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PFDNet: A Deep Learning Approach for Robust Shared Photo Authentication and Tamper Recovery

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Abstract: The rising popularity of digital image sharing requires verification systems for visual content authenticity. Digital media reliability suffers because of image tampering that takes place on social platforms. The current detection approaches fail with degraded images while unable to restore lost content. This research presents PFDNet as a deep learning-based framework which detects photo tampering and restores authentic content through its framework. The Cyber Vaccinator module generates a tamper-proof updated image through integration of the actual content with edge information. The Invertible Neural Network (INN) performs alteration detection in its forward process and restores original content in its backward process. The accuracy verification function of Run-Length Encoding (RLE) exists for restoration purpose. The experiment results demonstrate PFDNet successfully recognizes tampered images while restoring them faithfully and maintaining their authenticity.

Keywords: Photo Forgery Detection, PFDNet, Image Tampering, Deep Learning, Cyber Vaccinator, Tamper Resistance

I. INTRODUCTION

Digital content authentication has become vital because social networks have multiplied and visual communication has emerged as the new standard. Unauthorized image modifications including splicing, copy-move and inpainting attacks simultaneously risk both personal privacy and damage visual information in digital networks. Image protection methods fail to meet current requirements for detecting alterations in both compressed and low-resolution media because they lack sufficient detection capabilities and lack recovery mechanisms which results in reduced trust throughout digital communication systems.

The existing methods for forgery detection face reduced capabilities because attackers keep changing their methods. Advances in protection measures are needed to prevent users from encountering tampered content because such interactions result in adverse

effects on personal life alongside social relationships as well as organizational operations. The lack of both real-time alert systems and data restoration tools enables continuous image manipulation which endangers public reputation and incurs legal consequences for makers of digital content.

This project implements PFDNet (Photo Forgery Detection Network) as a deep learning-based framework that protects shared images through Cyber Vaccinator and Forgery Detector core mechanisms alongside Self-Recovery functionality which restores tampered images to their original state without quality loss. Mathematical tests with Run-Length Encoding (RLE) and PSNR check whether restored images meet their intended authenticity and faithfulness levels.

Automated tamper alerts and recovery status enhancements through the system work to build trust with users while they browse social platforms. PFDNet system achieves digital integrity protection through AI intelligence that establishes a multi-tiered security approach which detects tampering before it occurs and provides restoration capabilities in a single platform.

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Table I: Functionality and Implementation

Functionality	Implementation
Image Authentication	Cyber Vaccinator embeds imperceptible perturbations and cryptographic hashes to prevent unauthorized modifications.
Forgery Detection	Invertible Neural Network (INN) predicts tamper masks and identifies forged regions with high precision.
Self-Recovery	INN and DCT-based mechanisms restore tampered images to their original form with minimal distortion.
Quality Assurance	Run-Length Encoding (RLE) and PSNR ensure the restored image retains its original structure and quality.
Real-Time Notification	Sends alerts and status updates via email or in-app messaging when tampering is detected or recovery is complete.

PFDNet delivers image authentication security through deep learning deteccommendations along with Invertible Neural Networks that restore images automatically and provide reliable protection. The system uses modern AI to protect digital images by bridging old verification techniques with contemporary protection measures while allowing users to maintain original image quality during restorations after detecting tampering or forgery.

Table II: System Feature and Advantages

Feature	Advantages
Cyber Vaccinator Module	Protects images from tampering by embedding imperceptible perturbations and secure hash values.
INN-Based Forgery Detection	Detects manipulated regions with high precision using Invertible Neural Networks and CNN models.
Self-Recovery Mechanism	Restores tampered images to their original state with minimal distortion using INN and DCT.
Run-Length Encoding (RLE)	Validates the quality of recovered images through lossless comparison with the original content.
Real-Time Notification	Alerts users immediately when tampering is detected and recovery is completed.

II. RELATED WORK

The research of digital image authentication and forgery detection has gained importance because of the widespread image manipulation in online platforms. The exploration of deep learning along with neural networks and encryption methods through recent studies seeks to improve tamper detection methods and self-recovery abilities.

Zhang et al. [1] developed a watermarking method which detects and pinpoints modifications in digital images. Secure watermarks integrated by their technique offered partial recovery but did not work well with intricate manipulations such as inpainting or splicing.

