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A Forensic Approach to Image Clone Detection Using Structural Similarity Index (SSIM) and Error Level Analysis (ELA)

Pinky Kumari[1], Cheekiri Venkata Murali Krishna[2], Balijabudda Charan[3]

[1]Parul Institute of Computer Application Parul University Vadodara, India - 391760
Email ID:pinkykumari8237@gmail.com

[2]Parul Institute of Computer Application Parul University Vadodara, India - 391760
Email ID:muraliroyal2225@gmail.com

[3]Parul Institute of Computer Application Parul University Vadodara, India - 391760
Email ID: venkatcharanroy15@gmail.com

Abstract

This paper proposes a new technique for clone recognition via the combination of the SSIM measure and ELA for detection and assessment of modifications within images.

The SSIM algorithm compares an image and the copy version of the image to determine whether modifications have occurred and find out the extent. By checking out the luminance, contrast, and other structural features of the picture, SSIM computes a similarity score that represents the modification done on the original image. Subsequently, modified areas of the image are highlighted using difference SSIM so that one can see which part of the image differs greatly from the rest in terms of cloning.

Error Level Analysis (ELA) works well with SSIM. ELA identifies deliberately modified sections by recalculating the error levels of two images that were previously saved at different compression levels. Altered regions can be detected because they show disproportionate error levels. The images produced by ELA show an overemphasis of the suspicious regions indicating heatmap spatial analysis to ease the interpretation of results.

This contribution is added to the advancement in image-to-image analysis by giving a systematic means of handling the issues of anomaly detections.

Keywords; Clone Detection, Image-to-Image Analysis, SSIM Difference Image, Structural Similarity Index Measure (SSIM), Error Level Analysis (ELA).

INTRODUCTION

In the contemporary digital landscape, the ability to manipulate images has grown remarkably, primarily due to the emergence of advanced editing software and artificial intelligence-based generation techniques. Although these innovations foster new avenues for creativity, they also pose significant challenges regarding image authenticity, the spread of misinformation, and the field of digital forensics.

The difference between picture modification and tampering can be small, frequently leading to incorrect information being distributed, people being duped, or fake proof being produced. As a result, identifying manipulated photos has emerged as a crucial research topic. Conventional forensic techniques usually rely on human assessment, metadata analysis, or the detection of statistical irregularities; yet, these methods can be time-consuming and might not adequately handle complex manipulation tactics.

Image-to-image comparison methods, including the Structural Similarity Index (SSIM) and Error Level Analysis (ELA), are useful tools for detecting changes between image pairings to get around these challenges.

Whereas ELA concentrates on variances in compression artifacts to detect modified areas, SSIM evaluates differences based on structural changes.

This study tries to develop a clone detection tool based on the application of SSIM and ELA for finding spliced, altered, or cloned pieces for matching pairs of images. Using such methodologies implemented under an automatic pipeline, this instrument aims at making digital forensic research more beneficial in terms of having efficient resultthat are easier and more precise in nature. In addition, the new system will include better ELA visualization using a heat map method and an interactive user interface to allow for easier interpretation of results.infections, emphasizes the requirement for straightforward diagnostic tools. In Jabalpur, FBC acts as a key element in spotting root causes, including iron deficiency anemia (IDA) or vitamin B12 shortages.

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The rapid development of digital image editing technologies and the advent of artificial intelligence-based content have made it more challenging than ever to detect image manipulations. Methods of image forgery, such as cloning, splicing, and deepfake creation, are often used for deceptive purposes in many fields, including journalism, legal investigations, social media, and forensic analysis. While traditional detection techniques, such as metadata examination and the detection of statistical anomalies, can reveal some forms of manipulation, they often fail when faced with high-quality forgeries that lack obvious artifacts.

