ICPRAM Technical Report
Deblurring and recovery of binary images / CCL

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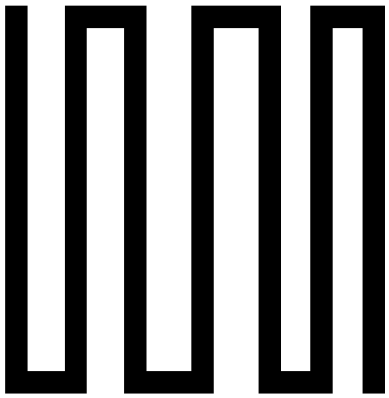
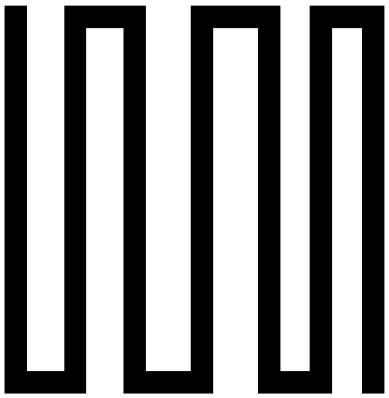
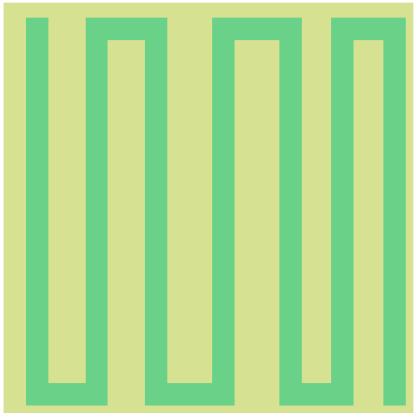
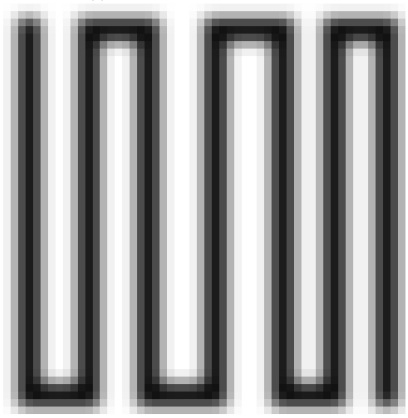
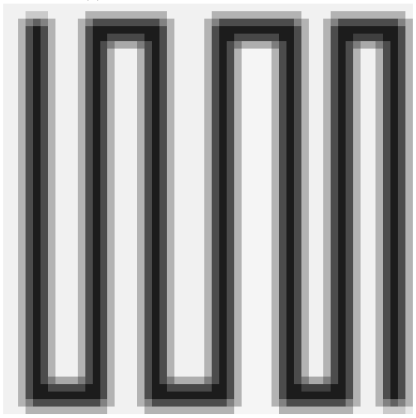
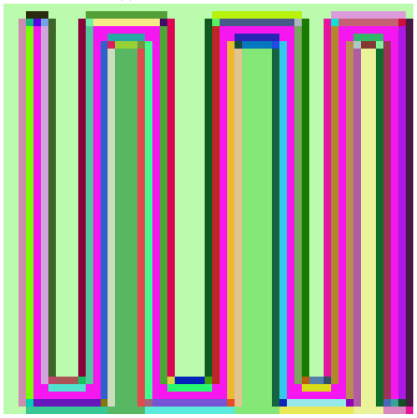
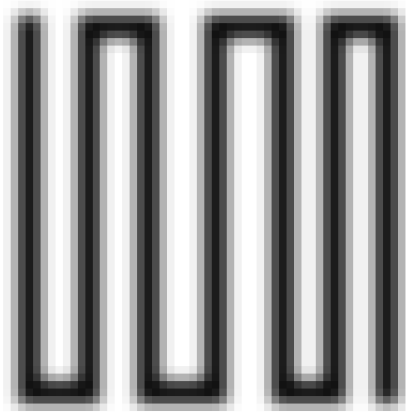
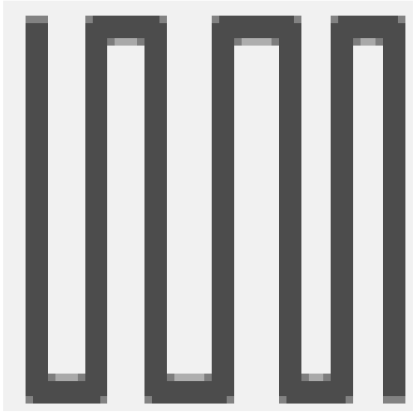
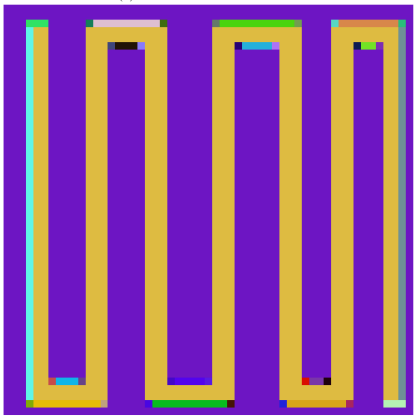
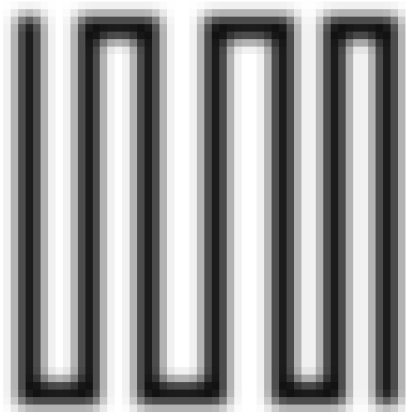
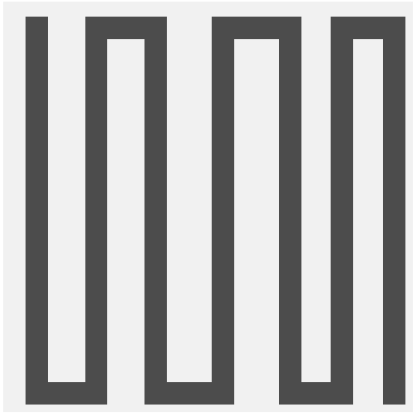
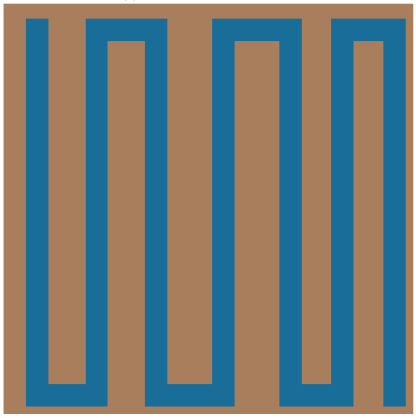
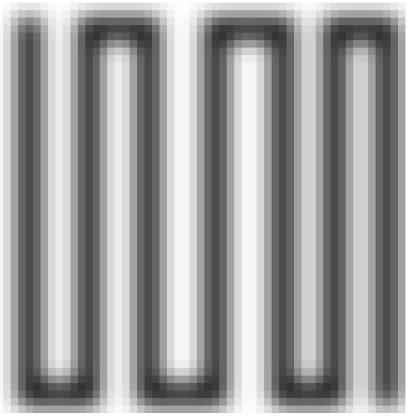
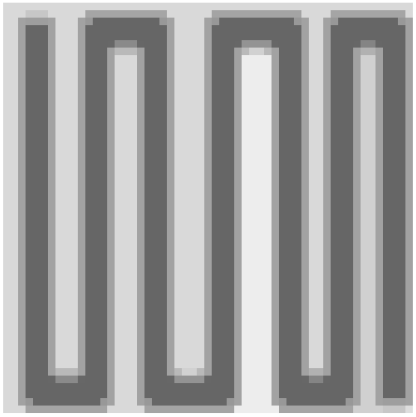
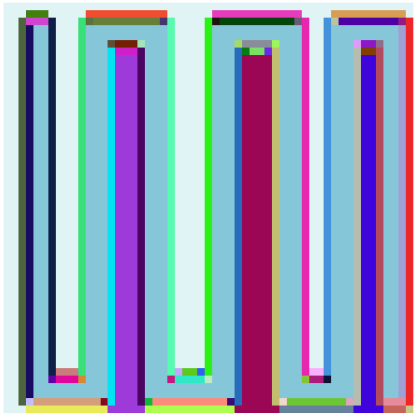
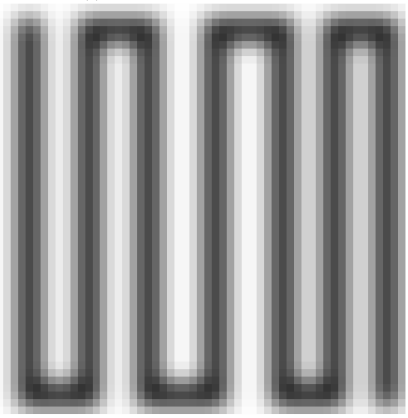
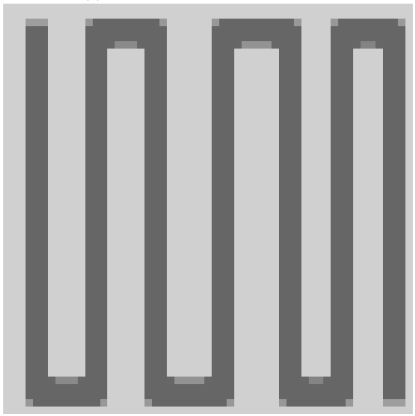
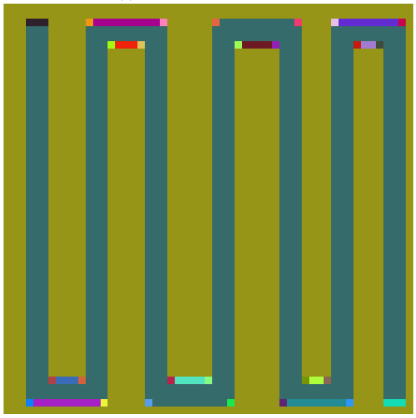
This technical report is a supporting document to display experimental data, especially the output images for connected component labelling (CCL) and image deblurring. In Section 1 we discuss the desirable and the undesirable results of our deblurring algorithm. Section 2 displays a number of results with varying parameter values tuned for the dataset to achieve desirable results. We also display unpleasant results that may be reached if the parameters are not turned. The images displayed in Section 1 are artificially generated images while the images used for experiments in Section 2 are from YACCLAB dataset [1]. The experiments were performed on more than 500 images from different categories such as fingerprint data, MRI images, scans of mitochondria, etc with different levels of blurring. The technical report and the software will be made public after acceptance of the paper.