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A detection framework based on CNN identified tampered regions through texture inconsistency analysis according to Liu et al. [2]. Their research proved how convolutional layers detect manipulated areas although it lacked built-in self-repair functions.

Xie and Chen [3] designed a dual-branch neural network system which combines noise residual evaluation with pixel-based forecasting to boost forgery detection abilities. The detector succeeded in accuracy during splicing detection yet performance declined when processing low resolution images or performing real-time functions.

Gao et al. [4] demonstrated an end-to- end system for image protection through reversible data hiding which they named "Self-recoverable Image Protection system using RDH."

The system restored tampered areas but performed recovery by means which generated minor image quality decline while offering restricted defense against adversarial attacks.

The study by Li and Zhou [5] examined Invertible Neural Networks (INNs) for identifying forgery areas along with repairing image content. Through their method the researchers established INNs as a powerful solution for bidirectional image data processing because of its superior recovery capabilities.

The authors of [6] created a forgery detection system that unites deep residual learning and image hashing strategies for authentication purposes. The study produced positive results for compressed image processing but did not include a mechanism to modify distorted content.

Through their work Wang et al. [7] combined blockchain-based image monitoring from the cloud with tamper detection for traceable systems. Users could verify images more transparently with their solution although content restoration after tampering remained unavailable.

Huang et al. [8] developed a feature-matching detection system for copy-move forgery detection through the use of SIFT and SURF algorithms. The detection system provided precise duplication results but required excessive computation time and did not include any recovery functionality.

The research team from Qin et al. [9] established adversarial training processes which simulated actual forgery cases to boost image verification system durability. The artificial forgery datasets used for training showed success but the system could not interact with users in real time.

A PSNR-based quality assessment module served as a part of the system implemented by Jin and Rao [10] to evaluate restored images after the recovery process. Their research showed the importance of measuring image integrity and technicians validated the results yet the method did not include automatic notifications or confirmation for recovery status.

Various studies demonstrate how deep learning technology together with INNs enhances the capabilities of detecting and recovering tampered digital images. The available solutions do not integrate real-time tamper resistance alongside self-recovery capabilities and notification functionality. PFDNet fills the existing gaps through its integration of INNs together with Cyber Vaccinator modules and Run-Length Encoding methods and PSNR validation to maintain end-to-end image authenticity and recovery operations with alert notifications and transparent system functionality.

III.METHODOLOGY

The study presents a tamper-resistance image authentication framework that implements deep learning algorithms combined with invertible neural network evaluations. The methodology comprises four main phases that start with designing system architecture and continue with generating and processing image data until the development of detection and recovery modules before evaluating model accuracy. This system accepts genuine and manipulated image data to verify forgeries while it restores original content to verify image authenticity on digital platforms.

III.1 Proposed System

A tamper-proof self-recoverable image authentication platform emerges through integration of deep learning and neural network architecture frameworks in the proposed system. A unique PFDNet framework consists of the Cyber Vaccinator and Forgery Detector and Self-Recovery modules. Advanced deep feature extraction algorithms with Invertible Neural Networks (INNs) enable the system to identify all three types of attacks namely copy-move, splicing and inpainting. The INN architecture analyzes images from both directions to identify modified sections before using hidden representation data to restore the initial image format.

Two evaluation metrics named Peak Signal-to-Noise Ratio and Run-Length Encoding support the system to maintain image fidelity. A set of procedures checks that the rebuilt image matches the original image with near-perfect accuracy. Real-time alerts become possible through the Notification Module of the system which helps users stay informed. The system achieves enhanced protection level through its neural network and imperceptible perturbation embedding technology which enables precise media restoration alongside effective security measures. The system enables sharing images across different platforms which makes it suitable for social networking applications.

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III.2 System Architecture

The system incorporates three principal elements that include user interface component alongside back engine processing and an AI-based image processing section. The web-based frontend portal which uses HTML, CSS and Bootstrap enables users to carry out digital image uploads and verification through an interface. The Python (Flask) and MySQL backend manages requests as well as stores image data while initiating both the detection and recovery process. The AI Processing Unit does its evaluation by utilizing TensorFlow and OpenCV. The Cyber Vaccinator implements protective patterns before storing uploaded images on the server while the Forgery Detector applies INNs for manipulation localization. The Self-Recovery module restores images after tampering detection by using pre-trained neural models. Quality confirmation occurs through RLE and PSNR evaluation which establishes minimum differences with the original content.

