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A Robust Hybrid Feature Extraction Technique for Enhancing Image Classification Accuracy

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Abstract: - Image classification is a fundamental task in computer vision with wide-ranging applications including medical diagnosis, remote sensing, surveillance, and multimedia retrieval. The performance of image classification systems largely depends on the quality of extracted features, which must be discriminative, robust to noise, and computationally efficient. Traditional feature extraction methods often struggle to capture both global structural information and fine-grained local patterns simultaneously. To address this limitation, this paper proposes a robust hybrid feature extraction technique that integrates complementary feature descriptors to enhance image classification accuracy. The proposed approach combines texture-based, shape-based, and statistical features into a unified feature representation. Local Binary Patterns (LBP) are employed to capture local texture information, Histogram of Oriented Gradients (HOG) is used to represent shape and edge structures, and statistical color moments are utilized to describe global image characteristics. Feature normalization and dimensionality reduction are applied to improve efficiency and reduce redundancy. The resulting hybrid feature vector is evaluated using standard classifiers, including Support Vector Machines (SVM) and k-Nearest Neighbors (k-NN). Experimental results on benchmark image datasets demonstrate that the proposed hybrid feature extraction technique significantly outperforms individual feature-based methods in terms of classification accuracy, robustness, and generalization capability. The findings confirm that combining complementary features provides a more comprehensive image representation, leading to improved classification performance..

***Keywords**: - Image classification, feature extraction, hybrid features, texture analysis, machine learning, computer vision.*

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1. Introduction

Image classification plays a crucial role in numerous computer vision and pattern recognition applications. It involves assigning semantic labels to images based on their visual content. With the exponential growth of digital image data, there is an increasing demand for accurate and efficient image classification systems. Applications such as medical image analysis, facial recognition, autonomous driving, remote sensing, and industrial inspection rely heavily on reliable classification techniques.

Despite significant progress in classification algorithms, feature extraction remains one of the most critical stages in an image classification pipeline. Features serve as numerical representations of visual information and directly influence the performance of classifiers. An ideal feature extraction method should be invariant to illumination changes, scale variations, rotation, and noise, while also being computationally efficient.

Traditional feature extraction techniques can be broadly categorized into texture-based, shape-based, and color-based approaches. Texture features capture local patterns and surface properties, shape features describe object boundaries and structural information, and color features represent global image characteristics. While each category has its strengths, relying on a single type of feature often results in limited performance, particularly for complex and diverse image datasets.

Recent research trends emphasize the use of hybrid feature extraction techniques that combine multiple feature descriptors to leverage their complementary strengths. Hybrid approaches aim to capture both local and global information, resulting in richer and more discriminative representations. However, designing an effective hybrid feature extraction framework requires careful selection, integration, and normalization of features to avoid redundancy and excessive computational cost.

This paper proposes a robust hybrid feature extraction technique that integrates texture, shape, and statistical features to enhance image classification accuracy. The motivation behind this work is to develop a feature representation that is comprehensive, robust, and adaptable to various image classification tasks. The proposed method combines Local Binary Patterns (LBP) for texture analysis, Histogram of Oriented Gradients (HOG) for shape representation, and color moments for capturing global statistical properties.

The main contributions of this paper are as follows:

1. A robust hybrid feature extraction framework that integrates complementary feature descriptors.
2. A systematic approach for feature normalization and dimensionality reduction.
3. A comprehensive evaluation demonstrating improved classification accuracy over single-feature methods.

The remainder of this paper is organized as follows. Section 2 reviews related work in image feature extraction and hybrid approaches. Section 3 describes the proposed hybrid feature extraction methodology. Section 4 outlines the experimental setup and classification framework. Section 5 presents and discusses the results. Section 6 concludes the paper and suggests future research directions.

2. Related Work

Feature extraction has been extensively studied in the field of computer vision. Early image classification systems relied heavily on handcrafted features such as color histograms, edge detectors, and texture descriptors. These methods provided interpretable and computationally efficient solutions but often lacked robustness in complex scenarios.

Texture-based feature extraction methods, such as Gray Level Co-occurrence Matrix (GLCM), Local Binary Patterns (LBP), and Gabor filters, have been widely used due to their effectiveness in capturing local patterns. LBP, in particular, has gained popularity because of its simplicity and robustness to illumination changes. However, texture features alone may fail to capture global structural information, limiting their discriminative power.

Shape-based features, including Histogram of Oriented Gradients (HOG), Scale-Invariant Feature Transform (SIFT), and Speeded-Up Robust Features (SURF), focus on edge orientation and object structure. HOG has been successfully applied in object detection and recognition tasks due to its ability to represent local shape information. Nevertheless, shape-based features may be sensitive to background clutter and noise.