1 Discussion on desirable and undesirable results

In this section we display both the desirable and undesirable results and discuss the possible reasons for achieving undesirable results. The images used for experiments in this section are artificially generated images considering possibility of counting the connected components manually. We show our results on original binary image, blurred image using Gaussian blurring with standard deviation of 1, 1.5 and 3. For each of the 3 levels of blurring we display 3 output generated by varying the parameters m and λ in Eq. 1 and Eq. 3 of the paper respectively.

1	(a) Original Image 	(b) Recovered image for m =0.15,λ =8 	(c) CC after contraction =2 
2	(a) Blured Image with std. dev. =1 	(b) Recovered image for m =0.02,λ =35 	(c) CC after contraction =90 

3	(a) Blured Image with std. dev. =1 	(b) Recovered image for m =0.02,λ =50 	(c) CC after contraction =42 
4	(a) Blured Image with std. dev. =1 	(b) Recovered image for m =0.02,λ =70 	(c) CC after contraction =2 
5	(a) Blured Image with std. dev. =1.5 	(b) Recovered image for m =0.02,λ =50 	(c) CC after contraction =78 
6	(a) Blured Image with std. dev. =1.5 	(b) Recovered image for m =0.02,λ =70 	(c) CC after contraction =38 

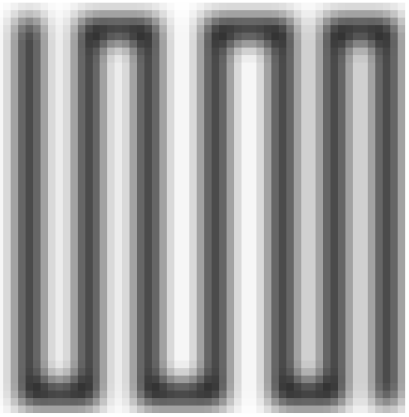
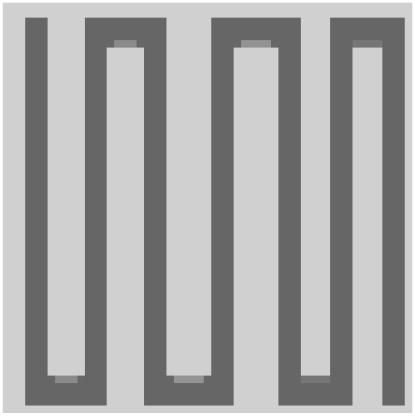
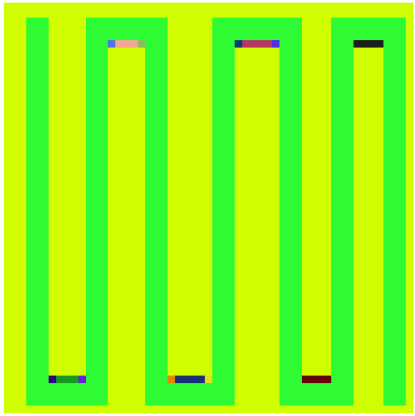
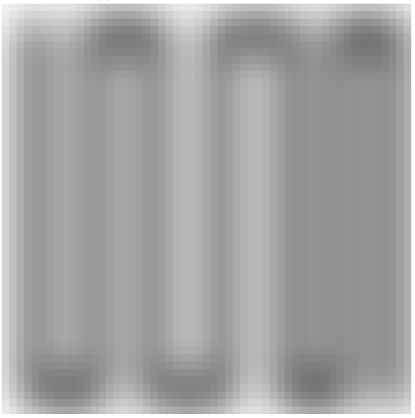
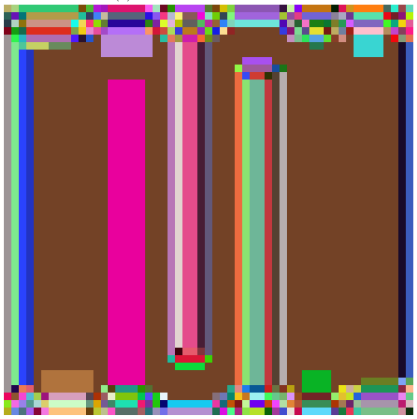
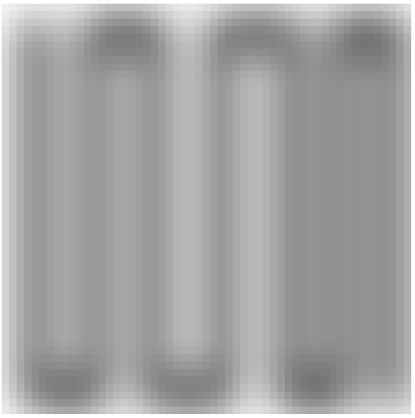
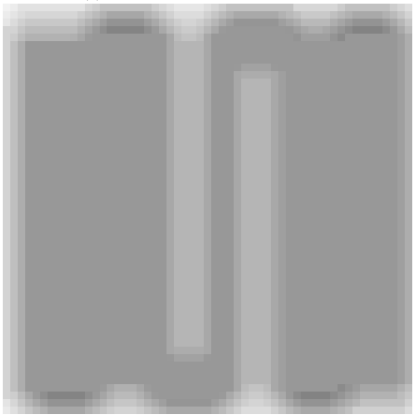
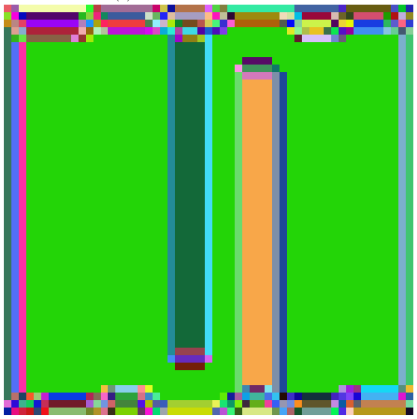
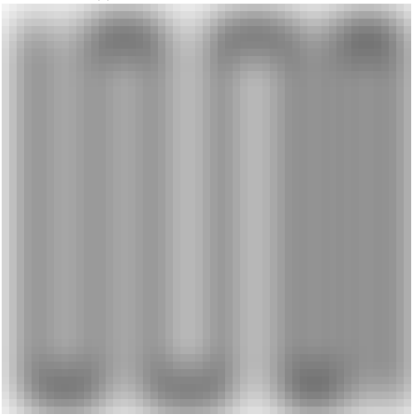
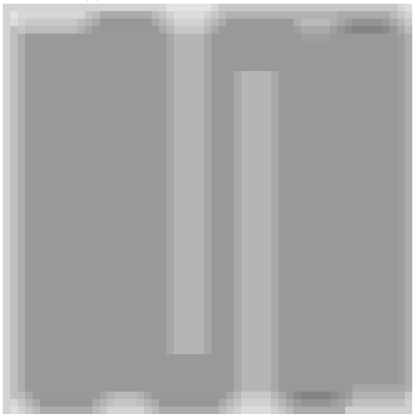
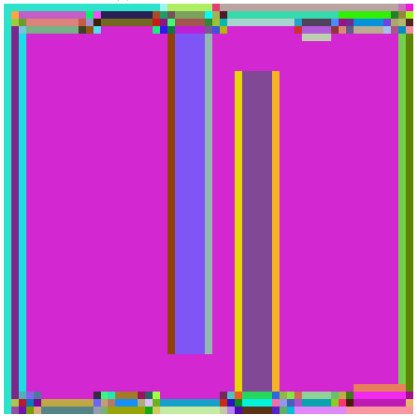
7	(a) Blured Image with std. dev. =1.5 	(b) Recovered image for m =0.02,λ =95 	(c) CC after contraction =16 
8	(a) Blured Image with std. dev. =3 	(b) Recovered image for m =0.02,λ =25 	(c) CC after contraction =331 
9	(a) Blured Image with std. dev. =3 	(b) Recovered image for m =0.02,λ =35 	(c) CC after contraction =264 
10	(a) Blured Image with std. dev. =3 	(b) Recovered image for m =0.02,λ =50 	(c) CC after contraction =155 

