POLSAR Image Classification via Clustering-WAE Classification Model

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November 13, 2019

Introduction

POLSAR - Plarimetric Synthetic Aperture Radar

- multi-channel and multi-parameter imaging radar system
- based on AE and embeded with k-means clustering.

WAE - Wishart Auto Encoder

- used for redudcing error between input and output via wishart distance
- based on auto encoder model and embeded with k-means clustering

WAE Classification Model

Wishart Distance:

$$\min_{W,b} \frac{1}{2N} \sum_{i=1}^{N} d_{Wishart} \left(H \left(y_i \right), H \left(x_i \right) \right) \quad (1)$$

where,

$$d_{Wishart} \left(H \left(y_i \right), H \left(x_i \right) \right) = Tr \left(H(x_i)^{(-1)} H \left(y_i \right) \right) + \ln \left| H \left(x_i \right) \right|$$

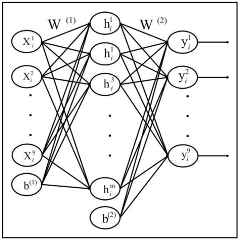

Figure: The structure of WAE network.

Brief Review on AE Based Data Clustering

AE Network and K-means Clstering:

$$\min_{W,b} \frac{1}{N}\sum_{i=1}^{N}\|x_i - y_i\|^2 + \lambda\sum_{i=1}^{N}\left\|f^t(x_i) - c_i^*\right\|_F^2$$

$$c_i^* = \arg\min_{c_j^{t-1}}\left\|f^t(x_i) - c_j^{t-1}\right\|_F^2 \quad (2)$$

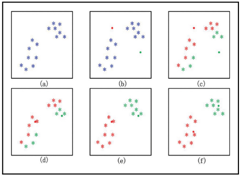

Figure: The schematic of K-means algorithm.

Otimization:

$$c_j^t = \frac{\sum_{x_i \in C_j^{t-1}} f^t(x_i)}{\left|C_j^{t-1}\right|} \quad (3)$$

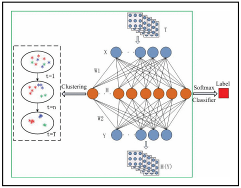

Figure: Framework of the our proposed method.

CLUSTERING-WAE CLASSIFICATION MODEL

$$\langle T_i \rangle = \begin{bmatrix} T_i^{11} & T_i^{12} & T_i^{13} \\ T_i^{21} & T_i^{22} & T_i^{23} \\ T_i^{31} & T_i^{32} & T_i^{33} \end{bmatrix} \rightarrow x_i = \left[x_i^1, x_i^2, x_i^3, x_i^4, x_i^5, x_i^6, x_i^7, x_i^8, x_i^9\right] \tag{4}$$

$$\begin{gathered} \min_{W,b} \frac{1}{2N} \sum_{i=1}^{N} d_{Wishart}\left(H\left(y_i\right), H\left(x_i\right)\right) + \lambda \sum_{i=1}^{N} \left\| h_i^t - c_i^* \right\|_F^2 \\ c_i^* = \arg\min_{c_j^{t-1}} \left\| h_i^t - c_j^{t-1} \right\|_F^2 \end{gathered} \tag{5}$$

$$c_j^t = \frac{\sum_{x_i \in C_j^{t-1}} h_i^t}{\left| C_j^{t-1} \right|} \qquad (6)$$

Softmax Equation:

$$P\left(l = j | h_i; \theta\right) = \frac{\exp^{h_i^T \theta_j}}{\sum_{k=1}^{K} \exp^{h_i^T \theta_k}} \qquad (7)$$

Table: Detailed Steps of Algorithm

Algorithm 1: Clustering-WAE classification model

Input: The training samples $X = [x_1, x_2, ..., x_i, ..., x_N]$ of POLSAR image, the label of training samples: $Y = [y_1, y_2, ..., y_i, ..., y_N]$, the number of class K, the maximum number of iterations T.

Step1: Initialize the weights $W^{(1)}$ and $W^{(2)}$ of WAE network to get the hidden representation $H^0 = [h_1^0, h_2^0, ..., h_i^0, ..., h_N^0]$ of training samples X, choose1% training sample to initialize the K cluster center $C^0 = [c_1^0, c_2^0, ..., c_K^0]$.

while $t \leq T$ **do**

Step2: Use the improved BP algorithm of function (8) to optimize the objective function (5).

$$\min_{W,b} \frac{1}{2N} \sum_{i=1}^{N} d_{Wishart}\left(H\left(y_i\right), H\left(x_i\right)\right) + \lambda \sum_{i=1}^{N} \left\| h_i^t - c_i^* \right\|_F^2 \qquad (5)$$

$$c_i^* = \arg\min_{c_j^{t-1}} \left\| h_i^t - c_j^{t-1} \right\|_F^2$$

$$W^1 = W^1 - \alpha \left(\frac{\partial}{\partial W^1} d_{Wishart}\left(H\left(y_i\right), H\left(x_i\right)\right) + \frac{\partial}{\partial W^1} \left\| h_i^t - c_j^{t-1} \right\|_F^2 \right)$$

$$W^2 = W^2 - \alpha \frac{\partial}{\partial W^2} d_{Wishart}\left(H\left(y_i\right), H\left(x_i\right)\right) \qquad (8)$$

Step3: With the Clustering-WAE network, we could obtain the hidden representations H^t of training samples, and recalculate the cluster center C^t of Eq.(6).

$$c_j^t = \frac{\sum_{x_i \in C_j^{t-1}} h_i^t}{\left| C_j^{t-1} \right|} \qquad (6)$$

Step4: Use the hidden representations of training samples as the input of Softmax classifier in order to train the classifier of Eq.(7).

$$P\left(l = j | h_i; \theta\right) = \frac{\exp^{h_i^T \theta_j}}{\sum_{k=1}^{K} \exp^{h_i^T \theta_k}} \qquad (7)$$

end while

Step5: Use the optimized Clustering-WAE classification model to classify

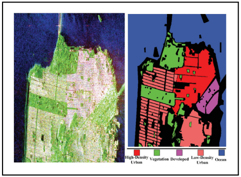

Figure: Pauli RGB and ground-truth image of San Francisco.

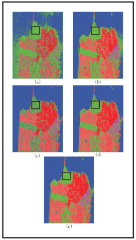

Figure: Classification results of different methods: K-means, Wishart, AE, WAE, and Clustering-WAE.

Table: Classification performances of San Francisco with different methods.

	K-means	*Wishart*	*AE*	*WAE*	*Clustering-WAE*
High-density	29.95	49.63	**66.22**	65.44	65.19
Water	75.76	97.13	**99.90**	99.83	99.73
Vegetation	38.82	**92.62**	68.47	83.57	80.32
Developed	55.97	57.84	57.18	65.99	**68.39**
Low-density	**92.63**	74.20	73.63	80.27	89.43
OA	66.50	83.33	84.08	87.44	**88.53**
Kappa	0.53	0.75	0.75	0.82	**0.83**