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Topic-Modeling Guided Semantic Clustering for Enhancing CNN-Based Image Classification using Scale-Invariant Feature Transform and Block Gabor Filtering

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Abstract

This study proposes a topic-modeling-guided framework to enhance CNN-based image classification through semantic clustering prior to model training. Images are transformed into visual documents using local descriptors derived from either Scale-Invariant Feature Transform (SIFT) with Sobel edge detection or Block Gabor Filtering (BGF). Latent Dirichlet Allocation (LDA) is applied to identify latent topics and generate semantically coherent clusters, followed by cluster-specific CNN training. Two topic-guided integration strategies, namely Maximum Proportion Topic (MPT) and Weight Proportion Topic (WPT), are used to associate test images with specialized models. Experiments on the Brain Tumor 256×256 dataset demonstrate that the proposed framework consistently outperforms non-clustered CNN training (91.79%) and baseline clustering methods based on IPCA and K-means (91.89% and 71.25%). The highest accuracy of 95.24% is achieved by the SIFT-based pipeline with MPT, while the BGF-based pipeline reaches 93.76% using WPT. These findings confirm that incorporating latent semantic structure via topic modeling significantly improves classification performance.

Keywords: Image Clustering; Latent Dirichlet Allocation; Convolution Neural Network; Block Gabor Filtering; Scale-Invariant Feature Transform

Introduction

Image classification remains a fundamental task in computer vision. Recent advances in deep learning, particularly convolutional neural networks (CNNs), have dramatically improved classification accuracy. However, conventional CNN training typically treats all images as independent and equally weighted samples, which may fail to capture the latent semantic structure inherent in complex datasets. Images often contain heterogeneous visual content, where local patterns and contextual cues contribute unequally to semantic categories. To address this challenge, topic-modeling techniques such as Latent Dirichlet Allocation (LDA) offer a promising approach for discovering underlying semantic structures and grouping images into coherent clusters.

Methodology / Proposed Approach

This work proposes a hybrid approach that integrates LDA with CNN models for image classification. The dataset used in this study are publicly available data on Kaggle, namely the Brain Tumors 256×256, consisting of 3,096 images with 4 classes, such as normal, glioma, meningioma, and pituitary. In this work, we split training and testing set into 80:20. The proposed method first transforms each image into a document representation composed of visual words prior to clustering. Two experimental setups are conducted using different key-point extraction techniques: (1) Scale-Invariant Feature Transform (SIFT) combined with Sobel edge detection, and (2) Block Gabor Filtering (BGF). In this study, the BGF was configured with 4 scales and 8 orientations, following the experimental settings reported by Yibing Ma (Ma et al., 2016). These descriptors

are clustered via K-means to construct a visual vocabulary, after which Bag-of-Words representations are generated to model each image as a visual document. The resulting document representations are analyzed using LDA to extract latent topics. The optimal number of topics, determined via coherence score, is set to 7 for SIFT-based features and 5 for BGF-based features. With hyperparameters $\alpha = \beta = 0.001$ and 25 iterations, each image was assigned to the cluster corresponding to its dominant topic. To ensure a fair and comprehensive performance assessment, the proposed method is compared against a baseline clustering approach based on Incremental Principal Component Analysis (IPCA) and K-means.

After the image clustering stage, the training images within each cluster are used to train multiple CNN architectures, including AlexNet, GoogLeNet (Inception v1), and several ResNet variants (ResNet18, ResNet34, ResNet50, ResNet101, and ResNet152). For both the proposed and baseline methods, a learning rate of 0.001 and 15 training epochs are applied. The corresponding test images are then employed to evaluate model performance and select the best-performing model for each cluster. These selected models are subsequently integrated into a unified framework. For the proposed method, both the SIFT-based and BGF-based approaches employ two topic-guided model integration techniques: Maximum Proportion Topic (MPT) and Weight Proportion Topic (WPT). In contrast, the baseline clustering method applies two ensemble strategies, namely same-cluster model prediction and unweighted ensemble voting.

Experimental Results & Discussion

	non-clustered (ResNet152)	Baseline (Same-Cluster)	Baseline (Voting)	SIFT (MPT)	SIFT (WPT)	BGF (MPT)	BGF (WPT)
Accuracy	91.79%	91.89%	71.25%	95.24%	94.91%	93.43%	93.76%

The proposed framework was compared with non-clustered CNN training and a baseline clustering approach. The non-clustered ResNet152 achieved 91.79% accuracy, while baseline same-cluster prediction reached 91.89% and unweighted voting dropped to 71.25%. In contrast, the topic-guided framework consistently performed better. The SIFT-based pipeline achieved the highest accuracy of 95.24% using the MPT strategy, while the BGF-based pipeline reached 93.76% at best. These results indicate that LDA-based semantic clustering improves class separability and enhances downstream CNN performance. The superior performance of SIFT suggests that local gradient-based descriptors align more effectively with topic modeling. Overall, topic-guided integration provides more reliable predictions than same-cluster model prediction and unweighted ensemble voting strategies.

Conclusion

This study proposed a topic-modeling-guided framework for image classification that integrates LDA-based semantic clustering with cluster-specific CNN training and topic-guided model integration. Experimental results indicate that incorporating latent semantic structure prior to CNN training consistently improves performance compared with non-clustered CNN and traditional clustering baselines. The findings reveal three key contributions. First, LDA-derived topic distributions provide meaningful structural information that enhances downstream deep learning performance. Second, local descriptors such as SIFT align more effectively with topic modeling than BGF. Third, the proposed topic-guided integration strategies offer a principled mechanism for model selection and prediction weighting, outperforming conventional ensemble approaches. These results establish that topic distributions can serve not only for clustering but also as effective guidance for cluster-specific deep model training and inference.

References

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BEST PRESENTATION AWARD

SESSION S6

**TOPIC-MODELING GUIDED SEMANTIC CLUSTERING FOR ENHANCING
CNN-BASED IMAGE CLASSIFICATION USING SCALE-INVARIANT FEATURE TRANSFORM
AND BLOCK GABOR FILTERING**

BY

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AND JESSADA TANTHANUCH**

in The 7th Asia Joint Conference on Computing and Electrical Technologies (AJCC 2026)

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