Image number	blur	m	λ	# CC
1	0 (original)	0.15	8	2
2	1	0.02	35	90
3	1	0.02	50	42
4	1	0.02	70	2
5	1.5	0.02	50	78
6	1.5	0.02	70	38
7	1.5	0.02	95	16
8	3	0.02	25	331
9	3	0.02	35	264
10	3	0.02	50	155

Table 1: Summary of the results shown above.

From the above experiments, following were the observations:

1. For the blurred input images, the recovered image is not necessarily a black and white image, rather is gray colored image even if the number of connected components in the recovered image match the original image. This is because the implemented algorithm takes an average pixel intensity of the pixels belonging to the same component. Moreover, a simple gray scale thresholding can be implemented to further improve the results, which we intend to do in the future work.

2. We observed deteriorated results when the blurring is high enough to create an overlap between the two non adjacent components. This can be clearly observed in image 8,9 and 10 where the standard deviation is 3 and the resulting output is not very pleasant.

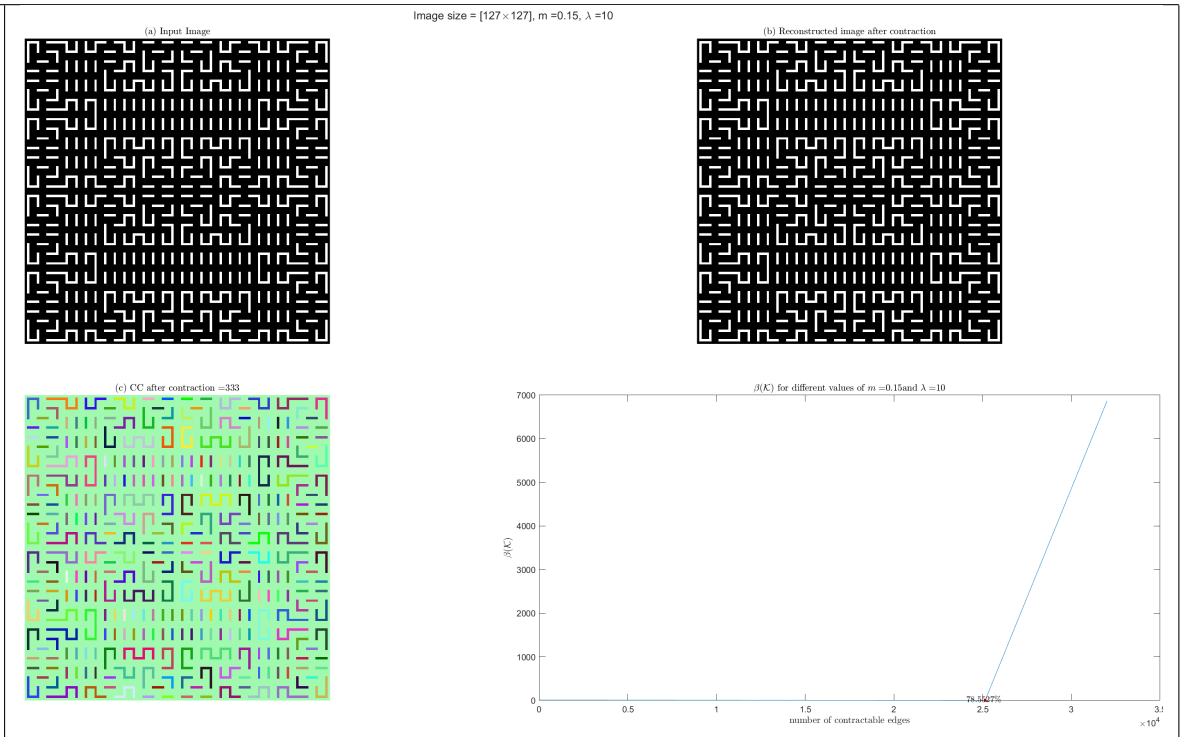
3. Impressive results with a low blurring level of standard deviation 1 and 1.5 are displayed Image 4 and 7. The recovered image can be further improved by preserving the gray values of the extremum in the input image or by gray scale thresholding.

4. Intuitively, having a thorough knowledge of the dataset, if the values of m and λ are kept constant, depending on the number of connected components, we can approximately estimate the amount of blurring on a test image.