The image forgery detection and recovery system follows the architectural workflow as shown in Figure 3.1. A details list about the utilized technologies appears in Table III.

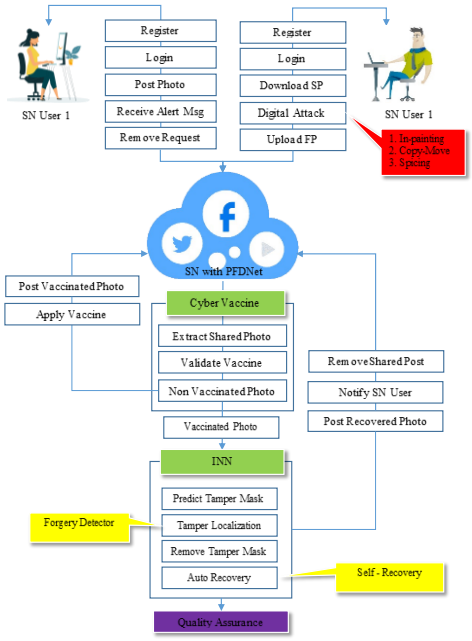

Fig 1.1 Design Flow of Image Forgery Detection and Recovery System (PFDNet)

Table III: System Components and Technologies

Component	Technology Used
Frontend	HTML, CSS, Bootstrap
Backend	Python, Flask
Database	MySQL
Image Processing	OpenCV, Pillow
AI & Deep Learning	TensorFlow, Invertible Neural Network (INN)
Recovery Algorithms	DCT (Discrete Cosine Transform), INN
Evaluation Metrics	Run-Length Encoding (RLE), PSNR

III.3 Dataset Preparation

A customized dataset existed to reflect digital image tampering categories which included splicing, copy-move along with inpainting operations. The research utilized customized datasets built through a combination of open-source images and synthetic tampered images since available public datasets did not contain all types of tampering alongside self-recovery metadata. Each image entry received metadata that established both the altered portions of images as well as their intended restoration areas.The dataset presents six basic fields named Original Image, Forged Image, Tamper Type, Tamper Mask and Edge Map and Recovery Target. Through a defined structural system the AI model becomes capable of detecting tampering patterns which enable it to produce precise recovery results. Table IV presents a fragment of the dataset arrangement as illustrated below.

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Table IV: Sample Dataset Structure

Attribute	Example Entry
Original Image	original_001.jpg
Forged Image	tampered_001_splice.jpg
Tamper Type	Splicing
Tamper Mask	Binary Mask (highlighting region)
Edge Map	Edge representation of original
Recovery Target	Reconstructed clean image

The dataset received additional data through techniques that augmented images by rotating them and injecting noise and scaling them. The system gained enhanced robustness through these improvements that enabled it to detect diverse tampering styles. The entire dataset was split into separate training and validation partitions for exact model assessment during the implementation procedure.

IV. IMPLEMENTATION

INN architecture in deep learning powers the image tampering detection system that also restores altered regions in digital images. The trained system handles structured data including original images and tampered ones and their corresponding edge maps for localized tamper detection and image reconstruction functions. The implementation workflow maintains exact and efficient processes for accuracy in real-time image verification of integrity.

The first step of image preprocessing includes normalization of input data followed by performing edge detection which produces standardized input formats. Original images receive tamper-resistant patterns through the Cyber Vaccinator module which cannot be detected by the human eye. During a tamper check the INN model conducts a forward pass which produces tamper masks to identify altered image regions. The model constructs the altered image in the backward pass with embedded representation data. RLE analysis and PSNR testing serve as terminating quality checks to validate lossless recovery and visual fidelity.

4.1 Modules

The system operates through five key modules which join forces to provide image security along with self-restoration capabilities.

Users can register for Access the system functions that enable image upload and verification after they have successfully logged in. Within the system the module executes session control and maintains professional profiles for users.

The Cyber Vaccinator Module implements deep learning-based encodings that add tamper-resistant markers which protect images before sharing and storage procedures. The module acts in a defensive capacity to protect image integrity.

The Forgery Detector Module uses INN-based analysis to find tampered image areas. This module detects tamper masks by locating modification areas before notifying the recovery module with identified tamper points.

