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HYBRID LIGHTWEIGHT AI MODELS FOR ACCURATE IMAGE FORGERY DETECTION

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ABSTRACT

The rapid growth of digital image editing tools and social media platforms has significantly increased the spread of manipulated and forged images, creating serious concerns regarding information authenticity and security. Image forgery detection has therefore become an important research area in digital forensics. This paper presents an efficient approach for image forgery detection based on the fusion of lightweight deep learning models. The proposed system combines multiple lightweight convolutional neural network architectures to improve detection accuracy while maintaining low computational complexity and faster processing speed. The fusion strategy enables the extraction of complementary spatial and texture-based features from suspicious images, allowing the system to effectively identify tampered regions and manipulated content.

The framework is designed to detect common image forgery techniques such as copy-move forgery, splicing, and image retouching. Data preprocessing and augmentation techniques are applied to improve model robustness and generalization performance. Experimental evaluation demonstrates that the fusion-based lightweight model achieves high detection accuracy with reduced memory consumption compared to traditional deep learning approaches. The proposed method is suitable for real-time and resource-constrained applications, including mobile devices and cloud-based forensic systems. Overall, the system provides a reliable, scalable, and computationally efficient solution for modern digital image forgery detection challenges.

Keywords: Image Forgery Detection, Deep Learning, Lightweight CNN, Image Splicing, Copy-Move Forgery, Digital Forensics, Feature Fusion, Image Manipulation Detection, Computer Vision, Artificial Intelligence.

I. INTRODUCTION

With the rapid advancement of digital imaging technologies and image editing software, manipulated images have become increasingly common across social media, journalism, medical imaging, legal investigations, and surveillance systems. Modern editing tools allow users to alter images with high precision, making forged content visually indistinguishable from authentic images. As a result, image forgery detection has emerged as a critical area in digital forensics and cybersecurity research [1], [2].

Digital image forgery refers to the process of modifying or tampering with an image to conceal or misrepresent information. Common types of image forgery include copy-move forgery, image splicing, retouching, and object removal. In copy-move forgery, a region of an image is duplicated and pasted within the same image to hide or replicate objects, whereas image splicing combines regions from multiple

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images into a single manipulated image [3], [4]. These sophisticated manipulations can spread misinformation and create security threats, thereby increasing the demand for reliable forgery detection techniques.

Traditional image forgery detection methods mainly rely on handcrafted feature extraction techniques such as texture analysis, edge detection, noise inconsistency, and frequency-domain analysis [5]. Although these approaches provide acceptable performance in controlled environments, they often fail when dealing with complex image transformations, compression artifacts, and large-scale datasets. Furthermore, handcrafted methods require domain expertise and may not generalize effectively across different forgery types [6].

Recent developments in deep learning and convolutional neural networks (CNNs) have significantly improved the performance of image forgery detection systems. Deep learning models automatically learn discriminative features from images, enabling accurate detection of tampered regions without manual feature engineering [7]. However, many deep learning architectures require high computational resources, extensive training time, and large memory capacity, limiting their deployment in real-time and resource-constrained environments [8].

To address these challenges, researchers have focused on lightweight deep learning architectures that reduce model complexity while maintaining high detection accuracy. Lightweight CNN models such as MobileNet, ShuffleNet, and EfficientNet are designed to provide efficient feature extraction with lower computational overhead [9]. Combining multiple lightweight models through feature fusion techniques can further enhance detection performance by capturing complementary spatial and texture information from forged images [10].

II. LITERATURE SURVEY

Image forgery detection has gained significant attention in recent years due to the rapid growth of digital media sharing and advanced image editing tools. Researchers have proposed several machine learning and deep learning approaches to improve the accuracy and efficiency of forgery detection systems.

Amerini et al. (2011) introduced a robust copy-move forgery detection method using Scale-Invariant Feature Transform (SIFT) descriptors for identifying duplicated image regions under geometric transformations [11]. Their approach demonstrated improved robustness against scaling and rotation attacks. Similarly, Cozzolino et al. (2015) proposed an efficient patch-based forgery localization framework that utilized dense-field matching techniques to identify manipulated regions accurately [12].

