CHAPTER 5 EXPERIMENTAL RESULT AND DISCUSSION

This chapter describes the comparison of the experimental performance between the proposed work and the previous work. Also the results in attack are shown.

5.1 Parameter Selection

First of all, we illustrated the relationship between the quality of the watermarked image and the signal strength used to embed the watermark. The PSNR values obtained from the watermarked testing images at various signal strengths were averaged, and the results are illustrated in Figure 5.1.

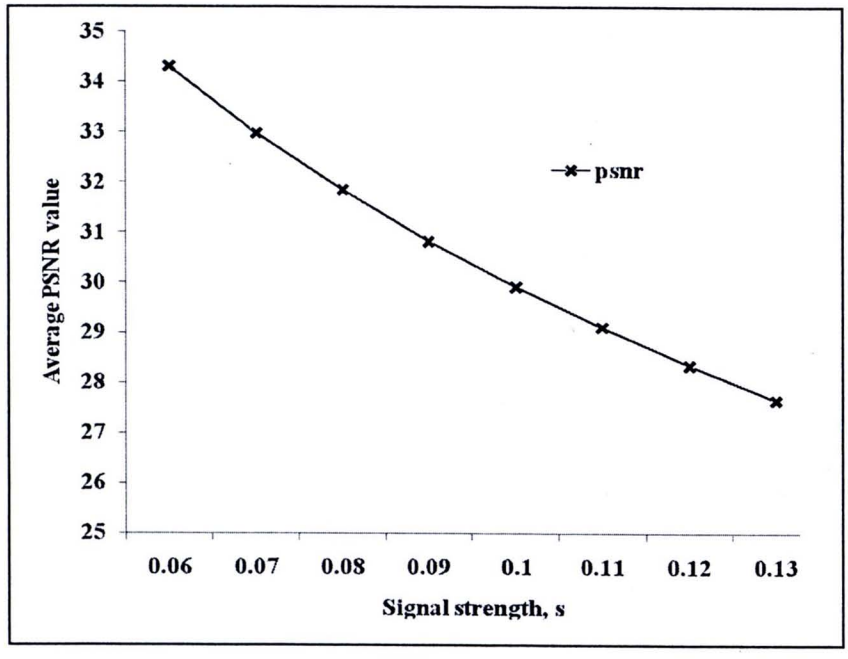

Figure 5.1 Average PSNR values at various signal strengths

According to the results obtained, we selected the signal strength of 0.09 that gave the optimum performance between the quality of the watermarked image and the retrieved watermark, i.e. average PSNR $\approx$ 30.83 dB and the average NC $\approx$ 0.86. This signal strength was used to the rest of our experiments.

5.2 Performance Comparison

Next, we compared the performance of our proposed watermark retrieval method to the previous method in [8]. Note that, with the same signal strength, the resultant watermarked image from both compared methods obtained the same PSNR. The performance of the two watermark retrieval methods at various signal strengths is shown and compared in Figure 5.2.