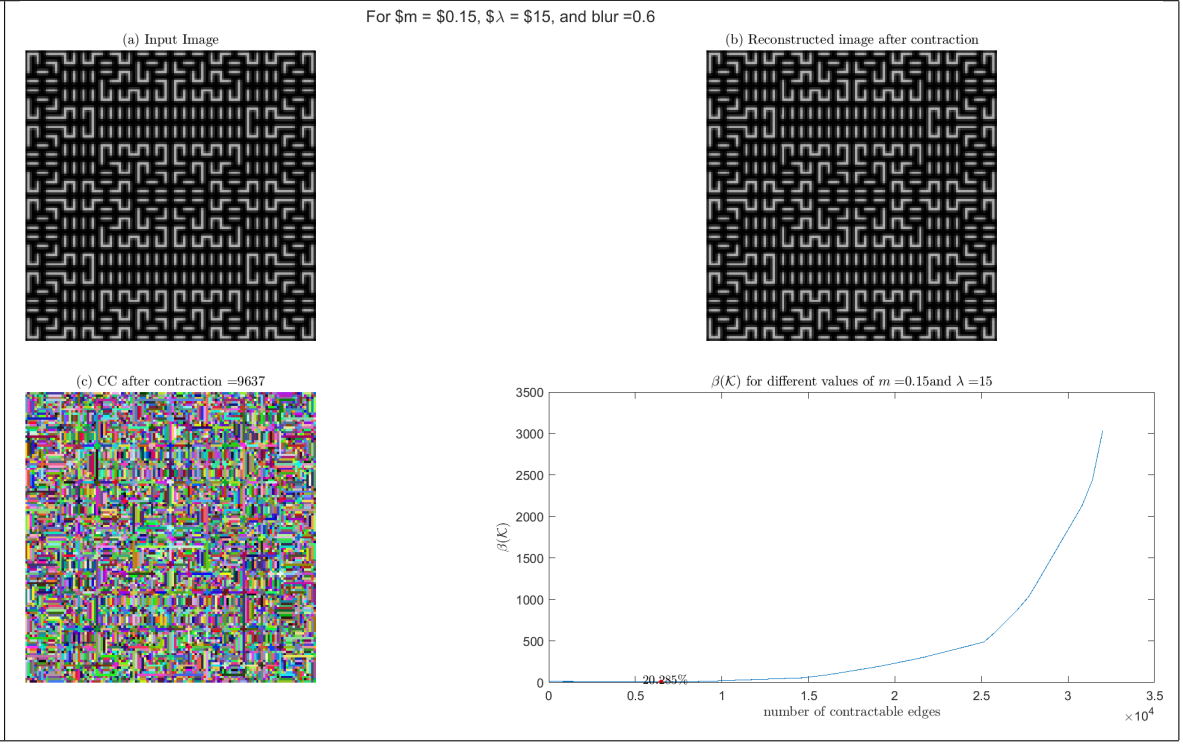
2 Some more results!

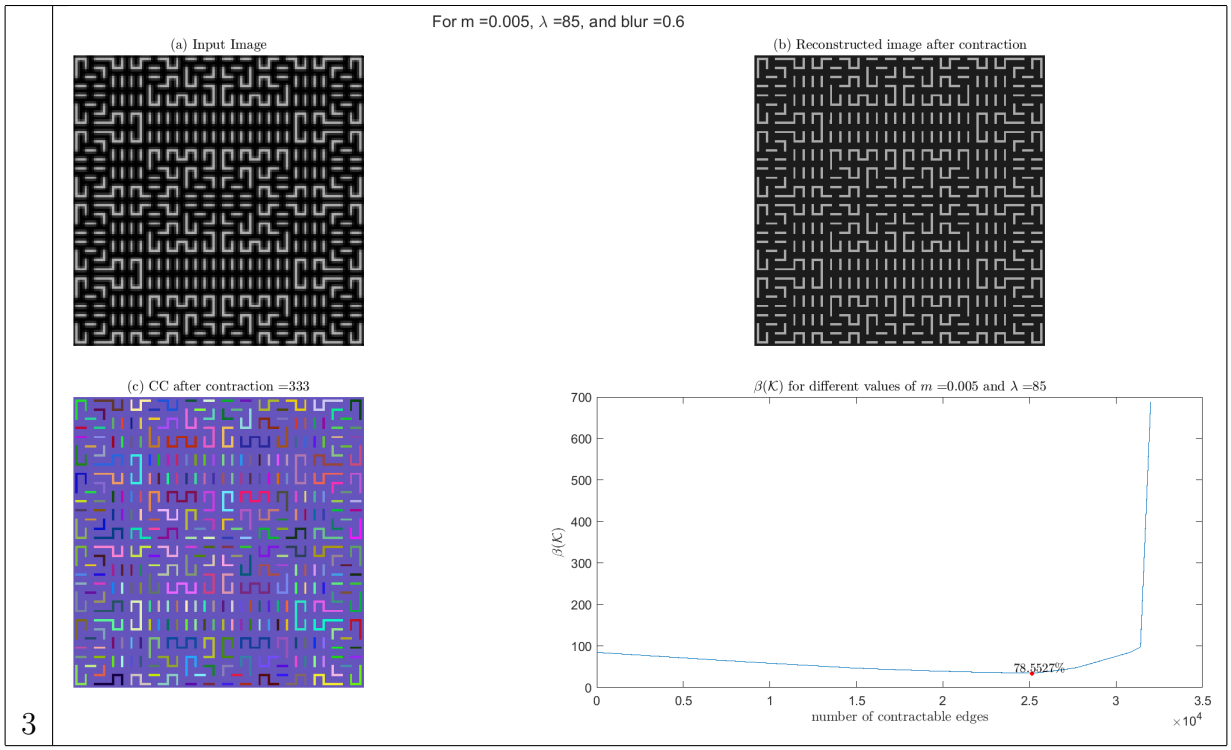
2.1 Results on data with multiple straight lines - 1.

1



2





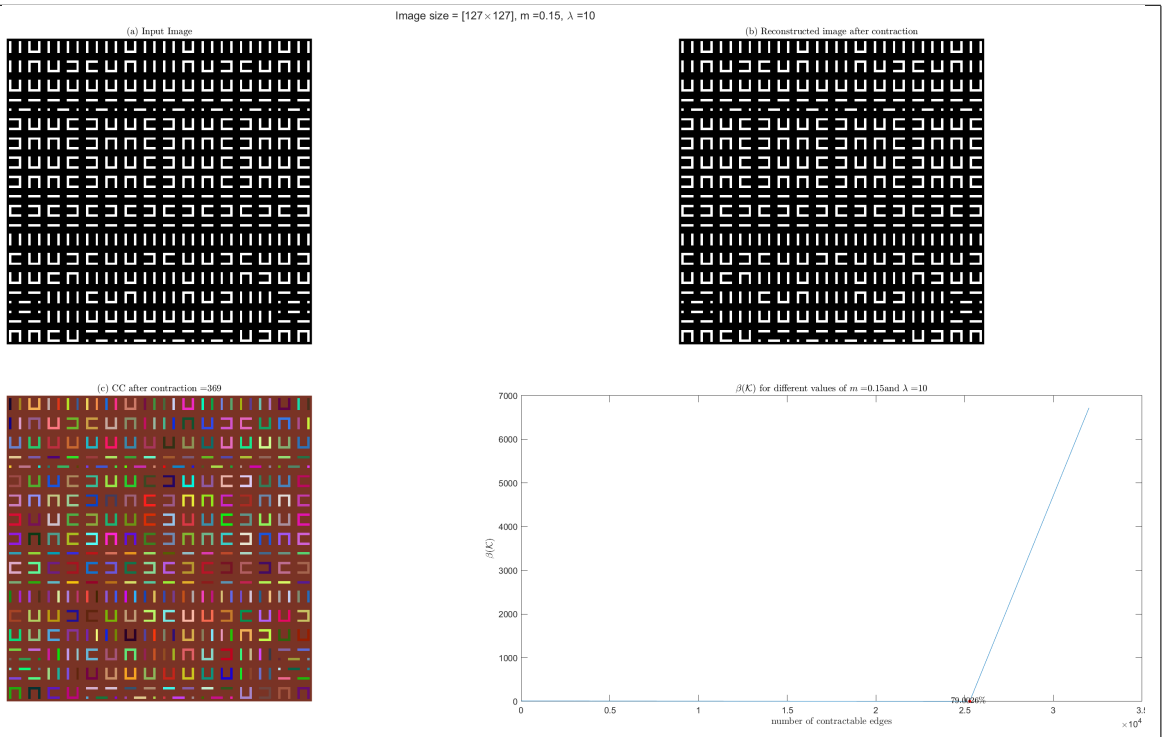
3

Image number	blur	m	λ	# CC
1	0 (original)	0.15	10	333
2	0.6	0.15	15	9637
3	0.6	0.005	85	333