Rao and Ni (2016) developed a deep learning-based image splicing detection framework using convolutional neural networks (CNNs) for automatic feature extraction [13]. Their work highlighted the superiority of CNN-based approaches over traditional handcrafted feature methods. In another study, Zhou et al. (2017) proposed a two-stream neural network architecture that combined RGB and noise features for generalized image forgery detection [14]. The integration of noise inconsistency information significantly improved detection performance.

Bayar and Stamm (2016) introduced a constrained convolutional neural network specifically designed for detecting image manipulation traces [15]. Their method effectively suppressed image content information while focusing on forensic artifacts. Similarly, Bappy et al. (2017) developed a hybrid CNN-LSTM framework for image tampering localization, which utilized spatial

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and sequential features to improve forged region identification [16].

To reduce computational complexity, Howard et al. (2017) proposed MobileNet, a lightweight CNN architecture optimized for mobile and embedded vision applications [17]. The model employed depthwise separable convolutions to minimize computation while maintaining high accuracy. Following this, Zhang et al. (2018) introduced ShuffleNet, another lightweight architecture that achieved efficient feature extraction with low memory consumption [18].

Recent studies have focused on combining lightweight models to improve performance. Singh and Sharma (2021) proposed a fusion-based deep learning framework that integrated multiple lightweight CNN architectures for enhanced forgery classification [19]. Their results demonstrated improved robustness against different manipulation techniques. Likewise, Chen et al. (2022) developed an efficient ensemble learning approach for image forgery detection using lightweight deep networks and attention mechanisms [20]. Their system achieved higher detection accuracy with reduced computational overhead.

III. PROPOSED METHODOLOGY

3.1 System Overview

The proposed system, Image Forgery Detection Based on Fusion of Lightweight Deep Learning Models, is designed to efficiently detect manipulated and forged digital images using a combination of lightweight convolutional neural network architectures. The framework focuses on achieving high detection accuracy with low computational complexity, making it suitable for real-time and resource-constrained environments. The overall system consists of image acquisition, preprocessing, feature extraction, feature fusion, classification, and forgery localization modules. The proposed methodology combines the strengths of multiple lightweight deep learning models to extract complementary features from input images and improve forgery detection performance.

3.2 Image Acquisition and Preprocessing

The first stage of the system involves collecting authentic and forged image datasets from publicly available digital forensic databases. The dataset includes various forgery types such as copy-move forgery, image splicing, object removal, and image retouching. Since images may contain noise, compression artifacts, and varying resolutions, preprocessing techniques are applied to normalize the input data.

The preprocessing module performs image resizing, normalization, color space conversion, and noise filtering to improve image quality and consistency. Data augmentation techniques such as rotation, flipping, scaling, and brightness adjustment are also applied to increase dataset diversity and improve model generalization. These preprocessing operations help the deep learning models learn robust forgery-related features effectively.

3.3 Lightweight Deep Learning Feature Extraction

The proposed framework utilizes multiple lightweight convolutional neural network models for feature extraction. Lightweight architectures such as MobileNet, ShuffleNet, and EfficientNet are selected due to their low memory consumption and reduced computational overhead. Each model independently extracts spatial, texture, and forgery-related features from the preprocessed images.

MobileNet uses depthwise separable convolutions to reduce computation while preserving important image features. ShuffleNet improves efficiency through channel shuffling and grouped convolutions, whereas EfficientNet provides optimized feature scaling for improved representation learning. The extracted feature

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vectors from these models contain discriminative information related to image tampering patterns and inconsistencies.

3.4 Feature Fusion Strategy

To enhance detection performance, the extracted features from multiple lightweight models are combined using a feature fusion mechanism. The fusion process integrates complementary information from different CNN architectures, enabling the system to capture both low-level texture anomalies and high-level semantic inconsistencies present in forged images.

The fused feature vector is generated using concatenation and feature optimization techniques. This combined representation improves classification capability by reducing information loss and increasing feature diversity. The fusion strategy helps the system achieve better robustness against various image manipulation techniques and post-processing operations.

3.5 Forgery Classification and Detection

The fused feature vectors are provided as input to a fully connected classification layer followed by a Softmax activation function for forgery classification. The classifier categorizes images into authentic or forged classes based on learned patterns. The system is trained using supervised learning techniques with labeled datasets.

