Gray-scale image data analysis

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I perform image recovery analysis on two different images: hot air balloons image and Lenna image. Gray-scale image data has matrix structure whose entries represent pixel values ranging from 0 to 1. Hot air balloons image consists of a matrix $[0,1]^{217\times 217}$ and Lenna image consists of $[0,1]^{497\times 373}$. I compare our nonparametric regression method (NonparaM) with an alternative method: low rank tensor CP decomoposition (CPT).

1 Hot air balloons image analysis

Figure 1 shows the mean absolute error versus rank under the different missing rates $20\%, 40\%, 60\%$, and 80%. I randomly sampled the entries of image matrix according to the missing rate and performed matrix completion based on CPT and NonparaM method with rank $r = 2, , 4, \ldots, 20$ and $H = 20$. I repeated this analysis 5 times to check the stability of analysis. We see that our method outperforms CPT in all combinations of ranks and missing rates. In addition, our method exhibits a smaller standard error in 5 repeated experiments. One possible explanation is that our method guarantees estimated entries having value in $[0,1]$ while CPT estimation may fall outside the valid range $[0,1]$.

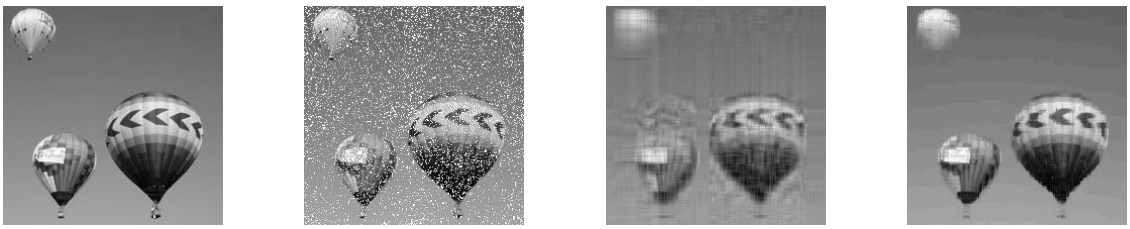
Figure 1: Estimation error versus rank under different missing rates. Panels (a)-(d) correspond to missing rate $20\%, 40\%, 60\%$, and 80%, respectively. Error bar represents the standard error over 5 repeated image recovery under the same conditions.

In this case. choose best (different) r based on MAE.
In the next example. it's fine to choose a common r=10 for all cases.

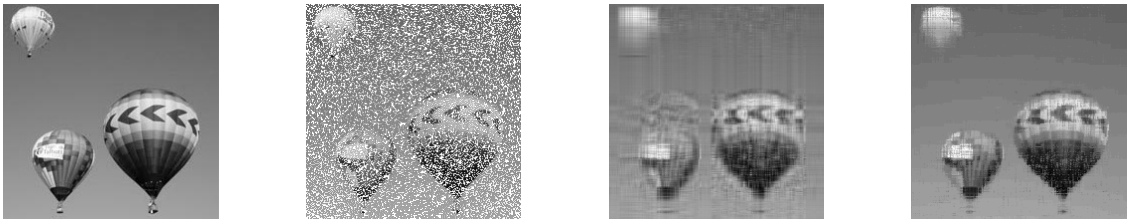
Next, I visualize the output of image matrix completion based on two methods.I set the rank $r = 10$ and resolution parameter $H = 20$ for the analysis. Figure 2 shows the original image, the image with missing entries, and recovered images from CPT and NonparaM. We see that our method has much clearer recovered image and closer to the original image in all missing rates over CPT method.

