In this section, we tested the performance of the NMF-NMF-SQ algorithm with the proposed blocking strategy. The parameters are set as: $p = 10$, $m = 100$, $r_1 = 1$, $r_2 = 1$, $M = 64$. The test data set is composed of four hundred $256 \times 256$ grey images, each image rotated in both loose and crop modes at the angle of 4, 8, 12 and 16 degrees. Rotational robustness performance of the hashing algorithm (with the restricted blocking strategy) against the algorithm [20] (without the restricted blocking strategy) is as follows.

A. Robustness to the Loose Rotation Mode

![ROC curves](image)

(a) ROC under the loose rotation of 4 degrees  
(b) ROC under the loose rotation of 8 degrees  
(c) ROC under the loose rotation of 12 degrees  
(d) ROC under the loose rotation of 16 degrees

Fig. 8. ROC curves of the NMF hashing before and after the use of the new blocking strategy against the rotation with the loose mode.

When the block radius is fixed as 100 (pixels), we can see from the ROC curves (Receiver Operation Characteristic) as shown in Fig. 8 that, the ROC curves of the NMF hashing with the new blocking strategy are always on the below of those corresponding curves calculated from the algorithm [20]. The reason is that the restricted blocking method has better avoided the effect of the rotation operations. Especially, for a bigger rotation angle, the more robustness bonus for the rotation is obtained from the new blocking strategy. This indicates that the restricted blocking strategy is effective to improve the robustness to the loose rotation.