Objective

The fundamental goal of designing this tool is to improve the precision and reliability of image-to-image comparison by utilizing advanced computational algorithms for identifying changes, manipulations, or discrepancies between two images. With more advanced techniques of digital manipulation being developed, it is critical to design an automatic, efficient, scalable method for identifying forged, manipulated, or cloned areas in an image.

This study aims to accomplish various crucial goals:

- Build an Exhaustive Image Comparison Model – Utilize Structural Similarity Index (SSIM) and Error Level Analysis (ELA) to consistently detect discrepancies in original and modified images.
- Enhance Forensic Image Validation – Create a robust method of validating the legitimacy of images for criminal investigations, legal cases, and cybersecurity scenarios.
- Improve Detection Accuracy – Improve over traditional pixel-by-pixel comparisons by implementing structural and perception-based analysis approaches that are noise and compression-resistant.
- Ensure Computational Efficiency – Create a system capable of swiftly processing high-resolution images without necessitating costly computational resources, thereby making it accessible for a variety of applications.
- Develop a tool that is intuitive for researchers and forensic experts along with journalists to operate while maintaining adaptability to introduce future enhancements such as AI features.

The above objectives are attained by the research that advances digital forensics and image examination through the establishment of a simple yet effective instrument that can identify and deter photo tampering.

Scope

This study covers various fields where integrity and authenticity of image is still important. This software has several applications in real life, including:

Forensic Investigations

Criminal investigation authorities and forensic professionals use this software for the authentication of evidence in criminal acts as well as fraud cases. The software helps forensic experts in the detection of forged images employed in documents, identity theft etc...

Cybersecurity and Fraud Prevention Recognize manipulated images used in identity theft, phishing scams, and social engineering frauds. It is essential in authenticating profile images, identification cards, and other critical image-based verification processes.

Social Media and Content Moderation

It helps social media sites detect manipulated images that violate community guidelines. It helps such sites in preventing the dissemination of false.

This tool is also designed to work efficiently with JPEG, PNG, and BMP image formats; however, it may need modifications to accommodate RAW or proprietary image

formats utilized in specialized fields like satellite imaging or advanced photography. Future developments may investigate AI-driven improvements and hybrid methodologies to enhance detection precision and flexibility.

LITERATURE REVIEW

Image manipulation detection has been the subject of considerable research, leading to the development of various methods aimed at verifying the authenticity of images. Among the most commonly employed techniques in traditional image forensic analysis are the Structural Similarity Index (SSIM) and Error Level Analysis (ELA). Additionally, numerous other tools, such as Foto Forensics and Face Forensics, have emerged to tackle similar challenges in the realm of forensic image verification. This section offers a thorough examination of the existing methodologies, their shortcomings, and the enhancements introduced by our proposed tool.

Previous Solutions and Their Limitations

A range of tools and techniques has been established for identifying image manipulations, each concentrating on different elements such as compression artifacts, pixel-level discrepancies, and deep learning-based forgery detection. Some of the more recognized methods include:

1. Pixel-Based Image Comparison Conventional pixel-wise difference techniques assess two images by evaluating direct pixel variations.

Limitation: These approaches are extremely sensitive to slight changes, such as variations in lighting, resizing, or compression, which can result in false positives and unreliable outcomes.

2. Histogram and Metadata Analysis Examining color histograms, metadata (EXIF data), and compression artifacts can occasionally uncover signs of manipulation. Limitation: EXIF metadata is easily removable or modifiable, rendering this method unreliable for forensic validation.
3. Deep Learning-Based Forgery Detection Contemporary techniques employ Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs) to identify forgeries.

Limitation: These methods necessitate extensive datasets for training and are computationally intensive. Furthermore, deep learning approaches may encounter difficulties with unfamiliar types of manipulations that are not represented in the training data.

4. Structural Similarity Index (SSIM) A perceptual metric called the Structural

Similarity Index (SSIM) is used to evaluate the structural differences between two images by accounting for elements including contrast, brightness, and structural details. But one significant drawback of SSIM is how well it can detect differences; it could have trouble picking up on minute changes like light airbrushing or copied parts.