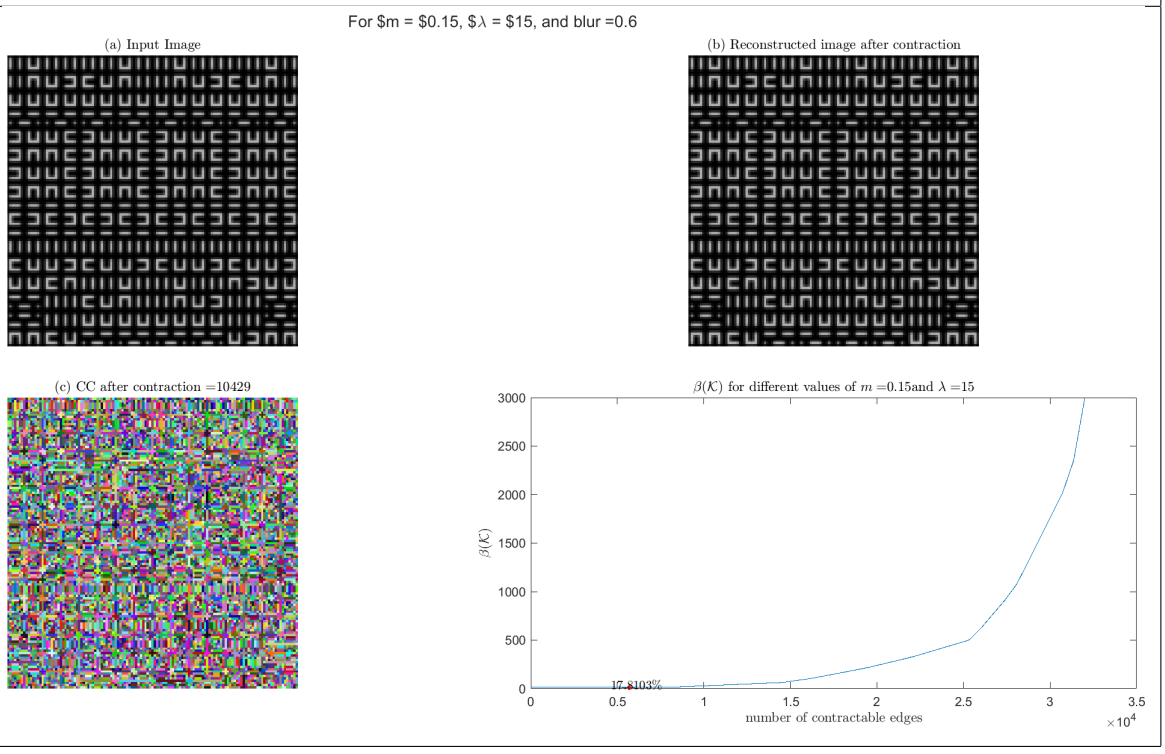
Table 2: Summary of the results shown above.

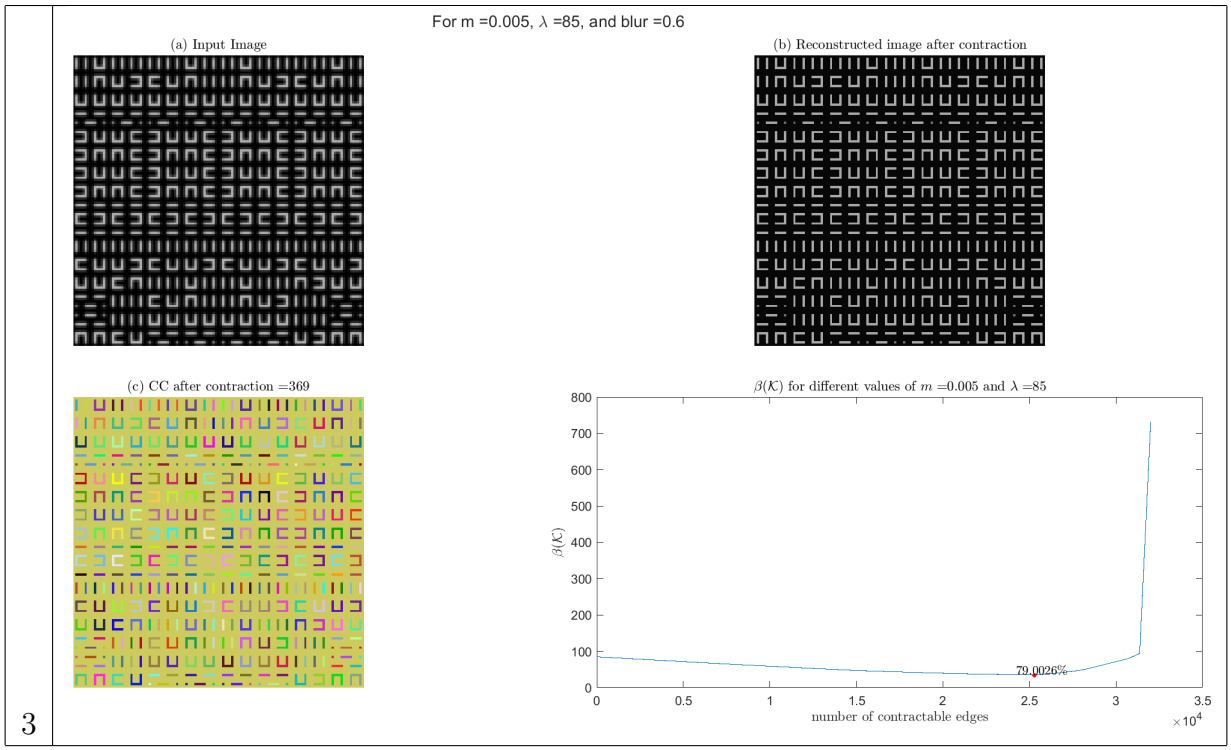
2.2 Results on data with multiple straight lines - 2.