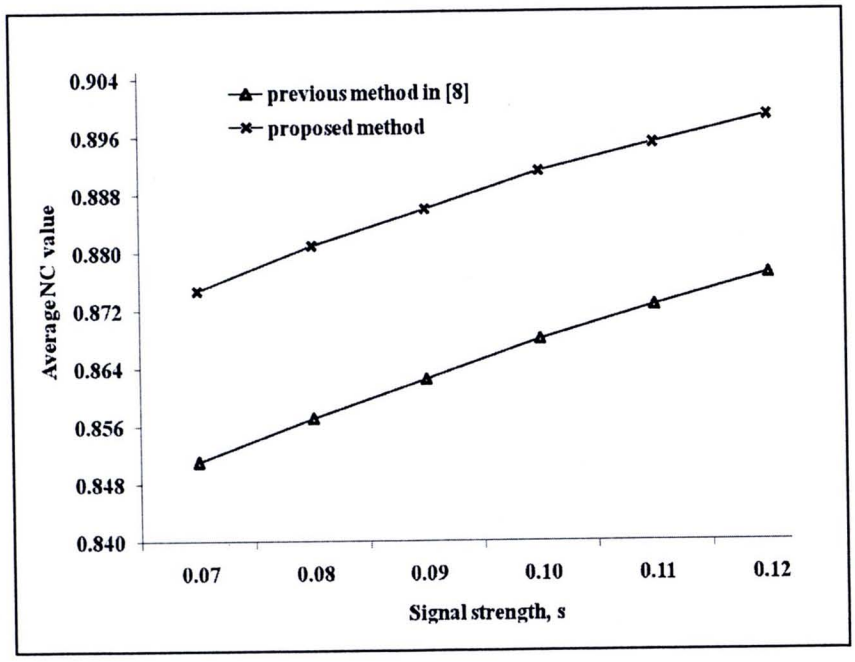

Figure 5.2 Average NC values between two watermark retrieval methods at various signal strengths

It is obvious from the above figure that our proposed method outperformed the previous one, at all signal strength values.

5.3 Verifying the Genuine Watermark

To verify the existence of the genius embedded watermark, a specific NC value must be established and used as a threshold. This threshold can also be used to differentiate

between two different versions of the retrieved watermark. Theoretically, the calculation of NC between two different watermarks, after XORing with a pseudo-random bit-stream, results in the NC value of approximately 0.5. In practice, however, this might not be true. Hence, two experiments were carried out to determine a suitable threshold. In the first experiment, we computed the NC values between the original watermark and the one obtained directly from the non-watermarked testing image. For the second experiment, we computed the NC values of the retrieved watermark from two retrieval methods, and compared the results with 998 pseudo-randomly generated watermarks and 2 original watermarks. The highest NC value obtained from both experiments would be used as a threshold. The experimental results obtained with the signal strength of 0.09 and the PSNR of 30.83 dB are shown in Figures 5.3 and 5.4. Note that the capital letters A and B in Figure 5.4 indicate the NC values of 0.862 and 0.886 obtained from the previous and proposed watermark retrieval methods respectively.

According to the results shown in the above two figures, the highest NC value of 0.6852 was obtained from the testing images '*Bird*' in the first experiment, while the highest NC value of 0.6864 was obtained from a random watermark in the second experiment. Thus we used the NC value of 0.6864 as the threshold to validate the retrieved watermark in the remaining experiments.

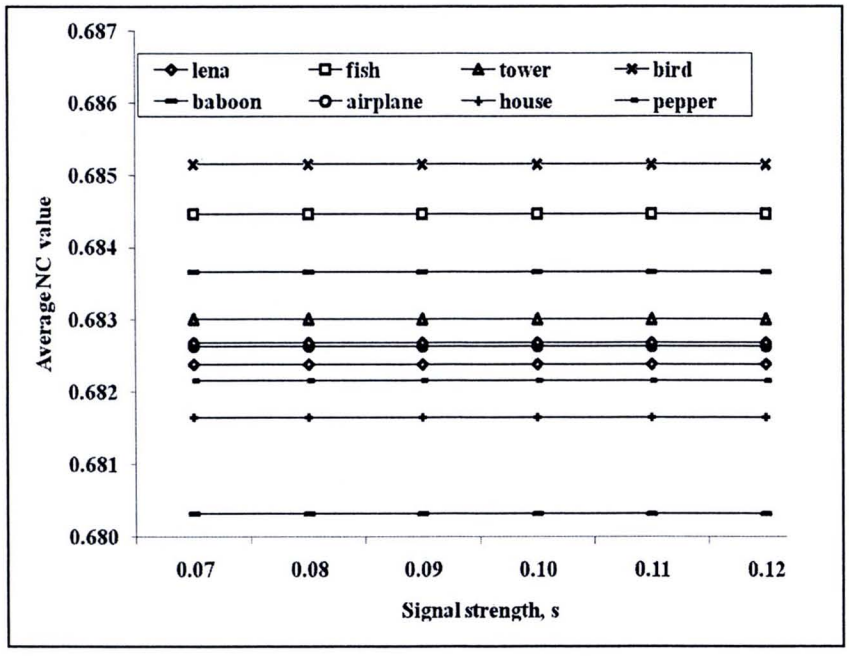

Figure 5.3 NC values obtained from the original non-watermarked images at various signal strengths