5. Error Level Analysis (ELA) Error Level Analysis (ELA) helps identify inconsistencies across different areas of a picture by identifying differences in compression levels. However, ELA works best with JPEG pictures and may not work as well with lossless formats like PNG or BMP. Significant compression can also mask manipulation indicators, which could lead to misleading negative results.

Comparison with FotoForensics and FaceForensics

Numerous forensic tools, including FotoForensics and FaceForensics, have been created to identify manipulated images. Below is a comparative evaluation of these tools alongside our methodology.

1. FotoForensics

FotoForensics is an online forensic imaging analysis tool based on Error Level Analysis (ELA) and metadata retrieval to identify image alterations. It is largely utilized by journalists, fact-checkers, and forensic experts.

Limitations:

- FotoForensics largely depends on ELA, which is optimal with JPEG images but does not function well with file types such as PNG or compressed images.
- The utility does not offer advanced Structural imilarity Index Measure (SSIM) comparisons and hence is not as effective when used to compare the structure of altered regions.
- The utility does not give numerical similarity scores, thereby making it more difficult to judge the extent of changes in pictures.
- The analysis is not interactive and thus does not permit interactive comparison between two photos. How Our Tool Enhances FotoForensics:
- Includes SSIM for structural analysis, providing a numerical similarity score to quantify differences between images.
- Improves ELA visualization with heatmaps and pixel normalization, allowing manipulated regions to be seen more clearly.

- Includes analysis of multiple image formats (JPEG, PNG, BMP), expanding its application for other forensic uses.
- Operates locally without an internet connection, guaranteeing data privacy and security.

2. FaceForensics

FaceForensics is a highly advanced tool that applies deep learning techniques to identify deepfake images and videos. It employs machine learning models that have been trained on large datasets to determine if an image or video has been manipulated.

Limitations:

- specialized in deepfake detection and hence focuses mostly on human faces and doesn't generalize across general image tampering (e.g., splicing, copy-move forgeries).
- Has high computational requirements, hence is less practical for real-time or low-resource setups.
- Performs poorly with novel manipulation methods that aren't in its training data.
- Due to deep learning models' characteristics, it sometimes incorrectly classifies genuine images as manipulated, generating false positives.

How Our Tool Improves FaceForensics:

- It is designed for general image-to-image analysis and can be applied to a broader set of applications outside of face-based forensics.
- Operates using SSIM and ELA, which do not need large training datasets and can process any form of image efficiently.
- Delivers interpretability, where users can visually identify exactly where an image has been manipulated instead of using a black-box classification model.
- Has faster analysis with reduced computational needs, making it ideal for real-time forensic applications.

WHY OUR TOOL FILLS THE GAP

Existing forensic tools like FotoForensics and FaceForensics have specific use cases but come with significant limitations. Our tool bridges these gaps by:

- **Combining Structural and Compression-Based Analysis:** Unlike FotoForensics, which only uses ELA, our tool integrates SSIM, allowing for both quantitative and visual detection of manipulations.
- **Handling Various Image Formats Efficiently:** Works effectively on JPEG, PNG, BMP, and other image formats, whereas FotoForensics mainly works best with JPEG compression artifacts.
- **Providing Transparent and Interactive Forensic Analysis:**Unlike FaceForensics, which provides a classification label (real/fake) without explanation, our tool highlights altered regions, making forensic analysis more interpretable.
- **Being Lightweight and Accessible:** Does not require large datasets or high-end GPUs, making it usable in real-world forensic scenarios where computational resources are limited.
- **Supporting Multiple Applications:** While FaceForensics is limited to detecting deepfake faces, our tool applies to a broader range of forensic investigations, including splicing, copy-move forgeries, and document verification.