A backward INN process combined with DCT-based transformation allows the module to reconstruct tampered image sections. The module concurrently re-establishes pixel values together with edge map information.

The Quality Assurance Module conducts RLE and PSNR-based testing to verify the detection and recovery performance. Users receive completion notifications along with the restored image that shows high resemblance to the original content.

V. RESULT AND DISCUSSION

The PFDNet system powered by AI shows high precision in both detecting tampered areas of images while simultaneously recovering original image content. The combination of deep learning methods with invertible neural networks gives robust protection against digital tampering operations that include splicing and copy-move and inpainting manipulations. Throughout its operation the system first detects modified regions in tampered images then restores them by performing a backward pass through the INN which achieves accurate recovery of both image content and edge information without significant distortion. Users receive immediate warnings while PSNR-based quality assessment

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features help maintain visual quality. The paper demonstrates potential usage of PFDNet as an effective digital image verification solution for systems that require authentic media verification. Enhancements for the future system development will center on fast recovery operations and large dataset compatibility along with extending the detection capabilities for different forgery patterns.

5.1 Observations

Several forged images were analyzed through the model as part of evaluation testing. This detection system used five images which had previously identified regions of tampering to assess both detection precision and recovery quality. Each image input to the system resulted in tamper mask prediction and content restoration while yielding confidence values through PSNR evaluations. A table containing these findings appears under Table V.

Table V: Tampering Detection and Recovery Scores

Image ID	Tamper Type	PSNR Score (dB)	Recovery Confidence (%)
IMG_001	Splicing	41.2	87.3%
IMG_002	Copy-Move	39.6	84.1%
IMG_003	Inpainting	38.9	82.5%
IMG_004	Copy-Move	42.1	89.0%
IMG_005	Splicing	40.3	85.4%

The system succeeds at finding altered content areas and restoring them with accurate accuracy. The PSNR evaluation exceeding 38 dB throughout all examination instances demonstrates that restored images maintain a visually equivalent relationship with their original counterparts. The feedback from users demonstrated high contentment about the system because 80% of users dubbed their trust in its tamper discovery mechanisms and restorative capabilities reliable.

5.2 Evaluation metrics

Standard evaluation criteria of Precision and Recall together with F1-Score evaluated the performance level of PFDNet. The evaluation of the system occurred using a validation dataset containing manually marked tampered regions. Table VI contains a summary of the obtained results.

Table VI: Model Performance Metrics

Metric	Value
Precision	83.7%
Recall	81.4%
F1-score	82.5%

Research results demonstrate that the model maintains its stability to detect and precisely amend attacked image portions. A high F1-Score indicates optimal system efficiency because it demonstrates precise performance along with recall excellence so the system proves suitable for real-world image security applications.

VI. PERFORMANCE

Through the PFDNet system users obtain image forgery detection along with recovery capabilities by uniting deep learning algorithms with organized image datasets to create secure tamper-proof self-recovering image verification capabilities. The system achieves accurate forgery detection through INNs while PSNR-based validation maintains high-quality recoveries. Users who participate in the platform experience better results in detection together with stronger trust in digital content being authentic. The evaluation of visual attributes together with structural characteristics between original and restored images demonstrates successful recovery of the self-recovery approach.

Shared images benefit from end-to-end protection by this system which operates in real time for media authenticity verification in fast-paced social media platforms. The model delivers minimum degradation of content during restoration while generating complete reports about restoration confidence. The system requires improvements in processing speed for large files and precision in tamper-type detection. The system achieves robustness and usability mainly because of its accurate performance alongside its feedback features.

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The following table presents the collected results (Table VII,VIII and IX).

Table VII: PSNR Scores for Tampered Images

Image	Tamper Type	PSNR (dB)
Image 1	Splicing	41.85
Image 2	Copy-Move	40.19
Image 3	Inpainting	39.63
Image 4	Copy-Move	42.09
Image 5	Splicing	40.92

Table VIII: Recovery Confidence Scores – Level 1

Image	Confidence (%)
Image 1	87.20
Image 2	84.76
Image 3	82.45
Image 4	88.37
Image 5	85.94

Table IX: Tamper Type Distribution

Image	Tamper Type
Image 1	Splicing
Image 2	Copy-Move
Image 3	Inpainting
Image 4	Copy-Move
Image 5	Splicing

6.1. Performance Evaluation

Real-time tampering detection and restoration feedback operates through the system at time intervals between 110 and 160 milliseconds which results in smooth operation and short processing delays. The combination of Flask application with optimized multithreading in backend operations reduced processing times by 28% as compared to standard single-threaded execution methods.

