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q-SNE: Visualizing Data using q-Gaussian Distributed Stochastic Neighbor Embedding

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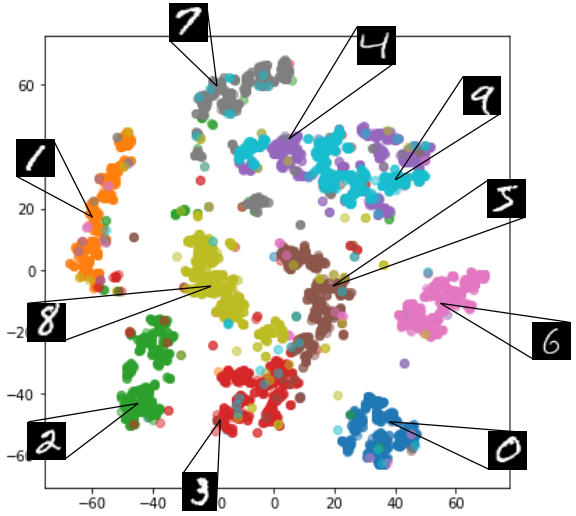
Dimensionality Reduction

Dimensionality reduction technique is used to visualize the data in high-dimensional space

High-dimensional space

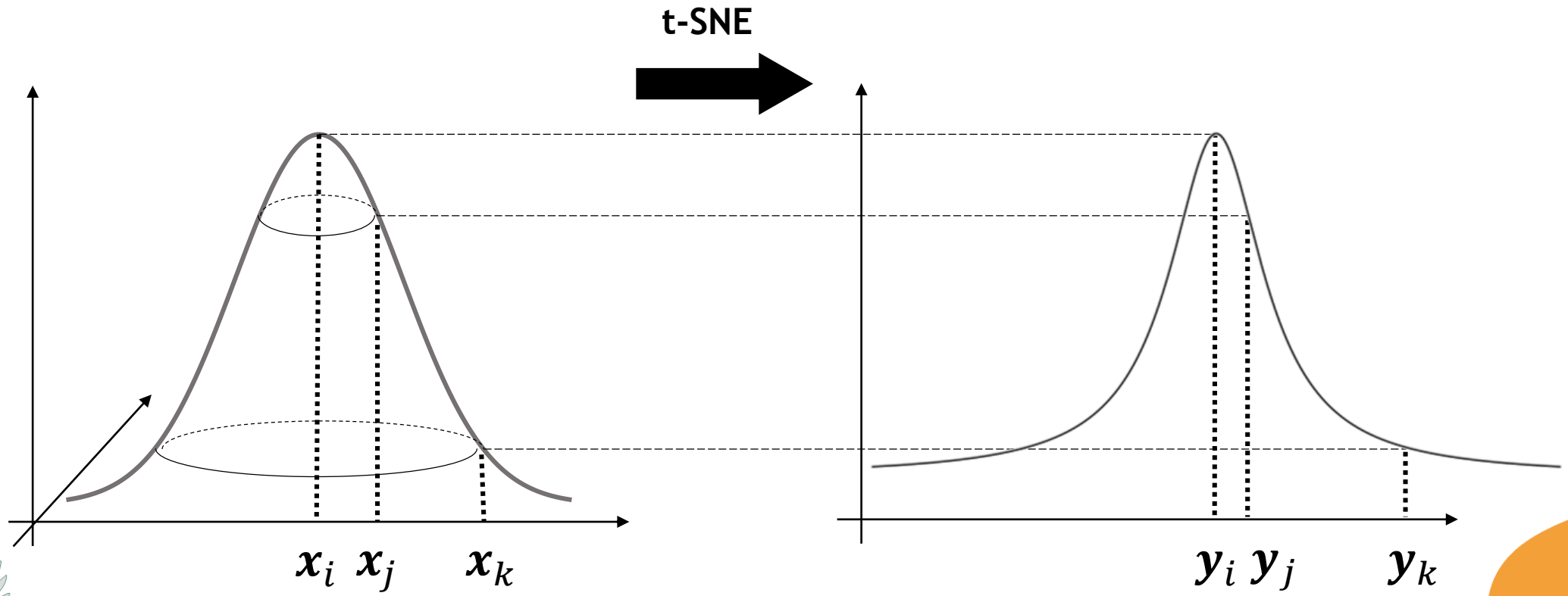
Dimensionality reduction



Low dimensional space

Dimensionality Reduction using t-SNE

- t-distributed stochastic neighbor embedding (t-SNE)
  It is proposed by Hinton et.al (2008) for dimensionality reduction.