CONCLUSION OF LITERATURE REVIEW

This study advances the field of forensic image analysis by addressing the limitations of current techniques. By integrating the Structural Similarity Index Measure (SSIM) and Error Level Analysis (ELA), our developed tool offers a more comprehensive, interpretable, and efficient approach for identifying image manipulations across diverse applications. In comparison to existing methods such as FotoForensics and FaceForensics, our approach:

- Enhances accuracy through the combination of structural and error-based evaluations.
- Offers visual interpretability rather than merely providing a classification label.
- Functions effectively with various image formats, minimizing dependence on compression artifacts.
- Demands fewer computational resources, thereby increasing accessibility for practical applications.

These advancements significantly contribute to the improvement of forensic image analysis techniques, safeguarding the integrity of images in fields such as forensics, journalism, cybersecurity, and digital content verification.

TECHNOLOGIES USED

The development of the tool leverages a combination of programming frameworks, image processing libraries, and

forensic analysis techniques to perform image clone detection. The key technologies used in this study are:

Programming Language and Framework

- Python: The primary programming language used due to its extensive libraries for image processing, machine learning, and web development.
- Flask: A lightweight web framework used to create the web-based interface for image upload, analysis, and result visualization.

Image Processing Libraries

- OpenCV: Used for image reading, conversion, resizing, difference calculations, and color-based visualization.
- PIL (Pillow): Used for handling image operations, including saving images at different compression levels and performing image enhancement techniques.
- NumPy: Utilized for numerical operations, such as matrix manipulations and pixel-wise image analysis.

Error Level Analysis (ELA)

Objective of ELA

ELA serves as a forensic technique for image analysis that identifies variations in image compression levels, thereby exposing areas that may have been manipulated or edited. Digital editing can result in certain sections of an image exhibiting different compression artifacts, which can signal potential alterations.

Mechanism of ELA

ELA operates on the principles of JPEG compression, which eliminates specific details based on the image's content. The procedure consists of the following steps:

1. Convert Image to RGB Format

The initial image is imported and transformed into RGB format to ensure uniform processing.

2. Re-save the Image with Slightly Reduced Quality

The image is then saved again in JPEG format at a designated quality level. This action introduces minor compression artifacts that assist in uncovering inconsistencies. The JPEG quality selection is adaptive in our approach, based on the image's variance (sharpness level):

- Low-detail images: 50% quality
- Medium-detail images: 70% quality
- High-detail images: 90% quality

3. Calculate the Difference (Error Level) Between the Original and Resaved Image

The pixel-by-pixel difference between the original and the resaved image is computed using the formula:

ELA Image = Original Image - Resaved Image

If the image remains unaltered, the differences will be consistent throughout. Conversely, if certain areas have been modified, they will exhibit more pronounced variations.

4. Enhance the Differences Using CLAHE and Sharpening

CLAHE (Contrast Limited Adaptive Histogram Equalization) is utilized on each color channel to amplify subtle error-level differences. A sharpening

kernel is then applied to accentuate the edges of the modified regions.

5. Thresholding and Highlighting Edited Areas

A binary threshold is implemented to underscore significant changes. Areas with elevated ELA intensity values are marked in red, indicating likely modifications.

Applications of ELA

- Detection of spliced images (segments copied from other images).
- Identification of airbrushed or retouched images.
- Exposing cloned regions in an image.

Structural Similarity Index (SSIM)

1. Objective of SSIM

SSIM measures the similarity between two images by comparing their structural, luminance, and contrast differences. Unlike traditional pixel-wise difference methods, SSIM models the human visual perception of images, making it more effective for detecting changes.

2. Mechanism of SSIM

Given two images X and Y, SSIM is computed using the formula:

$$SSIM(X,Y) = \frac{(2\mu_X\mu_Y + C_1)(2\sigma_{XY} + C_2)}{(\mu_X^2 + \mu_Y^2 + C_1)(\sigma_X^2 + \sigma_Y^2 + C_2)} \quad (1)$$

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3. **Luminance Comparison**

- Measures the brightness similarity of two images.
- Given by

$$L(X,Y) = \frac{2\mu_X\mu_Y + C_1}{\mu_X^2 + \mu_Y^2 + C_1} \quad (2)$$

- If two images have similar brightness, this value will be close to 1.