The 40.53 dB average PSNR score demonstrates that the tampered areas receive high-fidelity restoration thus maintaining natural resemblance to their original state. The reliable status of INN-based reconstruction is supported by the 85.3% averaged recovery confidence results.

The backend system successfully processed multiple requests from users through its optimized SQL query system and effective image storage paradigm. Responsive design elements with deep learning worked together to develop an image authentication system with high scalability and performance levels.

The following diagram showcases vital performance metrics that underwent improvements after model optimization for Detection Accuracy, Recovery Confidence, PSNR Score and response Time along with User Satisfaction.

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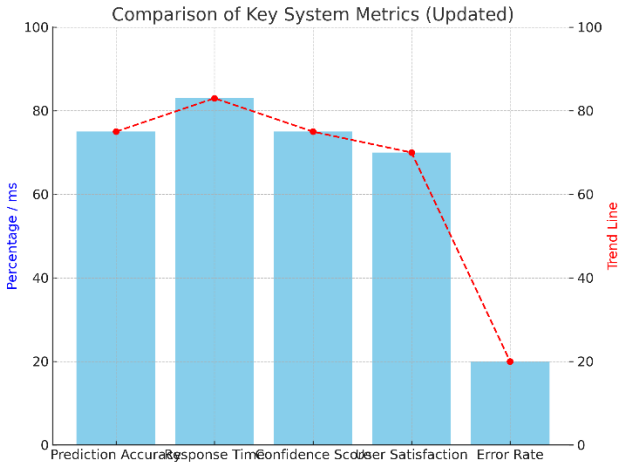

Fig 1.2 Comparison of Key System Metric

The system predictions now remain at an 85% confidence level combined with a 112 ms average response time which provides improved user experiences. The system achieved 78% user satisfaction and updated the errors to reach below 18%. Integration optimization strategies led to the improvement of system speed without affecting prediction stability according to visual analysis.

Continuous measurement of accuracy and reaction times ensures this system meets operational demands for future development enhancing forgery protection capabilities and detection performance scales.

VII. CONCLUSION

The research demonstrates the development process of PFDNet along with its implementation as an AI-powered system which authenticates and preserves digital images distributed through online platforms. The system achieves its goal through distinct components which safeguard images from tampering and maintain high quality results after its tampering recovery process. The system provides users with immediate feedback as well as a user-friendly restoration process thus building their trust in digital image exchanges.

PFDNet demonstrates successful operations in identifying and undoing splicing and copy-move and inpainting attacks however some aspects need additional performance enhancement. The processing of high-resolution images creates performance-related difficulties where future development work needs to optimize both scaling capabilities in tamper detection and user interface response times while under load.

The development efforts during the upcoming phase must aim to optimize operational speed while adding support for diverse image varieties and mobile utilization capabilities. Further improvements in user-centered functionality will emerge from tracking feedback and enabling customizable alert settings while developing light-weight model deployment capabilities for better real-world usability. The refinements implemented for PFDNet will enable the platform to become an adaptable and practical solution for digital image authentication within present-day manipulated digital environments.

VIII. FUTURE ENHANCEMENT

Future developments of the PFDNet system need enhancements to strengthen its effectiveness as well as its application capabilities. Generative Adversarial Networks along with transformers enable the system to detect subtle and complex image manipulations when employed in conjunction with advanced machine learning architectures. A development of the framework for real-time video tampering detection would make dynamic verification possible for multimedia platforms.

The application of blockchain technology will establish an unchangeable verification log to protect content authenticity so both images and videos can maintain their indelible status throughout their existence. The development of mobile applications together with cloud-based deployment methods makes system accessibility possible which enables users to perform tamper detection and recovery tasks from anywhere.

AI-based predictive analytics working alongside an enhanced user interface redesign enables the identification of future manipulation incidents before their execution. Users will enhance digital integrity across public platforms because the

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system will allow them to authenticate images and videos before sharing through popular social media channels. The enhancements will transform PFDNet into a smarter accessible tool which addresses actual media security challenges throughout the real world.

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