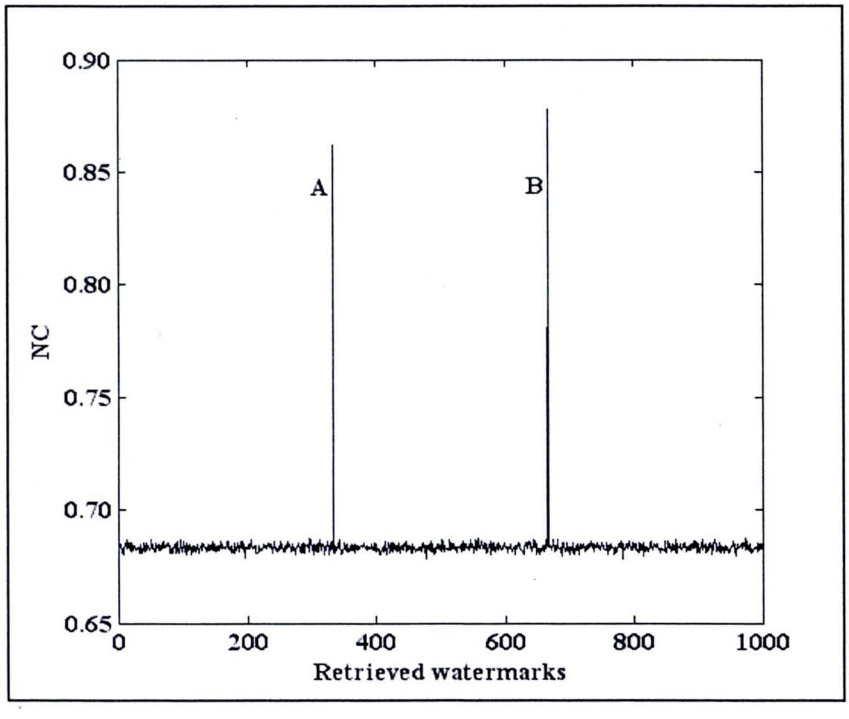

Figure 5.4 Comparison of NC values between 1,000 watermarks (2 genuine and 998 random watermarks)

5.4 Robustness of the Embedded Watermark

We finally evaluated the retrieval improvement in term of robustness against eight common image processing based attacks. In this experiment, we applied eight different types of attacks at various strengths to the watermarked image, and then computed the NC values from the attacked retrieved watermark. Those attacks e.g. the zero mean additive Gaussian distributed noise with the variances (σ^2) ranging from 0.001 to 0.5, JPEG compression standard with image qualities ranging from 95% to 5%, center image cropping at various percentages ranging from 10% to 90%, etc. Notice that the retrieval of watermark from the cropped watermarked image was achieved by replacing the cropped parts with the black color pixels. Also, the signal strength of 0.09 used in both compared methods gave the same PSNR value of 30.83 dB. The plots of the averaged NC values of the extracted watermarks after being attacked at various strengths are shown in Figure 5.5-5.7.