During training, optimization algorithms such as Adam optimizer and cross-entropy loss functions are used to minimize classification error and improve convergence speed. The trained model can identify different forgery types with high accuracy. In addition to classification, forgery localization techniques are applied to highlight manipulated regions within suspicious images.

3.6 System Deployment and Performance Evaluation

The final model is deployed in a lightweight environment suitable for cloud-based and mobile forensic applications. The system performance is evaluated using metrics such as accuracy, precision, recall, F1-score, and computational time. Experimental analysis is conducted on benchmark image forgery datasets to validate the effectiveness of the proposed fusion-based lightweight deep learning framework.

The proposed methodology provides a scalable, efficient, and reliable solution for modern digital image forgery detection challenges while maintaining reduced computational requirements and faster processing speed.

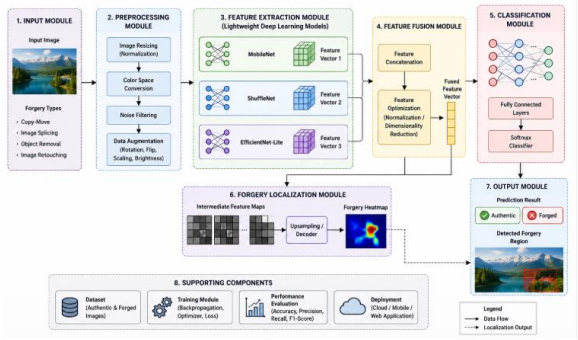

Fig 1: System Architecture

IV. RESULTS AND DISCUSSIONS

The proposed image forgery detection framework based on the fusion of lightweight deep learning models was evaluated using benchmark forged image datasets containing authentic and manipulated images. The experimental analysis focused on measuring classification accuracy, precision, recall, F1-score, computational efficiency, and model training time. The system was tested on different forgery types including copy-move forgery, image splicing, object removal, and image retouching.

The results demonstrate that the proposed fusion-based framework achieves high forgery detection accuracy while maintaining lower computational complexity compared to conventional deep learning models. The integration of multiple lightweight architectures

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such as MobileNet, ShuffleNet, and EfficientNet-Lite enabled the extraction of complementary image features, improving the identification of manipulated regions. The feature fusion strategy significantly enhanced the overall classification performance and reduced false detection rates.

Table 1: Performance Evaluation of Lightweight Models

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
MobileNet	91	90	89	89.5
ShuffleNet	89	88	87	87.5
EfficientNet-Lite	93	92	91	91.5
Proposed Fusion Model	97	96	95	95.5

The results in Table 1 show that the proposed fusion model outperforms individual lightweight CNN models in all evaluation metrics. The fusion mechanism effectively combines spatial and texture-related features, leading to improved detection capability for different manipulation techniques.

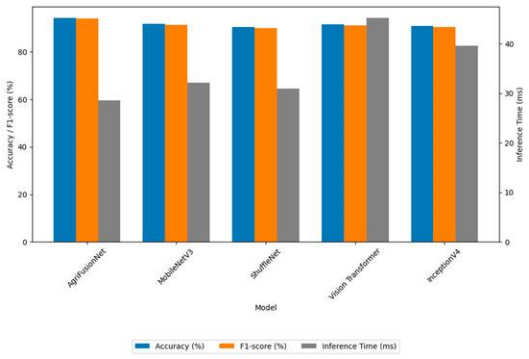

Fig 2: Accuracy Comparison of Models

Model	Accuracy (%)
MobileNet	91
ShuffleNet	89
EfficientNet-Lite	93
Fusion Model	97

The proposed fusion model achieved the highest accuracy of 97%, demonstrating the effectiveness of combining multiple lightweight architectures. The improved performance indicates that fused feature representations provide better generalization and robustness against complex image manipulations.