Color-based features, such as color histograms and color moments, provide valuable global information and are particularly useful in applications where color plays a significant role. However, color features alone are insufficient for tasks requiring fine-grained texture or shape discrimination.

To overcome the limitations of single-feature approaches, researchers have explored hybrid feature extraction techniques. These methods combine multiple feature descriptors to capture complementary information. Studies have shown that hybrid features often outperform individual descriptors, especially in complex classification tasks. However, challenges remain in effectively integrating features while maintaining computational efficiency.

With the rise of deep learning, convolutional neural networks (CNNs) have demonstrated remarkable performance in image classification by automatically learning hierarchical features. Despite their success, deep learning models require large labeled datasets and significant computational resources. In contrast, handcrafted hybrid feature extraction techniques remain attractive for applications with limited data and resource constraints.

This paper builds upon existing hybrid feature extraction research by proposing a robust and efficient framework that integrates texture, shape, and statistical features, achieving improved classification performance without the need for extensive training data.

3. Proposed Hybrid Feature Extraction Technique

3.1 Overview

The proposed hybrid feature extraction technique aims to create a comprehensive representation of images by combining complementary features. The framework consists of four main stages: preprocessing, feature extraction, feature fusion, and feature normalization. Figure 1 illustrates the overall architecture of the proposed system.

3.2 Image Preprocessing

Preprocessing is a crucial step to enhance image quality and reduce noise. In the proposed approach, images are resized to a uniform resolution to ensure consistency across the dataset. Noise reduction is performed using a Gaussian filter, and color images are converted to grayscale where necessary for texture and shape feature extraction.

3.3 Texture Feature Extraction Using LBP

Local Binary Patterns (LBP) are used to capture local texture information. LBP encodes the relationship between a pixel and its neighbors by thresholding neighborhood values against the center pixel. The resulting binary patterns are converted into decimal values and represented as histograms. LBP is computationally efficient and robust to illumination variations, making it suitable for texture analysis.

3.4 Shape Feature Extraction Using HOG

Histogram of Oriented Gradients (HOG) is employed to capture shape and edge information. HOG computes gradient orientations and magnitudes, which are aggregated into histograms over local regions. These histograms provide a robust representation of object shapes and structural details. HOG features complement LBP by focusing on edge and contour information.

3.5 Statistical Feature Extraction Using Color Moments

Color moments are used to describe the global statistical properties of images. The first three moments—mean, variance, and skewness—are computed for each color channel. These moments effectively summarize color distributions and provide additional discriminative information.

3.6 Feature Fusion and Normalization

The extracted LBP, HOG, and color moment features are concatenated to form a hybrid feature vector. To address differences in feature scales and reduce redundancy, feature normalization is applied using min-max scaling. Principal Component Analysis (PCA) is optionally employed to reduce dimensionality while preserving discriminative information.

4. Classification Framework and Experimental Setup

4.1 Dataset Description

The proposed method is evaluated on standard benchmark image datasets commonly used for classification tasks. These datasets contain images from multiple categories with varying illumination, background complexity, and object appearance.

4.2 Classifiers

Two widely used classifiers are employed to evaluate the effectiveness of the proposed hybrid feature extraction technique:

- **Support Vector Machine (SVM):** Known for its strong generalization capability and effectiveness in high-dimensional spaces.
- **k-Nearest Neighbors (k-NN):** A simple yet effective distance-based classifier.

4.3 Performance Metrics

Classification performance is evaluated using accuracy, precision, recall, and F1-score. These metrics provide a comprehensive assessment of classifier performance.

5. Results and Discussion

Experimental results demonstrate that the proposed hybrid feature extraction technique consistently outperforms individual feature-based approaches. The integration of texture, shape, and statistical features leads to improved classification accuracy and robustness. SVM achieves higher accuracy compared to k-NN, particularly in complex datasets.

The results highlight the effectiveness of feature fusion in capturing diverse visual information. The proposed approach also shows good generalization capability, making it suitable for various image classification applications.

6. Conclusion and Future Work

This paper presented a robust hybrid feature extraction technique for enhancing image classification accuracy. By integrating LBP, HOG, and color moment features, the proposed method captures complementary information, resulting in improved classification performance. Experimental results confirm the effectiveness of the hybrid approach compared to single-feature methods.

Future work will focus on integrating deep learning-based features with handcrafted descriptors, optimizing feature selection, and extending the framework to real-time and large-scale image classification tasks.

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