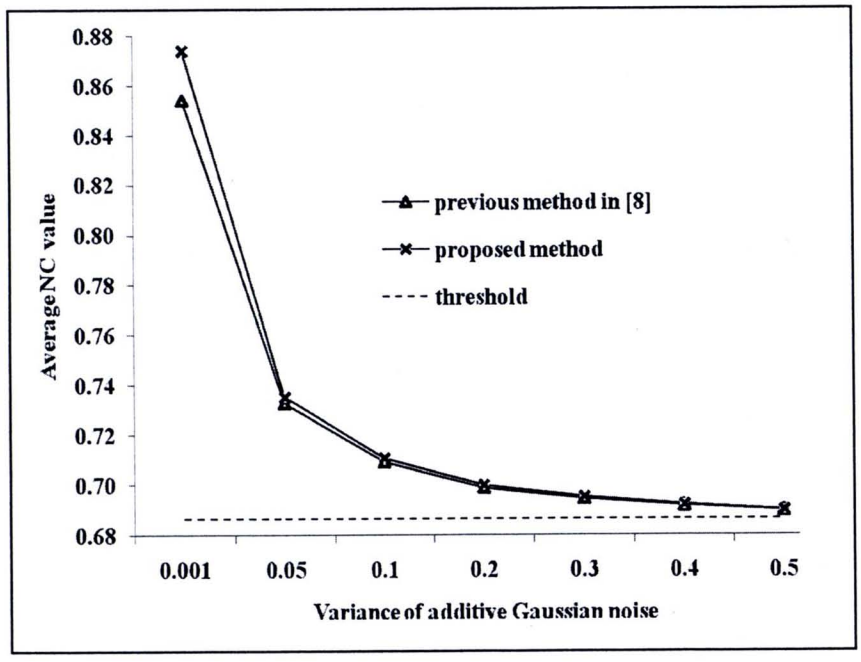

Figure 5.5 Average NC values at various variances of Gaussian noise

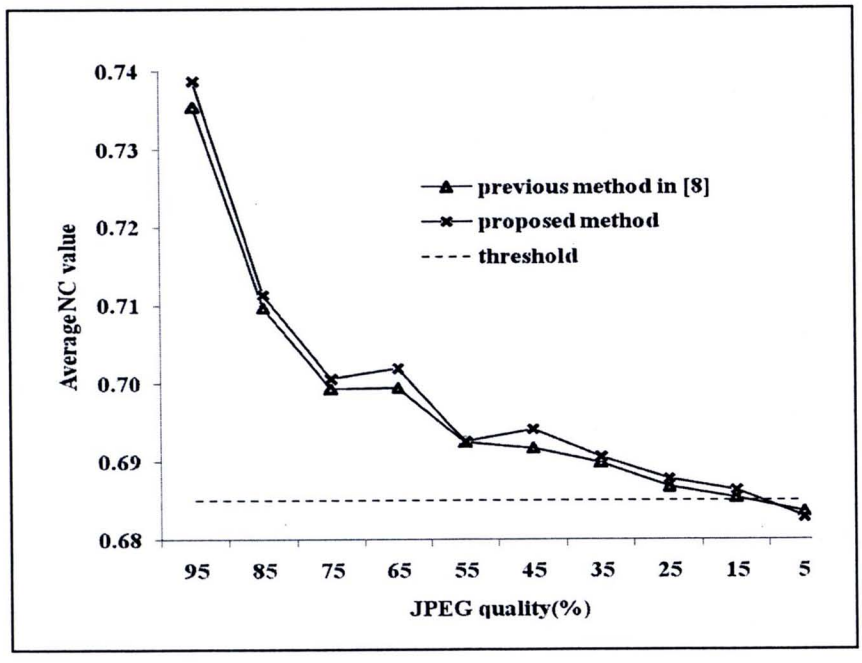

Figure 5.6 Average NC values at various JPEG image qualities

From the obtained results, the performance of our retrieval method against Gaussian noise was slightly better that from the previous method. However, in case of the JPEG

compression and the image cropping, the proposed method significantly outperformed another one. The main reason that our retrieval method did not perform well in case of the Gaussian noise was because the threshold used in the original pixel prediction process was based on the variances/standard deviations of the watermarked pixels. Hence, adding the Gaussian noise to the watermarked image caused the changes in the resultant variance/standard deviation or threshold which directly affected the performance of our retrieval method. It should be noted that, with our proposed method, the retrieval of the valid watermark could still be obtained even if the JPEG compression standard at 11% image quality was applied.