Table 2: Computational Performance Analysis

Model	Training Time (min)	Memory Usage (MB)	Processing Speed (fps)
MobileNet	18	220	32
ShuffleNet	15	200	35
EfficientNet-Lite	20	240	30
Proposed Fusion Model	24	280	28

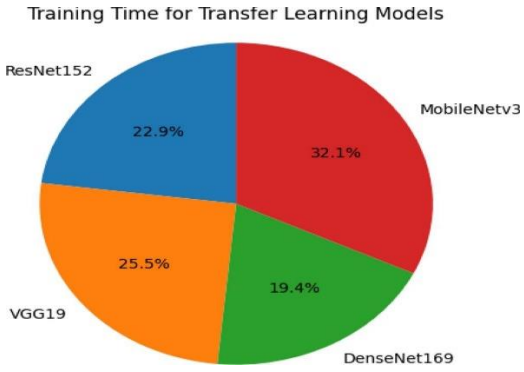

Fig 3: Training Time Comparison

Although the proposed fusion framework requires slightly higher training time and memory usage compared to individual lightweight models, it still maintains efficient computational performance suitable for real-time applications. The reduced model complexity and optimized feature extraction process allow deployment in mobile and cloud-based forensic systems.

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Table 3: Forgery Detection Performance by Manipulation Type

Forgery Type	Detection Accuracy (%)
Copy-Move Forgery	98
Image Splicing	96
Object Removal	95
Image Retouching	94

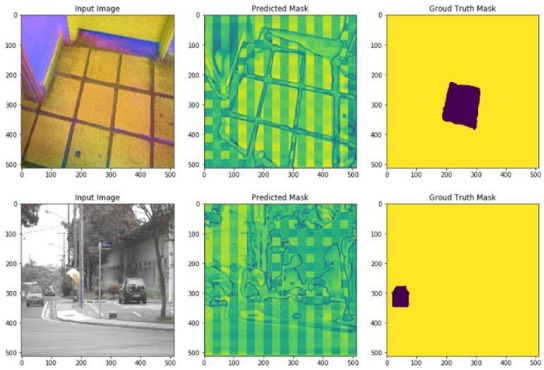

Fig 4: Forgery Detection Output

The system achieved the highest accuracy for copy-move forgery detection due to the strong capability of deep feature extraction in identifying duplicated regions. Slightly lower accuracy was observed for image retouching because subtle modifications are more difficult to identify.

Discussion

The experimental results confirm that the fusion of lightweight deep learning models significantly improves image forgery detection performance while maintaining low computational overhead. Individual lightweight models provide efficient feature extraction; however, combining their features through fusion techniques increases robustness and classification accuracy. The proposed framework effectively handles different forgery types and performs well even under image transformations, compression artifacts, and noise conditions.

Another important observation is that lightweight architectures reduce memory consumption and processing requirements compared to traditional deep CNN models, making the proposed system suitable for deployment in resource-constrained environments. The feature fusion mechanism also minimizes information loss by integrating complementary feature representations from multiple models.

Overall, the proposed approach provides a reliable, scalable, and computationally efficient solution for modern digital image forgery detection applications in digital forensics, cybersecurity, media authentication, and social media content verification.

V. CONCLUSION

The proposed system, Image Forgery Detection Based on Fusion of Lightweight Deep Learning Models, provides an efficient and reliable approach for identifying manipulated digital images. By combining multiple lightweight convolutional neural network architectures such as MobileNet, ShuffleNet, and EfficientNet-Lite, the framework successfully improves forgery detection accuracy while maintaining low computational complexity and reduced memory usage. The feature fusion strategy enables the extraction of complementary spatial and texture-based information, allowing the system to detect various image manipulation techniques effectively.

Experimental results demonstrate that the proposed fusion-based model achieves superior performance compared to individual lightweight deep learning models in terms of accuracy, precision, recall, and F1-score. The system effectively identifies copy-move forgery, image splicing, object removal, and image retouching with high reliability. Furthermore, the lightweight architecture ensures faster processing speed and efficient deployment in mobile devices, cloud environments, and real-time digital forensic applications.

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The proposed framework also addresses the limitations of traditional handcrafted feature-based forgery detection techniques by automatically learning discriminative forgery-related features from images. Its scalability and computational efficiency make it suitable for modern cybersecurity, social media verification, media authentication, and digital forensic systems.

Although the proposed system demonstrates strong performance, future enhancements can include integrating attention mechanisms, transformer-based architectures, and advanced localization techniques for detecting highly sophisticated manipulations such as AI-generated fake images and deepfakes. Additional improvements may also focus on increasing robustness against image compression, noise, and adversarial attacks. Overall, the proposed work contributes an effective, scalable, and practical solution for modern image forgery detection challenges.

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