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MoA+: Mixture of Autoencoders with Various Concentrations for Enhanced Image Clustering

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In this paper, we consider the improvement of the vanilla Mixture of Experts model [1] for unsupervised image clustering by introducing a mixture with various concentrations. This addresses expert dominance, enhancing training balance and clustering performance.

The model is tested on the MNIST dataset, a benchmark of n grayscale handwritten digit images $X_i, i = 1..n$, treated as a mixture with $M = 2$ components. Mixing probabilities are given by the matrix $P_n = (p_{i:n}^k)_{i=1,k=1}^{n,M}$, where $p_{i:n}^k$ is the probability of the image i to belong to component k. Minimax weights are defined as $A_n = (a_{i:n}^k)_{i=1,k=1}^{n,M} = P_n(P_n^T P_n)^{-1} = P_n^T(\Gamma_n)^{-1}$ [2].

In the MoA+ framework, each expert is a convolutional autoencoder (CAE), similar to simplified U-Net or SegNet, where image X_i is reconstructed into image $\hat{X}_{i,k}$ using k-th CAE with MSE error. A convolutional gate network assigns probabilities $p_{i:n}^k$, clustering images by selecting the most suitable CAE.

To address expert imbalance, MoA+ uses a modified loss function inspired by k-means, incorporating weights $a_{i:n}^k$:

$$\text{loss} = \sum_{k=1}^{M}\sum_{i=1}^{n} a_{i:n}^k (X_i - \hat{X}_{i,k})^2 \le \sqrt{\sum_{k=1}^{M} \frac{1}{\lambda_k^2}} \sqrt{\sum_{k=1}^{M} \left(\sum_{i=1}^{n} p_{i:n}^k (X_i - \hat{X}_{i,k})^2 \right)^2}$$

where λ_k are eigenvalues of matrix $\Gamma_n = P_n^T P_n$.

This regularizes the gate network, balancing expert contributions by minimax nature of λ_k.

Compared under identical conditions, the standard MoA achieved a Normalized Mutual Information (NMI) of ~ 0.08, while MoA+ scored ~ 0.8, showing significantly better clustering performance.

References

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