1



2



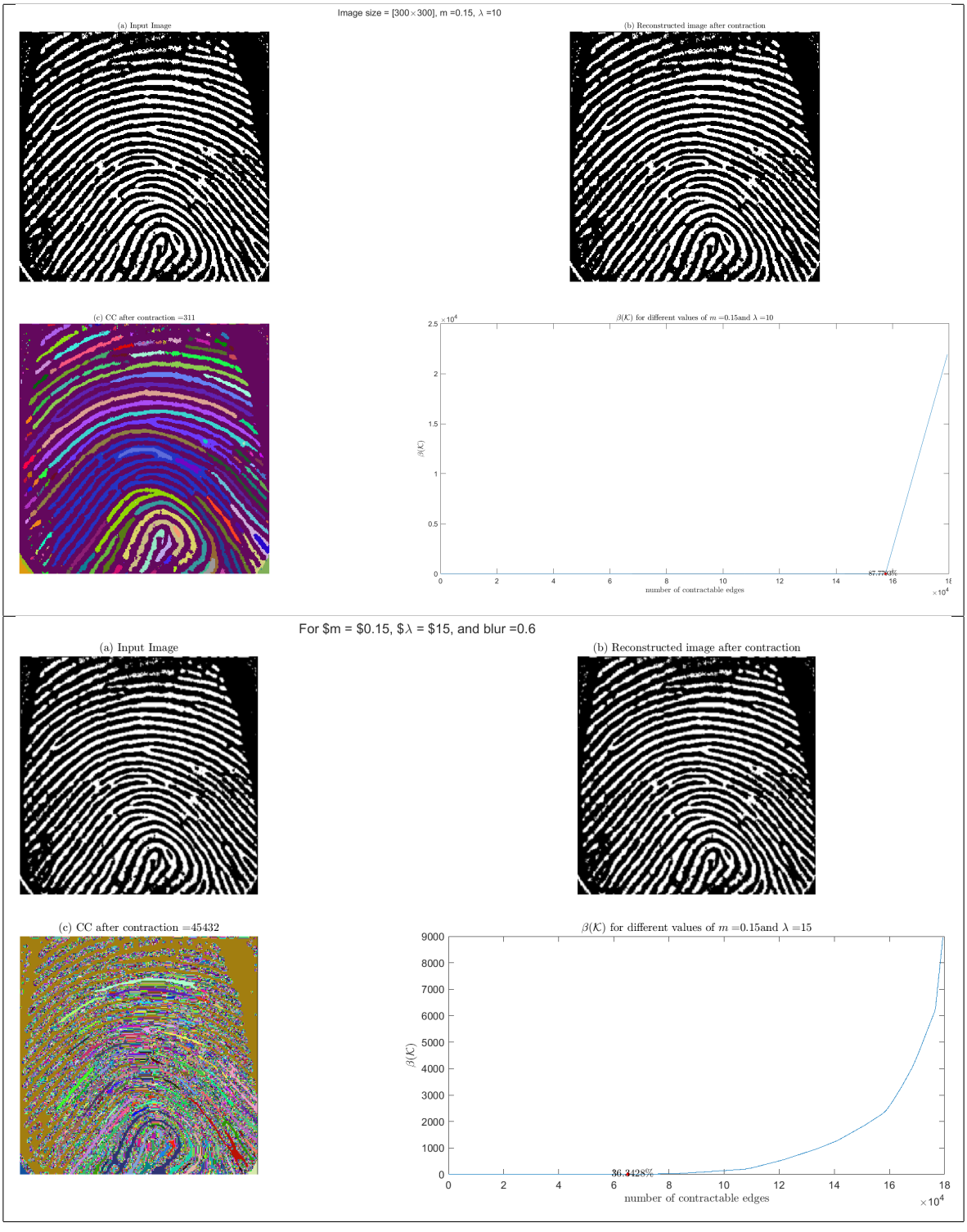


3

Image number	blur	m	λ	# CC
1	0 (original)	0.15	10	369
2	0.6	0.15	15	10429
3	0.6	0.005	85	369

Table 3: Summary of the results shown above.