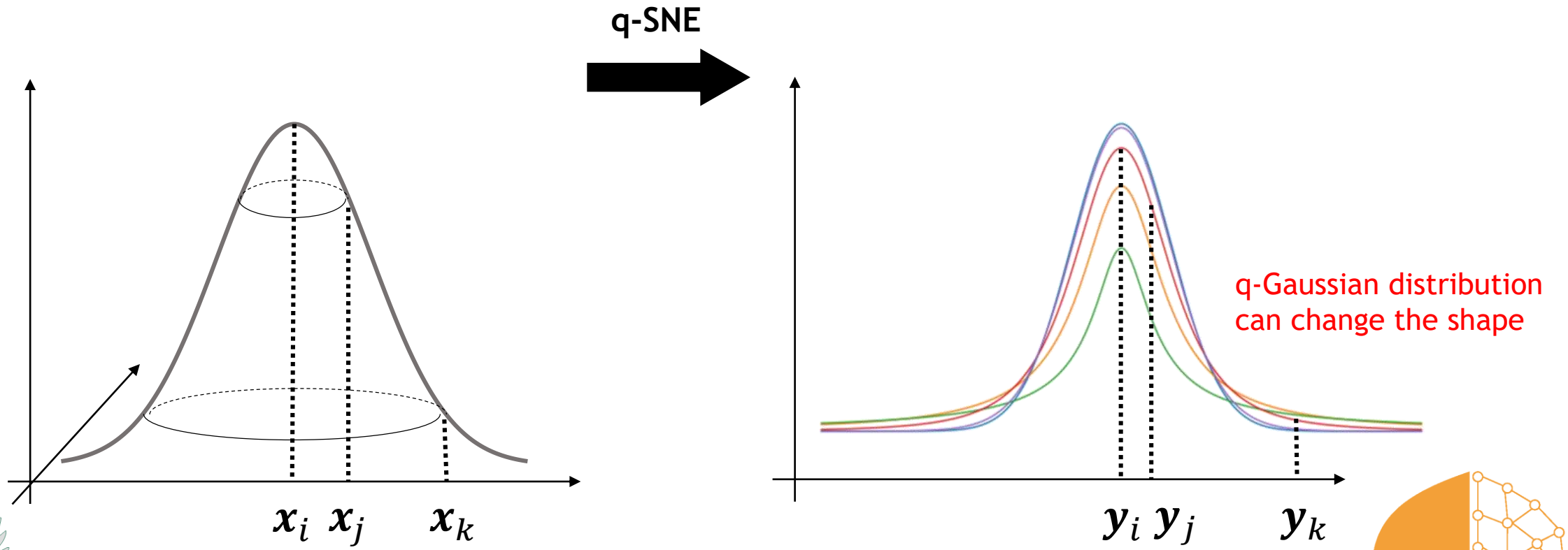


High-dimensional space
based on Gaussian distribution

Low-dimensional space
based on t-distribution

Proposed Dimensionality Reduction q-SNE

- q-Gaussian distributed stochastic neighbor embedding (q-SNE)
  It uses q-Gaussian distribution instead of t-distribution of t-SNE.