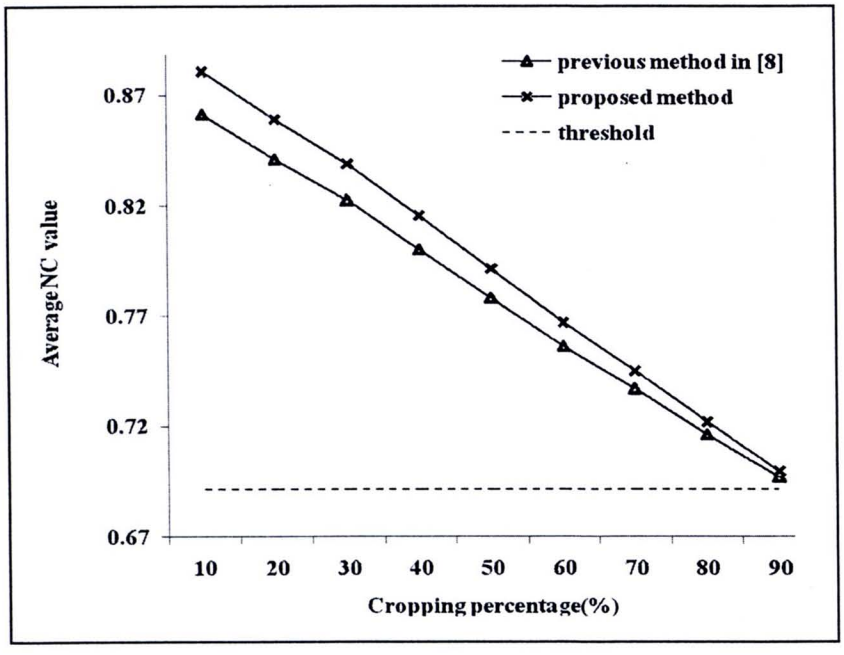

Figure 5.7 Average NC values at various percentages of cropping

Furthermore, salt pepper noise, blurring, brightness enhancement, contrast enhancement, the sharpening filter are also evaluated, compared and shown in Figures 5.8-5.12.

