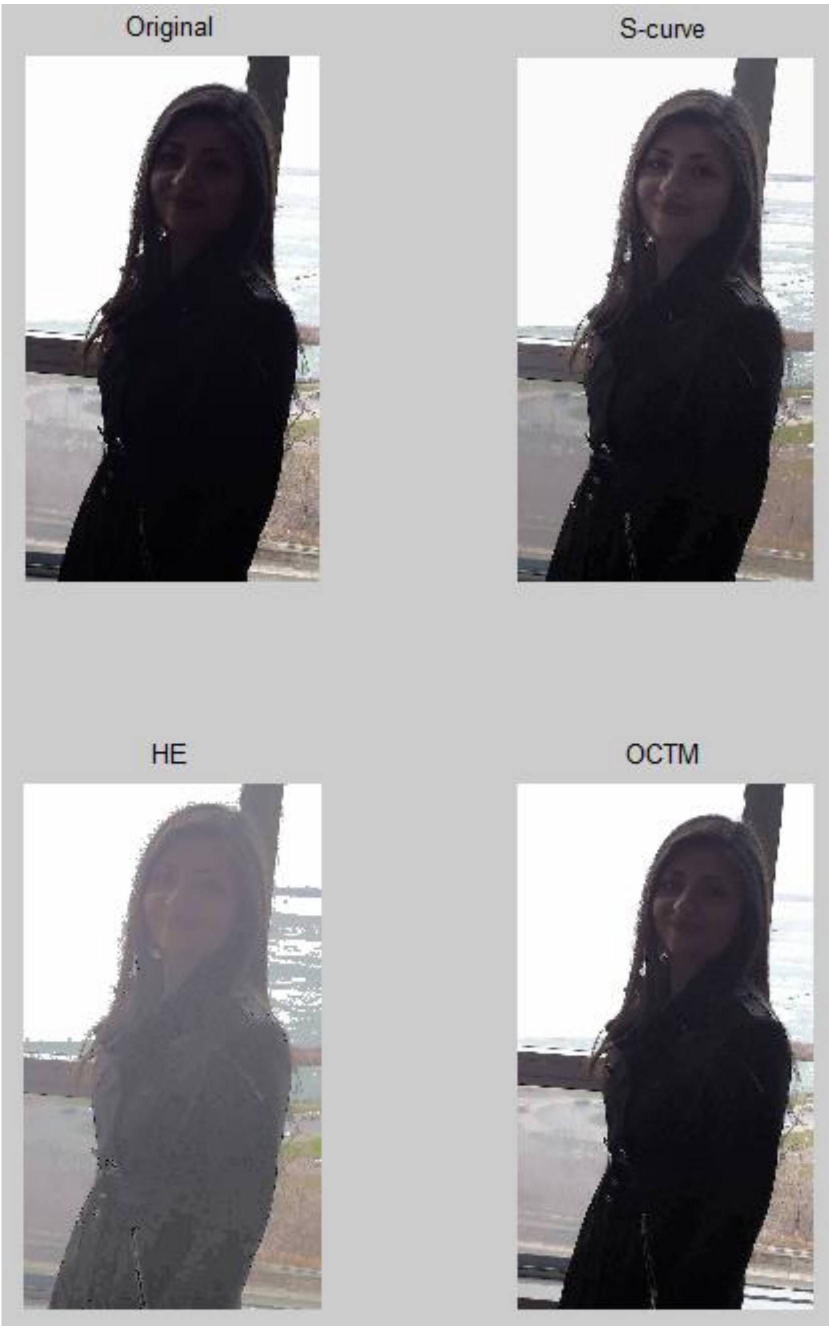


Figure 20: Histogram of the output of the different techniques

More examples of the algorithm being applied to backlit images:





References:

- http://photography.tutsplus.com/articles/mastering-backlighting--photo-9375
- http://epa.psy.ntu.edu.tw/documents/Huang_etal_2013.pdf