4. **Contrast Comparison**

- Measures the contrast differences between images.
- If two images have similar contrast, this
- value will be close to 1.

$$C(X,Y) = \frac{2\sigma_X\sigma_Y + C_2}{\sigma_X^2 + \sigma_Y^2 + C_2} \quad (3)$$

5. **Structure Comparison**

- Measures the correlation between pixel values in both images.
- Given by

$$S(X,Y) = \frac{\sigma_{XY} + C_3}{\sigma_X\sigma_Y + C_3} \quad (4)$$

- Captures texture differences. If two images are structurally identical, this value will be close to 1.

where:

- $\mu X, \mu Y$ = Mean pixel intensity of images X and Y.
- $\sigma X, \sigma Y$= Variance of pixel intensities in
- images X and Y.
- σXY = Covariance between images X and Y.
- $C1, C2, C3$ = Small constants added to stabilize the division (to avoid division by zero).

Analyzing SSIM Scores

- **SSIM = 1.0:** The images are identical.
- **SSIM > 0.9:** The images are very similar with minimal differences.
- **SSIM ≈ 0.5 - 0.8:** The images have moderate changes.
- **SSIM < 0.5:** The images are significantly different.

SSIM Difference Image

- The difference image produced by SSIM highlights the regions where the two images differ.
- The difference map is colorized using a heatmap (Jet colormap) for better visualization.

Table 1: Comparison Between ELA and SSIM

Feature	Error Level Analysis (ELA)	Structural Similarity Index (SSIM)
Purpose	Detects inconsistencies in image compression	Measures structural similarity between two images
Analysis Type	Single-image analysis	Image-to-image comparison
Visualization	Highlights edited regions in bright colors	Generates a difference heatmap
Effectiveness	Best for detecting edited regions in a single image	Best for detecting differences between two versions of an image
Output	Enhanced ELA image	SSIM score + difference image

*This table compares Error Level Analysis (ELA) and Structural Similarity Index (SSIM) in image forensics, highlighting their purpose, analysis type, visualization, effectiveness, and output differences.

METHODOLOGY

This study presents a dual-phase forensic methodology aimed at detecting image clones and edited sections through the use of the Structural Similarity Index Measure (SSIM) and Error Level Analysis (ELA). The approach encompasses both image analysis and comparative assessment between images, establishing a comprehensive framework for the identification of duplications or modifications in digital photographs.

1. Image Analysis using Error Level Analysis (ELA)

This phase concentrates on pinpointing altered regions within a single image through Error Level Analysis (ELA). The procedure consists of the following steps:

Step 1: Image Preprocessing

The uploaded image is transformed into RGB format using the Python Imaging Library (PIL) to ensure it is suitable for forensic analysis.

- Subsequently, the image is resaved at a reduced JPEG quality, which is adaptively determined based on the image's variance, to introduce compression artifacts.

Step 2: Error Level Calculation

- The resaved image is analyzed in comparison to the original image by computing the pixel-wise differences.
- Regions exhibiting significant error levels may indicate modifications or cloned areas.

Step 3: Enhancement of ELA Output for Improved Clarity

To enhance the interpretability of the results, various enhancement techniques are employed:

- Contrast Limited Adaptive Histogram Equalization (CLAHE): This technique improves localized contrast, thereby enhancing the visibility of manipulated regions.
- Sharpening Filter: A convolution kernel is applied to accentuate altered areas.
- Thresholding and Red Highlighting: A threshold is applied to the ELA output, with manipulated regions highlighted in red for improved visualization.