High-dimensional space
based on Gaussian distribution

Low-dimensional space
based on q-Gaussian distribution

q-Gaussian Distribution

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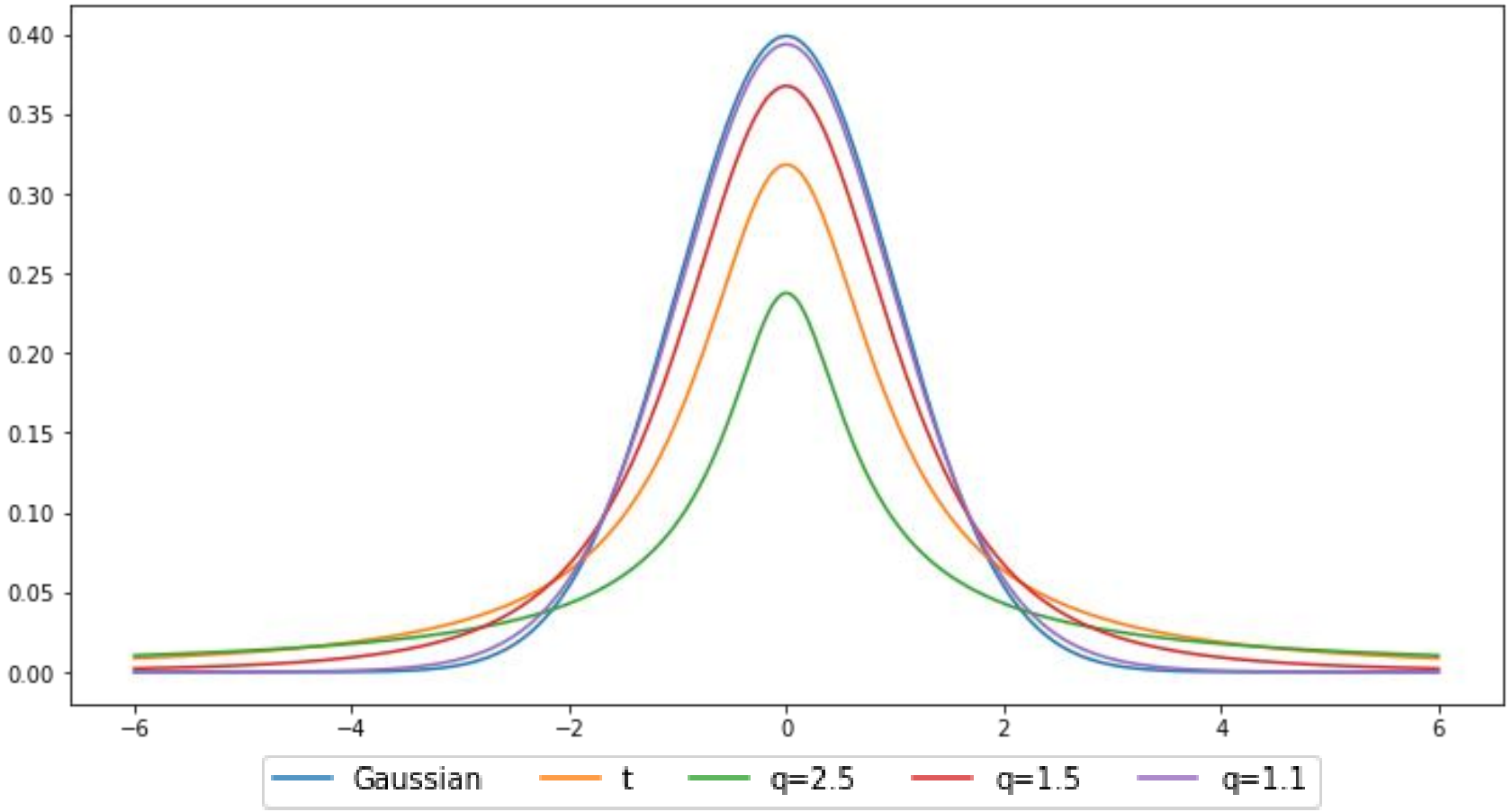
$$P_q(x;\mu,\sigma) = \frac{1}{Z_q}\left(1 + \frac{q-1}{3-q}\frac{(x-\mu)^2}{\sigma^2}\right)^{-\frac{1}{q-1}}, \qquad Z_q = \sqrt{\frac{3-q}{q-1}}\,Beta\left(\frac{3-q}{2(q-1)}, \frac{1}{2}\right)\sigma, \qquad 1 \le q < 3$$