2.3 Results on fingerprint data - 1

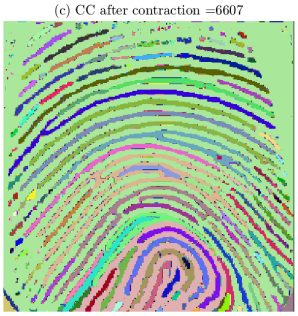


For m =0.002, λ =100, and blur =0.6

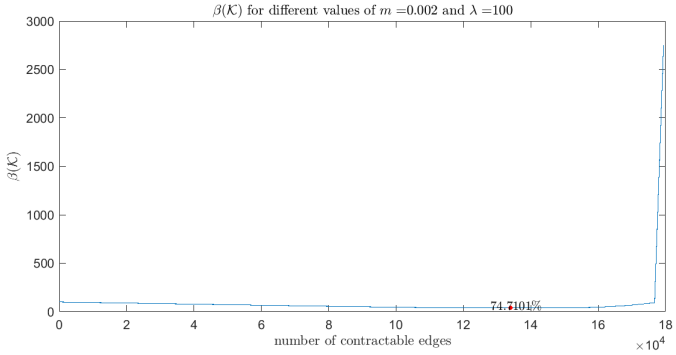
(a) Input Image

(b) Reconstructed image after contraction

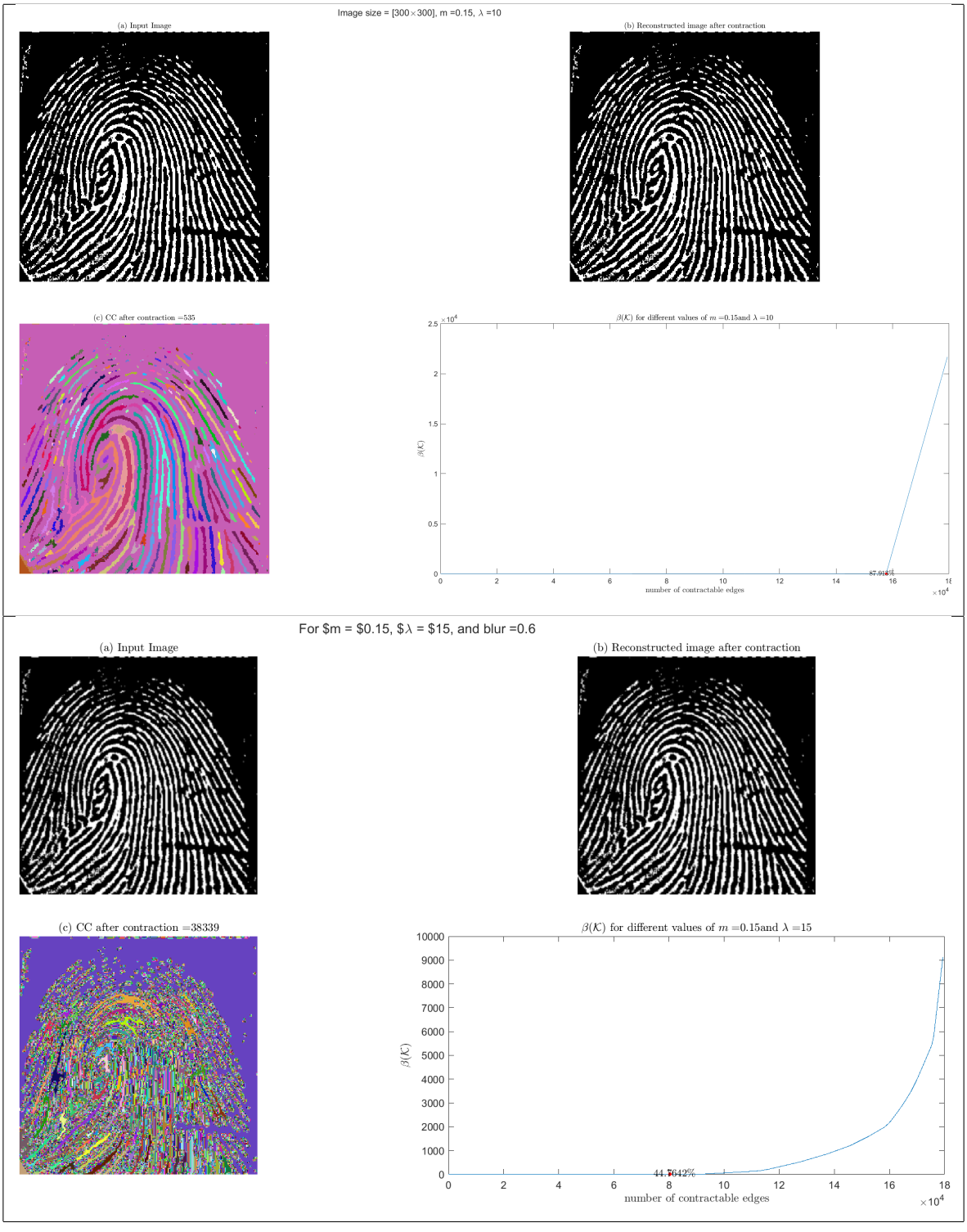
(c) CC after contraction =6607

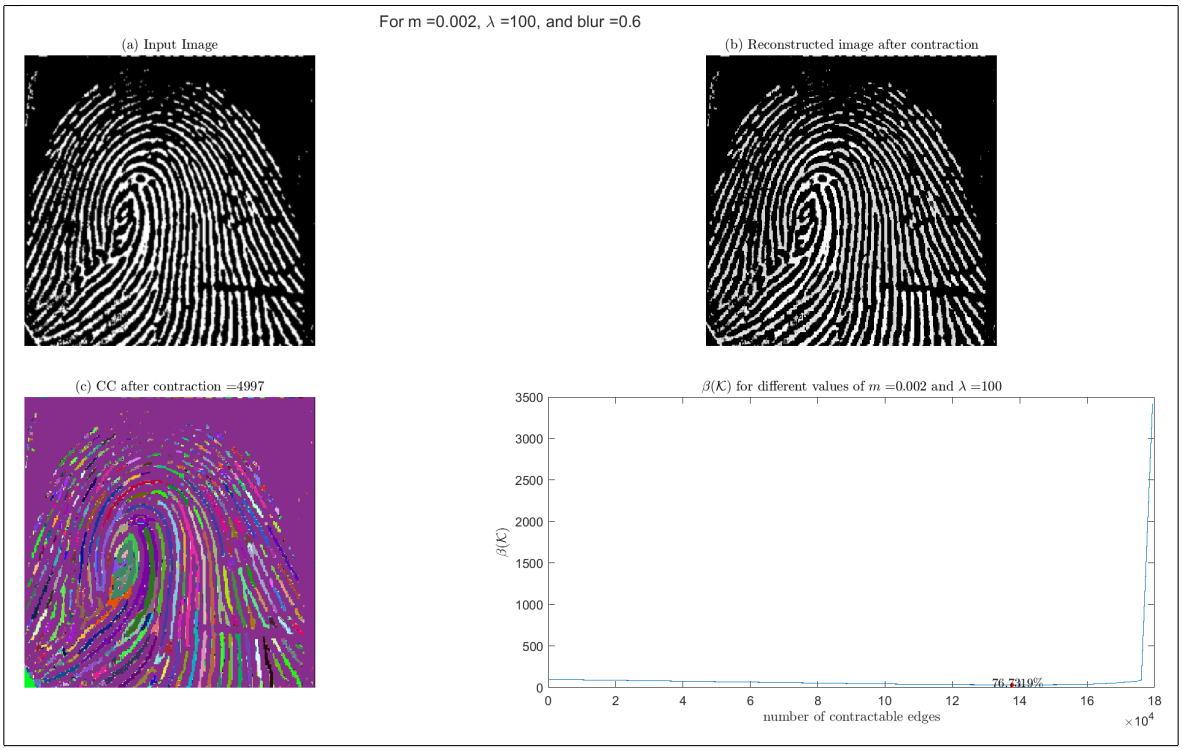


$\beta(\mathcal{K})$ for different values of m =0.002 and λ =100

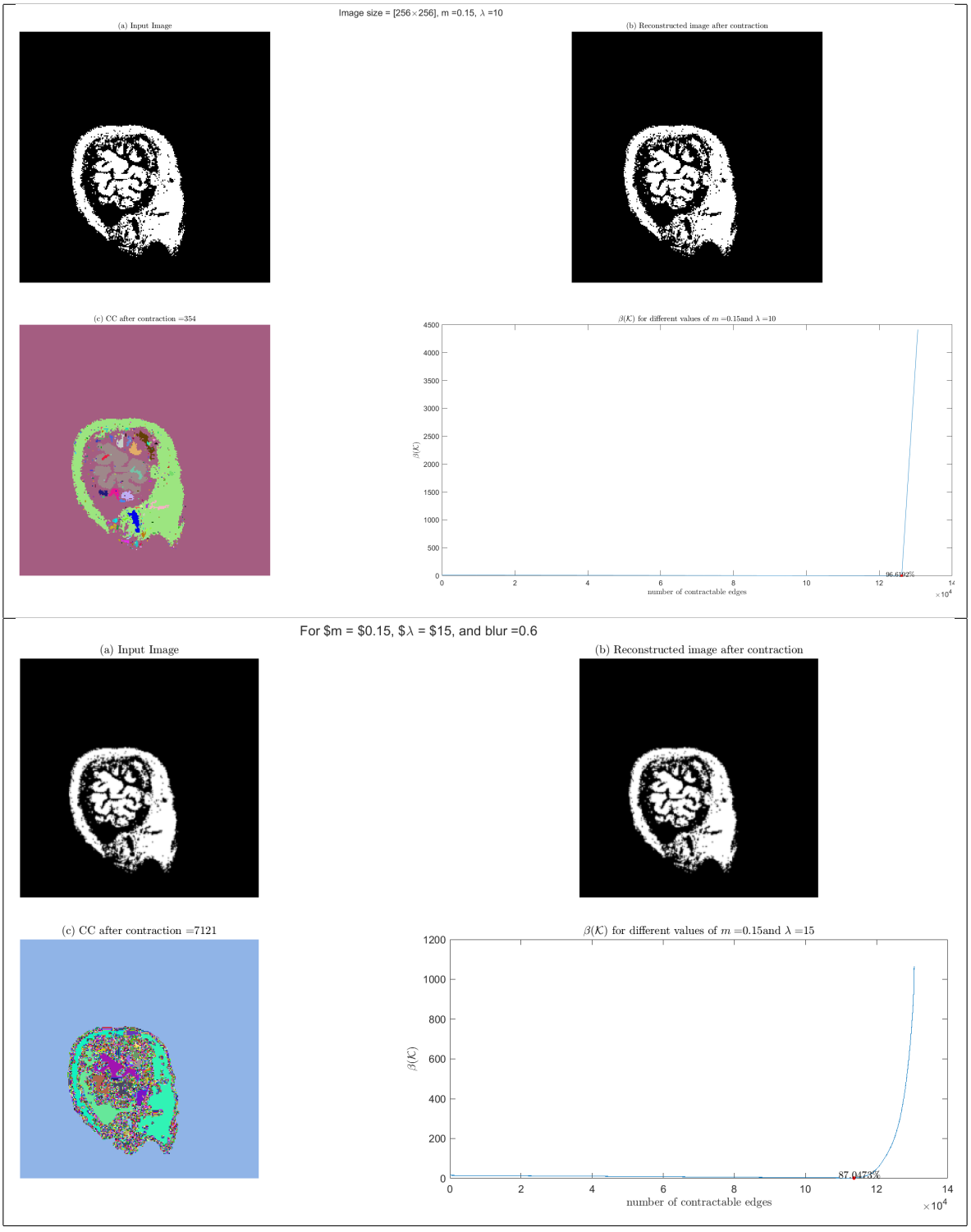


2.4 Results on fingerprint data - 2



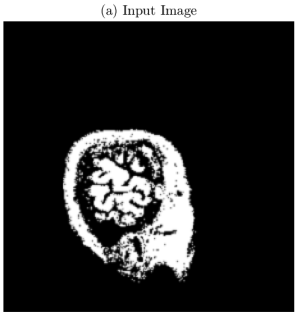

For m =0.002, λ =100, and blur =0.6
(a) Input Image
(b) Reconstructed image after contraction
(c) CC after contraction =4997
β(K) for different values of m =0.002 and λ =100
3500
3000
2500
2000
1500
1000
500
0
β(K)
0
2
4
6
8
10
12
14
16
18
number of contractable edges
×10^4
76.7319%

2.5 Results on MRI images - 1

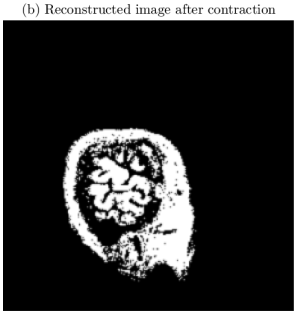


For m =0.01, λ =45, and blur =0.6

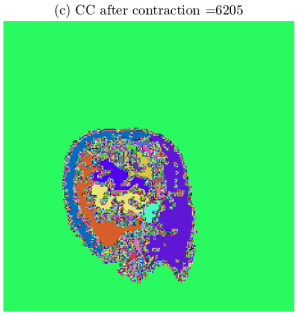
(a) Input Image



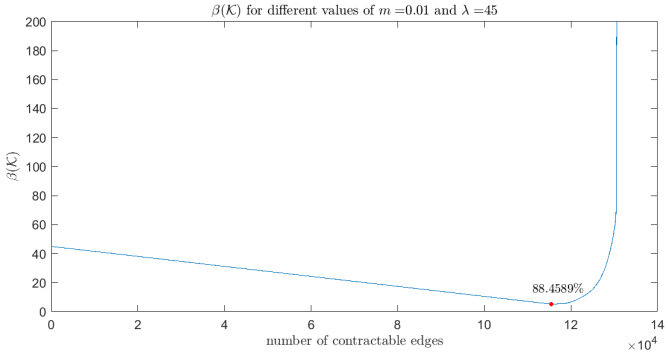
(b) Reconstructed image after contraction



