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MoA+: Mixture of Autoencoders with Varying 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 varying 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 $X_i, i = \overline{1, n}$, treated as a mixture with $M = 2$ components.

In the MoA+ framework, each trainable 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 trainable convolutional gate network assigns mixing probabilities $P_n = (p_{i:n}^k)_{i=1,k=1}^{n,M}$, where $p_{i:n}^k$ is the probability of the image i to belong to component k, clustering images by selecting the most suitable CAE.

To address expert imbalance, MoA+ uses a modified loss function inspired by k-means, incorporating minimax weights $A_n = (a_{i:n}^k)_{i=1,k=1}^{n,M} = (P_n^T P_n)^{-1} P_n = (\Gamma_n)^{-1} P_n$ [2]:

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

where λ_k are eigenvalues of matrix Γ_n. This regularizes the gate network, balancing expert contributions.

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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