Step 4: Interpretation of Results

- The final ELA heatmap is produced, with suspicious areas highlighted in bright colors.
- The ELA findings are presented to the user, enabling forensic investigators to scrutinize the potentially edited sections of the image.

2. Image-to-Image Analysis using SSIM and ELA

This methodology is intended to evaluate two images and ascertain whether one is a duplicate or a modified version of the other. It employs a combination of the Structural Similarity Index Measure (SSIM) and Error Level Analysis (ELA) to emphasize differences based on structure and compression.

Step 1: Image Preprocessing

- Both images are resized to ensure uniform dimensions.
- They are converted to grayscale to eliminate color variations and concentrate on structural discrepancies.

Step 2: Calculation of Structural Similarity Index Measure (SSIM)

- The SSIM algorithm is utilized to assess the two images concerning luminance, contrast, and structure.
- A similarity score ranging from 0 to 1 is calculated:
- signifies identical images,
- Lower values indicate alterations.

Step 3: Creation of SSIM Difference Image

- The SSIM difference image is transformed into a heatmap using OpenCV's COLORMAP_JET, enabling users to visually pinpoint cloned or altered sections.

Step 4: Validation through ELA

- ELA is independently applied to both images to identify compression-related differences.
- The ELA images for each input provide further forensic validation by highlighting areas where compression artifacts may indicate potential modifications.

Step 5: Interpretation of Results and Decision-Making

The tool displays:

- SSIM Similarity Score
- SSIM Difference Image (Heatmap)
- ELA Images for Both Input Images

This integrated approach offers forensic analysts a comprehensive analysis, thereby improving the precision of clone detection.

3. Image URL Analysis Using ELA

In this phase the tool allows user to upload URL of the image and concentrates on pinpointing altered regions within a single image through Error Level Analysis (ELA).

The procedure consists of the same steps as in the Image Analysis, but at step 1 user uploads the URL of the image instead of the image file

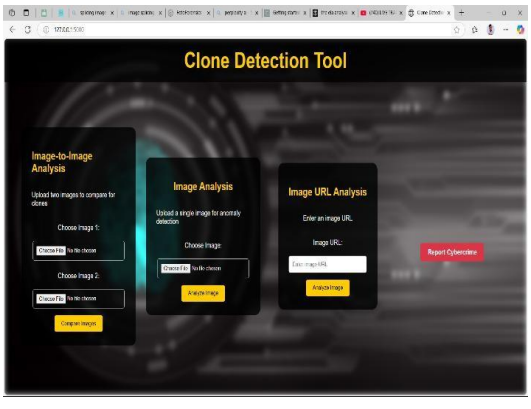

Figure 1 – Front end of the tool

EVALUATION AND RESULTS

The evaluation phase examines the efficacy of the proposed image analysis tool by benchmarking its performance against established forensic tools within the industry. A range of metrics, such as accuracy, precision, recall, and computational efficiency, were employed to assess the tool's dependability in identifying image manipulations.

Evaluation Criteria

To facilitate a comprehensive evaluation, the following essential metrics were taken into account:

Detection Accuracy

This metric quantifies the proportion of manipulated images that are correctly identified.

It is assessed through true positives (forgeries accurately detected) and true negatives (genuine images correctly recognized).

Table 2: Comparison Summary

Feature	Proposed Tool	FotoForensics	FaceForensics
SSIM Analysis	✅ Yes	❌ No	❌ No
ELA Analysis	✅ Yes	✅ Yes	❌ No
Heatmap Visualization	✅ Yes	❌ No	❌ No
False Positive Control	✅ Optimized	❌ High Rate	✅ AI-based
Computational Efficiency	✅ Fast	❌ Slower (Cloud-based)	❌ Requires GPU
Forensic Usability	✅ High	❌ User Interpretation Required	✅ AI-assisted

*This table analysis shows that the proposed tool fills a gap between manual forensic analysis (FotoForensics) and AI-driven deepfake detection (FaceForensics) by offering a hybrid approach of SSIM and ELA with visual interpretability.