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Loss Function of q-SNE

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$$p_{ij} = \frac{exp\left(-\left\|\boldsymbol{x}_j - \boldsymbol{x}_i\right\|^2 / 2\sigma_i^2\right)}{\sum_l \sum_{k \neq l} exp\left(-\|\boldsymbol{x}_k - \boldsymbol{x}_l\|^2 / 2\sigma_i^2\right)}$$

where σ_i is decided by using perplexity

High-dimensional space
based on Gaussian distribution

$$q_{ij} = \frac{\left(1 + \frac{q-1}{3-q}\left\|\boldsymbol{y}_j - \boldsymbol{y}_i\right\|^2\right)^{-\frac{1}{q-1}}}{\sum_l \sum_{k \neq l}\left(1 + \frac{q-1}{3-q}\|\boldsymbol{y}_k - \boldsymbol{y}_l\|^2\right)^{-\frac{1}{q-1}}}$$

Low-dimensional space
based on q-Gaussian distribution

$$Loss = \sum_i \sum_j p_{ij} \log \frac{p_{ij}}{q_{ij}} = \sum_i KL\left(P_i \| Q_i\right)$$

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Embeddings of High Dimensional Data

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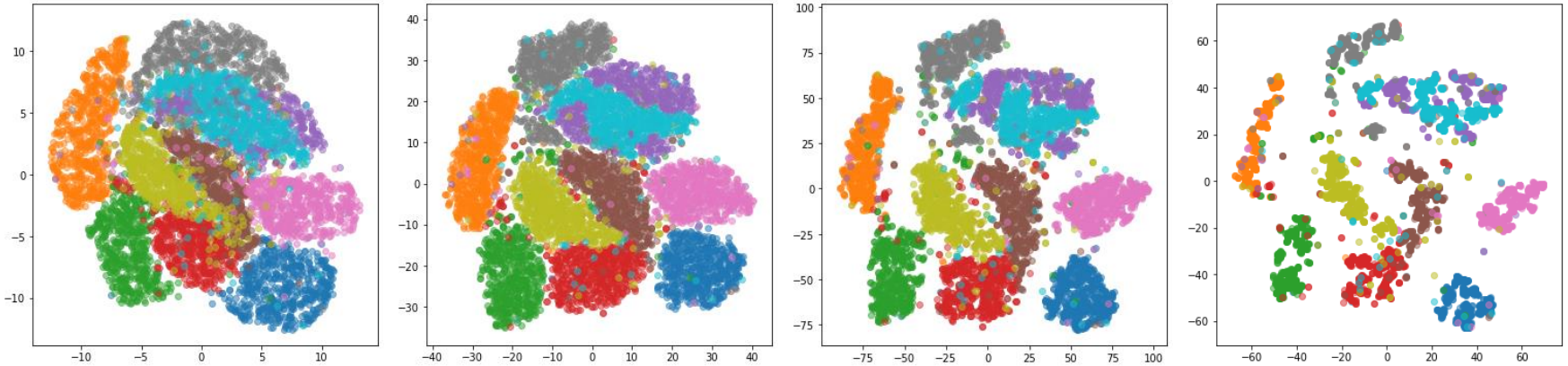
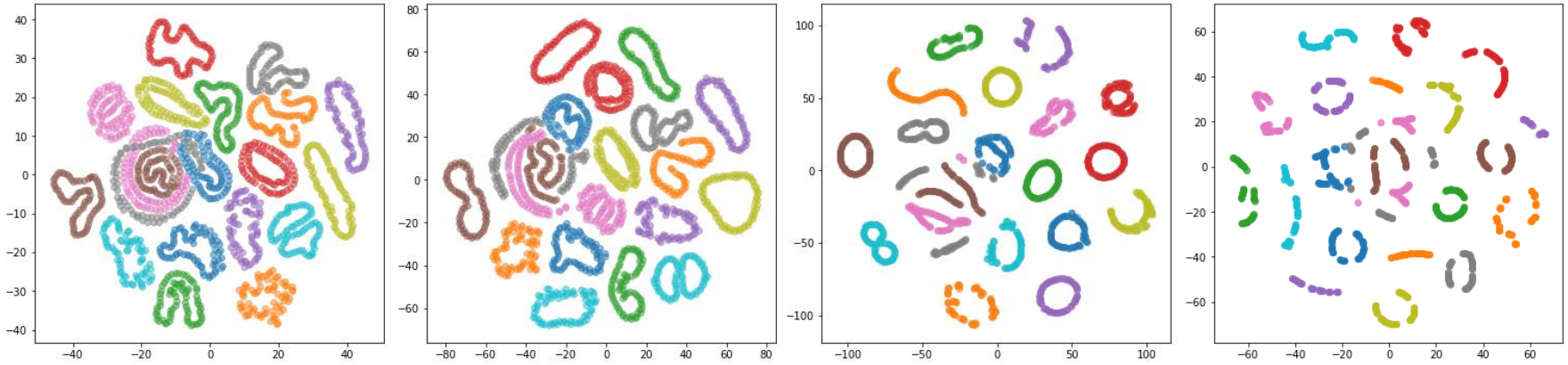
MNIST



