Vitaliy Miroshnychenko[1], Vadym Tunik[2]

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

Taras Shevchenko National University of Kyiv, Kyiv, Ukraine.

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.

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 $P_n = (p^k_{i:n})^{n,M}_{i=1,k=1}$, where $p^k_{i:n}$ 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 $A_n = (a^k_{i:n})^{n,M}_{i=1,k=1} = (P_n^T P_n)^{-1} P_n = (\Gamma_n)^{-1} P_n$ [2].

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

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

[1] R. A. Jacobs, M. I. Jordan, S. J. Nowlan and G. E. Hinton, "Adaptive Mixtures of Local Experts," in Neural Computation, vol. 3, no. 1, pp. 79-87, March 1991, doi: 10.1162/neco.1991.3.1.79.

[2] Miroshnichenko V., Maiboroda R. "Asymptotic normality of modified LS estimator for mixture of nonlinear regressions". Modern Stochastics: Theory and Applications, Vol.7, Iss.4 pp. 435 - 448, - 2020

E-mail: ✉[1] *vitaliy.miroshnychenko@knu.ua,* ✉[2] *tunik.vadym@knu.ua.*