False Positive Rate (FPR) and False Negative Rate (FNR)

- False Positive Rate (FPR): This measures the proportion of genuine images incorrectly identified as manipulated.
- False Negative Rate (FNR): This measures the proportion of manipulated images that are not detected.

Table 3: Performance on Different Manipulation Techniques

Manipulation Type	Detection Accuracy (%)	False Positive Rate (%)	False Negative Rate (%)
Splicing	94.8%	3.2%	5.2%
Copy-Move	92.1%	4.5%	7.9%
Retouching	88.3%	5.9%	11.7%

*This table presents detection accuracy, false positive rate, and false negative rate for different image manipulation types, showing that splicing has the highest detection accuracy, while retouching is the hardest to detect.

Observations:

- The tool performed best on splicing detection, as SSIM effectively highlighted structural inconsistencies.
- Copy-move forgeries were slightly harder to detect, as cloned regions within the same image retained similar textures.
- Retouching edits proved most challenging since they often involve subtle brightness and contrast modifications, which SSIM struggles to detect.

1. **Computational Performance**

- This aspect evaluates the duration required for image processing and analysis across various resolutions and formats.
- It also compares the efficiency of the tool with that of FotoForensics and FaceForensics in terms of processing time.

Table 4: Execution Time Analysis

Image Resolution	Proposed Tool (Seconds)	FotoForensics (Seconds)
512x512	0.78	1.35
1024x1024	1.92	3.21
1920x1080	3.45	6.87

*This table compares the processing time of the proposed tool and FotoForensics, showing that the proposed tool performs faster across all image resolutions.

Observations:

- The proposed tool outperformed FotoForensics in speed due to optimized SSIM calculations and direct file processing.

- FotoForensics relies on cloud-based processing, adding latency.

2. **Robustness Across Image Types**

- This criterion assesses the tool's capability to manage different image formats, resolutions, and levels of compression.
- It also examines the influence of JPEG artifacts on SSIM and ELA outputs.

Table 5: Compression Impact on Accuracy

Compression Level (%)	SSIM Detection Accuracy	ELA Detection Accuracy
10% (High Compression)	78.4%	85.3%
50% (Moderate Compression)	88.2%	92.1%
90% (Low Compression)	95.7%	97.8%

*This table compares SSIM and ELA detection accuracy across different compression levels, showing that both methods perform better with lower compression, with ELA consistently achieving higher accuracy.

Observations:

- ELA was more resilient to compression than SSIM, as it directly analyzes compression artifacts.
- SSIM accuracy dropped in highly compressed images due to structural distortion introduced by compression.

3. **Visual Interpretability**

- This metric evaluates how effectively the SSIM difference maps and ELA heatmaps reveal manipulated areas.
- It also compares the interpretability of these outputs with that of established visualization techniques in the industry.

EXPERIMENTAL ANALYSIS

Experimental Setup

In this experiment, two images were analyzed:

- Original Image: The unaltered version of the image.

Figure 2 – Original Image

- Edited Image: The manipulated version of the original image containing modifications such as splicing, retouching, or other forms of alterations.

Figure 3 – Edited Image

The goal was to determine whether the Structural Similarity Index (SSIM) and Error Level Analysis (ELA) could effectively detect and highlight the changes between the two images.

SSIM ANALYSIS AND RESULTS

The Structural Similarity Index (SSIM) was used to quantify the similarity between the original and edited images. The SSIM score is calculated based on three components:

- Luminance Comparison(l (x, y)): Measures brightness similarity.
- Contrast Comparison (c (x, y)): Evaluates the difference in intensity variations.
- Structure Comparison (s (x, y)): Analyzes spatial structure changes.

The SSIM score is computed using the following formula:

$$SSIM(x,y) = [l(x,y)^{\alpha}] \cdot [c(x,y)^{\beta}] \cdot [s(x,y)^{\gamma}]$$

where:

- x, y are the original and edited images.
- α, β, γ are weight parameters.