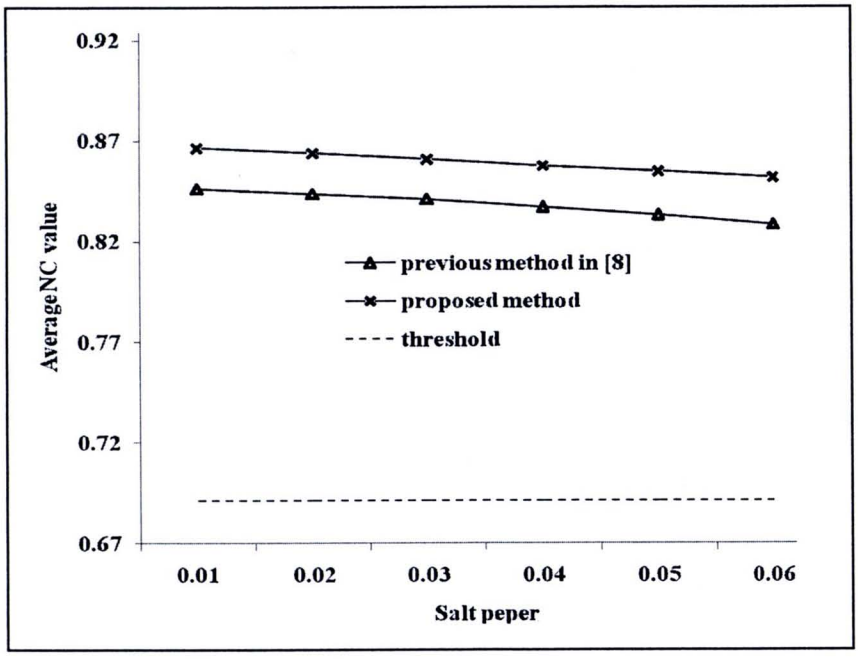

Figure 5.8 Average NC values at salt pepper

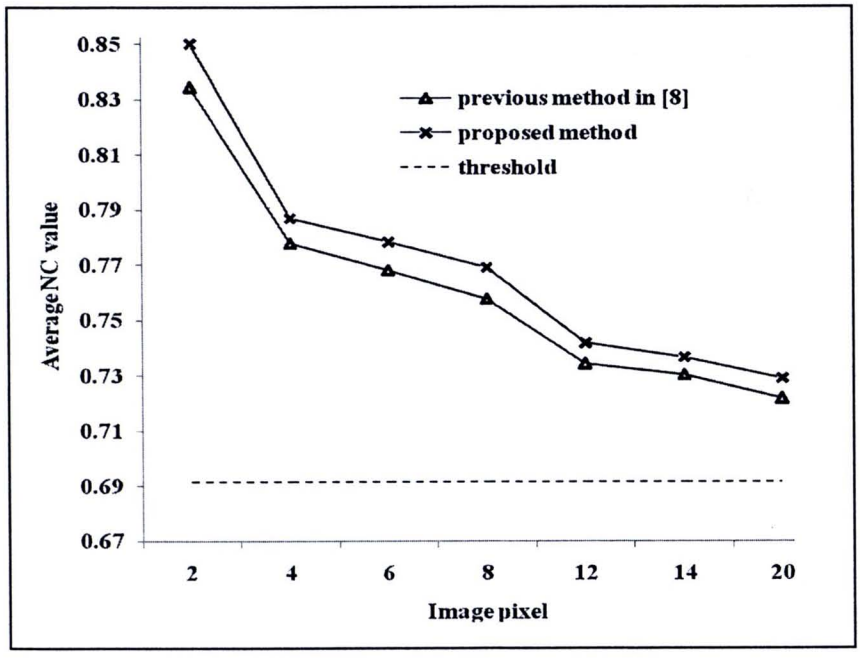

Figure 5.9 Average NC values at blurring

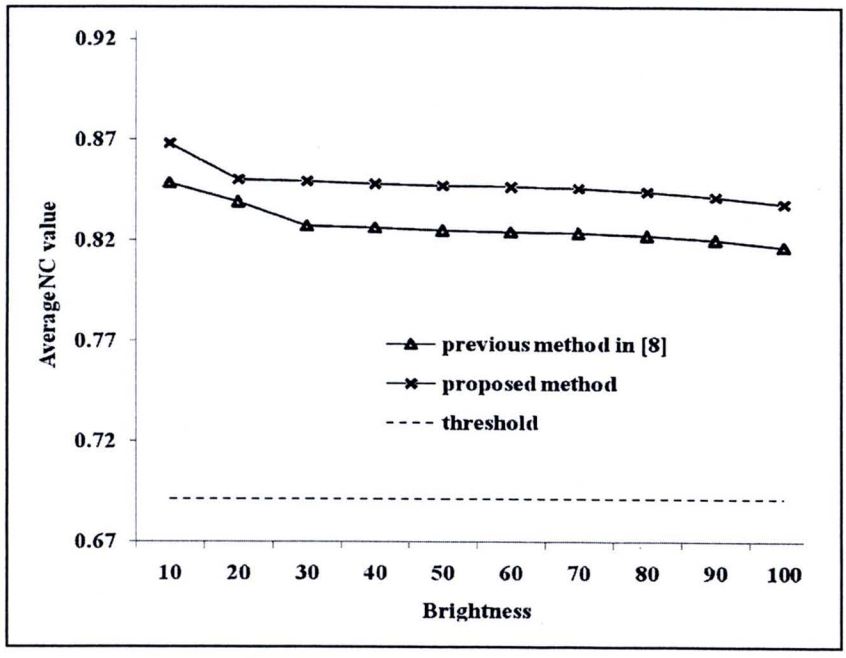