$q = 1.1$ $q = 1.5$ $q = 2.0$ (t-SNE) $q = 2.5$

COIL20



$q = 1.1$ $q = 1.5$ $q = 2.0$ (t-SNE) $q = 2.5$

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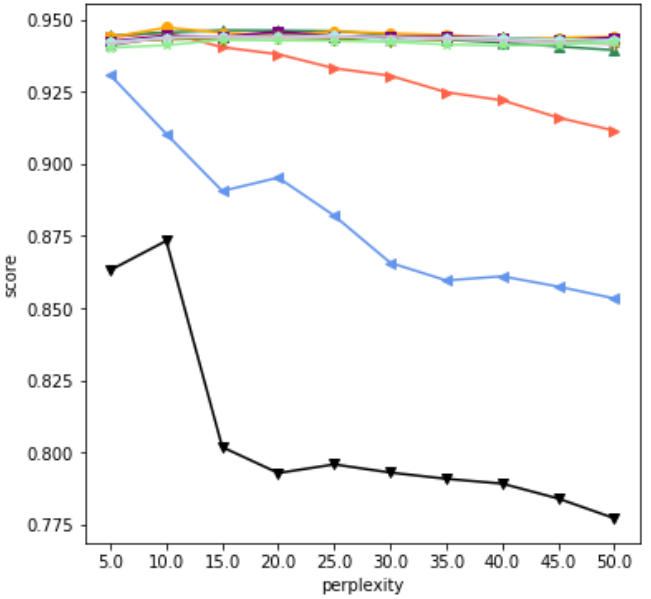
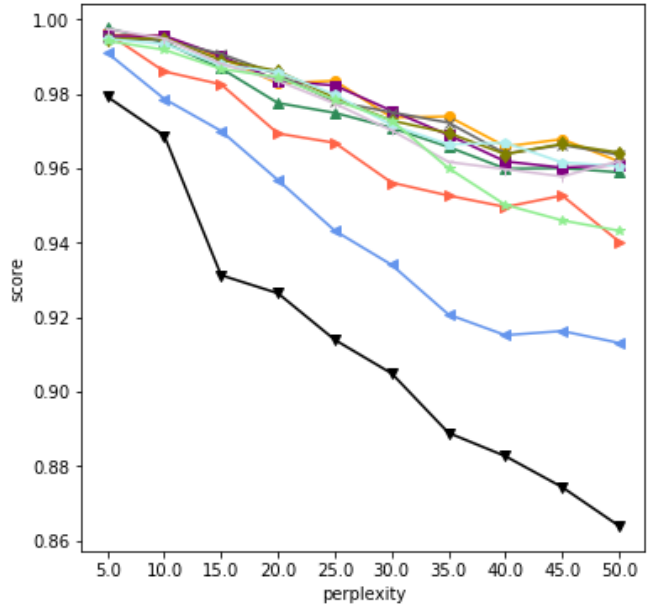
k Nearest Neighbor Accuracy on Embedding