2 Lenna image analysis

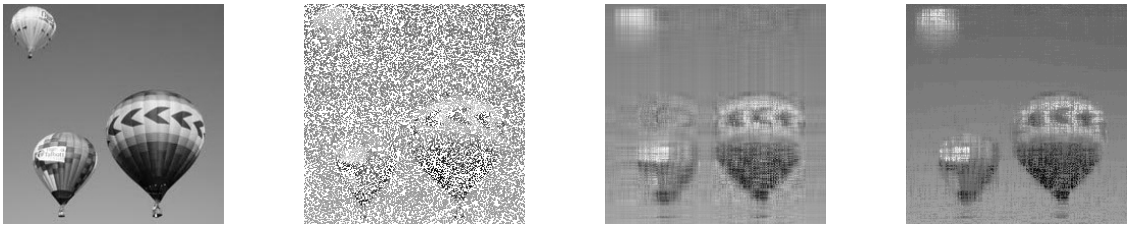
I perform the same image analysis in hot air balloon image data for Lenna image data. Similarly, Lenna image analysis results show outperformance of our method over CPT. Figure 3 shows estimation error versus rank under different missing rates and ranks and follows similar trend with Figure 1. Figure 4 visualizes recovered image under different missing rates and the setting: rank $r = 10$ and resolution parameter $H = 20$.



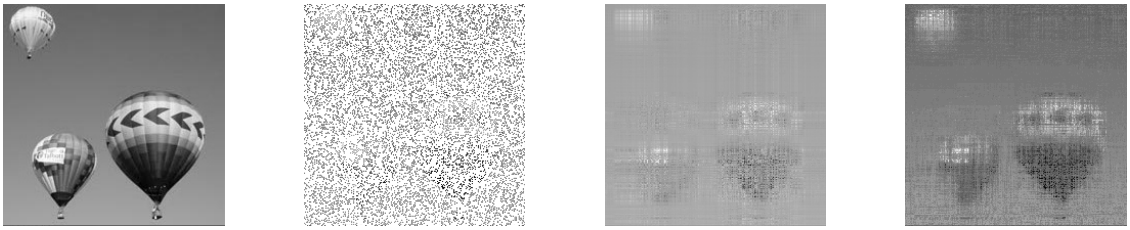
(a) When missing rate is 20%.



(b) When missing rate is 40%.



(c) When missing rate is 60%.



(d) When missing rate is 80%.

Figure 2: Performance of image recovery of our nonparametric regression method (NonparaM) and low rank tensor CP decomposition method (CPT) depending on different missing rates. Figures are original image, image with missing entries, recovered image from CPT, and recovered image from NonparaM in order.

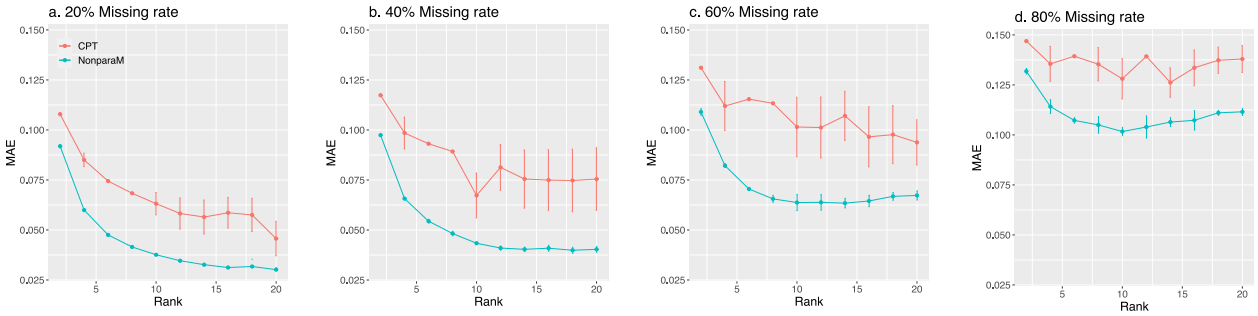


Figure 3: Estimation error versus rank under different missing rates. Panels (a)-(d) correspond to missing rate $20\%, 40\%, 60\%$, and 80%, respectively. Error bar represents the standard error over 5 repeated image recovery under the same conditions.

(a) When missing rate is 20%.

(b) When missing rate is 40%.

(c) When missing rate is 60%.

(d) When missing rate is 80%.

Figure 4: Performance of image recovery of our nonparametric regression method (NonparaM) and low rank tensor CP decomposition method (CPT) depending on different missing rates. Figures are original image, image with missing entries, recovered image from CPT, and recovered image from NonparaM in order.