Figure 5.10 Average NC values at brightness

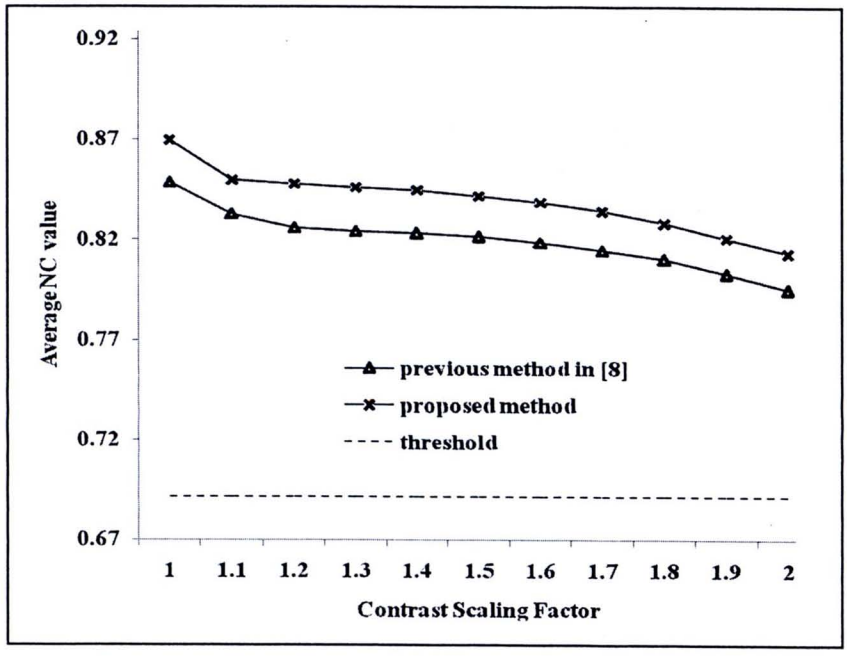

Figure 5.11 Average NC values at contrast scaling factor

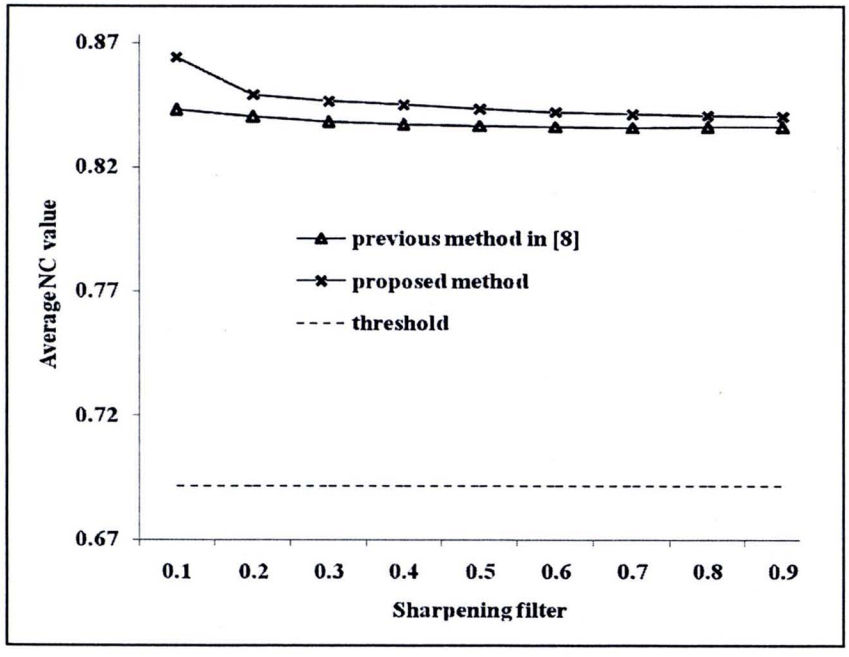

Figure 5.12 Average NC values at sharpening filter