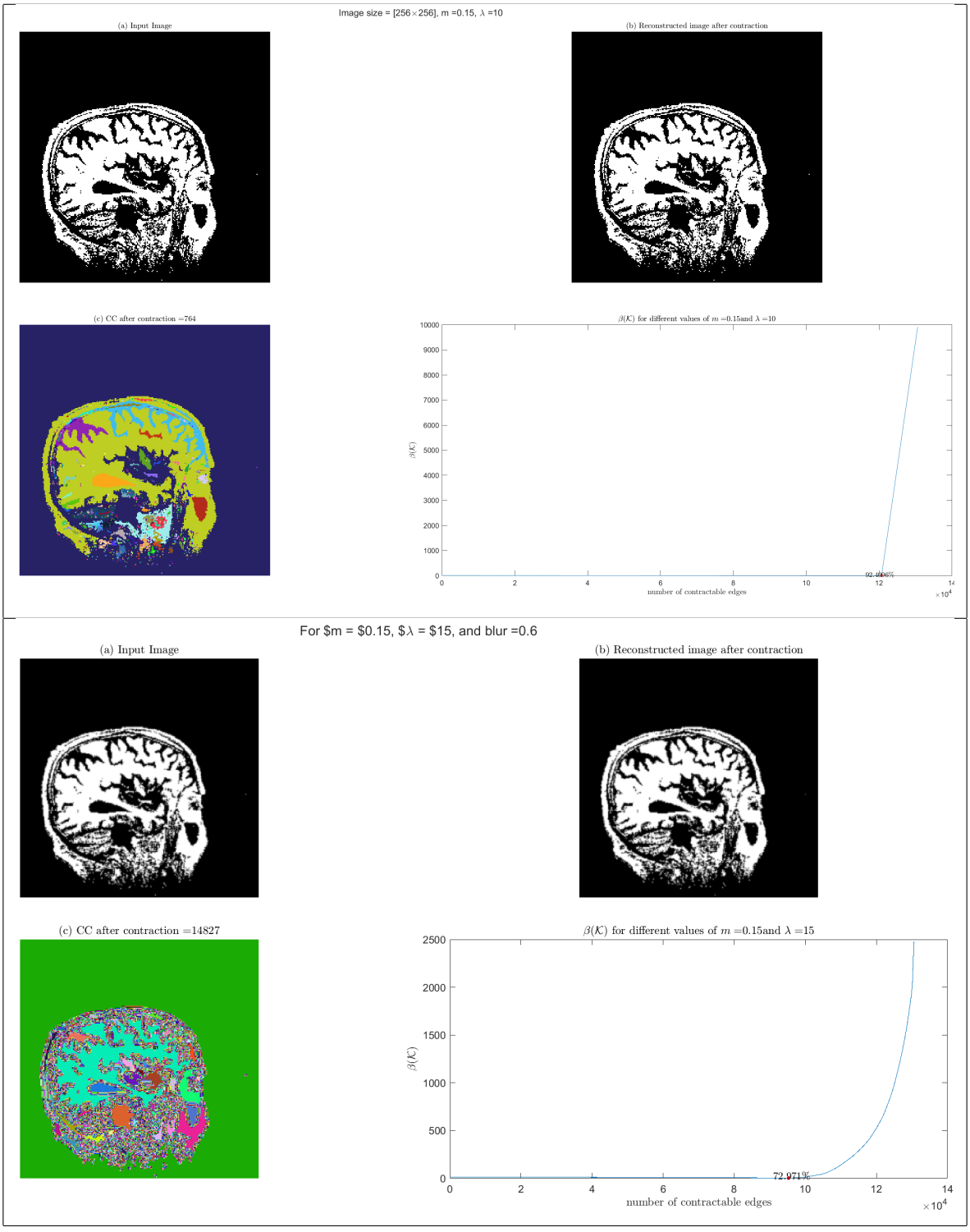
(c) CC after contraction =6205

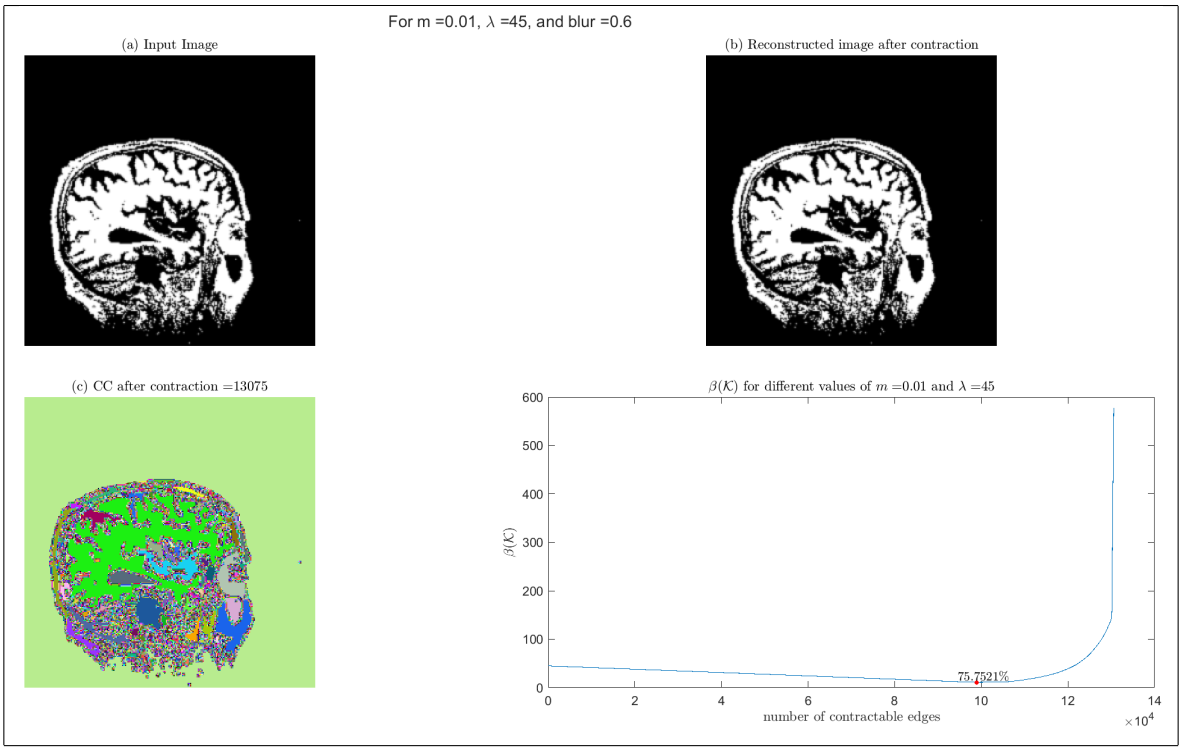


$\beta(\mathcal{K})$ for different values of m =0.01 and λ =45



2.6 Results on MRI images - 2





References

[1] Costantino Grana, Federico Bolelli, Lorenzo Baraldi, and Roberto Vezzani. YACCLAB - Yet Another Connected Components Labeling Benchmark. In *23rd International Conference on Pattern Recognition*. ICPR, 2016.