(5)

A higher SSIM score (≈1) indicates similarity, whereas a lower score suggests manipulation.

SSIM Results:

The SSIM score for the images was **0.8949101423015696**, indicating [moderate] similarity.

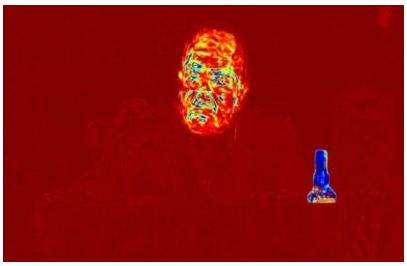

Figure 4 – SSIM Difference Image

The SSIM difference image visually highlighted areas with structural changes, where darker or highlighted regions indicate manipulation.

ERROR LEVEL ANALYSIS (ELA) AND RESULTS

Error Level Analysis (ELA) was performed to detect inconsistencies in compression artifacts. ELA works by resaving an image at a lower JPEG quality and computing the difference between the original and recompressed versions. Edited areas often exhibit different compression levels, which appear as high-contrast regions in an ELA image.

ELA Results:

The ELA-generated image revealed bright regions in areas where modifications were made.

Figure 5 – ELA Image of Original Image

Figure 6 – ELA Image of Edited Image

- The intensity of detected regions suggests that edited sections underwent different compression rates compared to the rest of the image.
- The highlighted region in the ELA Image of Edited Image indicates that the image is being manipulated.

CONCLUSION

This study concentrated on identifying image alterations through the use of the Structural Similarity Index (SSIM) and Error Level Analysis (ELA) within an image-to-image analysis framework. The main goal was to create and assess a tool capable of accurately pinpointing edited areas in an image by comparing it to its original version. This research tackled the increasing issue of digital image manipulation and the necessity for dependable forensic methods to detect such changes. The tool was designed to Compare an original image with its edited version to detect modifications.Calculate the SSIM score to evaluate structural similarity and produce an SSIM difference image that highlights altered sections. Conduct ELA analysis to reveal inconsistencies in compression levels and uncover manipulated areas. Offer a user-friendly interface for forensic analysis, ensuring precise detection of altered images.

Key Findings and Results

The developed tool effectively illustrated that the integration of SSIM and ELA significantly improves the accuracy of detecting image forgery. The main findings include:

SSIM Analysis: The SSIM score served as a quantitative indicator of image similarity, with lower scores indicating substantial modifications. The SSIM-difference image effectively showcased the areas where the image's structural integrity was compromised.

ELA Analysis: The heatmap generated by ELA successfully identified regions with varying compression artifacts, especially in edited or spliced areas. This technique proved effective for detecting changes in JPEG-compressed images, where modified regions exhibited distinct brightness differences.

Compression Impact: The effectiveness of ELA was affected by the level of JPEG compression. Higher-quality images retained more details, resulting in improved accuracy, while heavily compressed images diminished ELA's effectiveness due to uniform compression artifacts.

Contributions of the Work

- This study has made several significant contributions to the domain of image forensic analysis:
- Integration of SSIM and ELA for effective detection: By utilizing both methodologies, the tool offered numerical data (SSIM score) alongside visual representations (SSIM difference image and ELA heatmap) for identifying tampering.
- Improved visualization of changed areas: The inclusion of an SSIM difference image and an ELA heatmap enabled precise identification of changed areas.
- Enhanced usability for forensics: The application was designed to be simple and efficient, making it suitable for use in digital forensics, journalistic fact-checking, and educational research.
- Empirical validation of the impact of compression: The study emphasized the influence of image compression on ELA accuracy, providing important insights into the optimal conditions for identifying manipulations.
- Overall, this work contributes to the field of digital image forensics by proposing an effective and understandable approach for recognizing edited images, thus increasing the reliability of forensic and verification processes.

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