- Hyperparameter
  - k=10 (k nearest neighbor)
- Dataset
  - MNIST
  - COIL-20
  - OlivettiFaces
  - FashionMNIST
- Comparison techniques
  - SNE [E. Hinton et.al 2003]
  - t-SNE [E. Hinton et. al 2008]

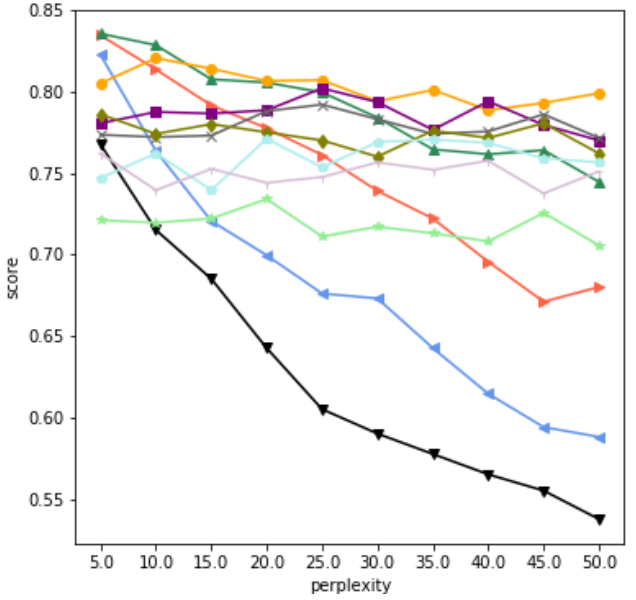
MNIST



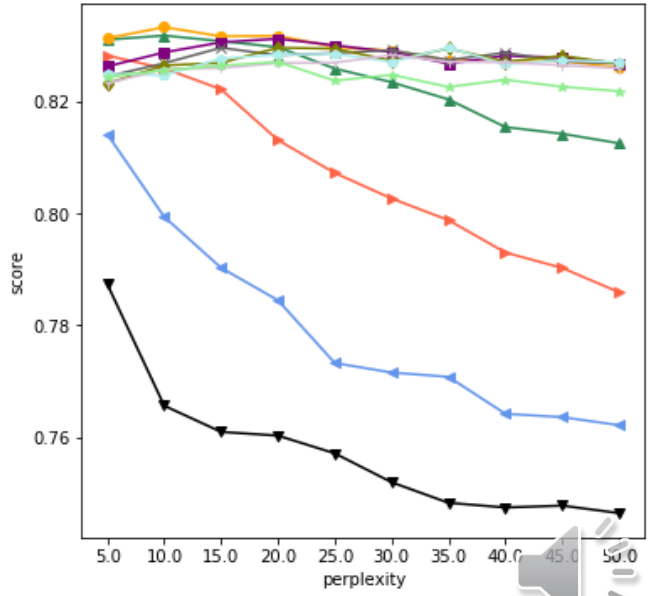
COIL-20

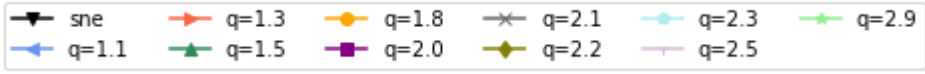


OlivettiFaces



FashionMNIST





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Conclusions

- We propose a novel dimensionality technique called q-Gaussian distributed stochastic neighbor embedding (q-SNE).
- The q-SNE uses q-Gaussian distribution in low-dimensional space.
- It can make better visualization by setting the hyperparameter q of q-Gaussian distribution.
- Through our experiments using k nearest neighbor, the q-SNE can win the classification accuracy on the embedding space.

Code on Python is here

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