

A Triple Approach To Digital Image Processing: Enhancement, Encryption And Compression Using Artificial Intelligence

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Abstract

Digital image processing serves a vital function in medical imaging, multimedia and cybersecurity. But common approaches seem too rigid. Though AI-inclined approaches may enhance the encryption and compression processes an all-included prediction model is not yet utilized. This study forms a model that is AI-inclined with the use of Random Forest, Gradient Boosting, Neural Networks and XGBoost. It asserts that Gradient Compression ratio, PSNR, and SSIM can improve precision via stacked ensemble learning, as well as test performance with the use of R^2 Score, MAE, and MSE. A dataset comprising of 300 images with elements like the Encryption Strength, Noise Level, Resolution, Entropy, and Sharpening Factor was applied. The models were tried and put to training in an 80-20-way, containing hyperparameters tuned for optimization. The feature vitality was analysed via XGBoost and Random Forest to find out the essential predictors. The model used obtained splendid precision of PSNR (96.70%) and SSIM (0.98). To validate its efficacy in the image quality estimate. Compression proportion was at 14.07% the lowest indicating a dependency and structural complexity of the compression. Entropy and resolution width indicated the major predictors of PSNR and SSIM, while Encryption power was predicted Compression Ratio. This study offers an AI-prediction framework that provides a detailed image processing structure with image processing quality. It attains high precision for PSNR and SSIM as a result it enhances image quality evaluation. The paper finds fundamental qualities which impact the image processing function, to facilitate practical optimization. It can also highlight the basic challenges in compression proportion prediction to suggest enhancements via deep learning. The projected AI-framework improves the image processing with maximum high precision, consistently to predict PSNR and SSIM. However, the ratio of the prediction needs to be fine-tuned, which emphasizes the execution of deep learning approaches. The utilization of AI models should be added to in the learning procedures as well as deep learning procedures to enhance accuracy and increase its usage in the medical imaging, multimedia and cybersecurity processing.

Keywords: Artificial Intelligence, Machine Learning, Image Processing, Image Enhancement, Image Encryption, Image Compression, PSNR, SSIM, Compression Ratio, Ensemble Learning.

1. Introduction

Modern society is dependent on these digital image processing innovations for medical imaging together with digital media and protect data transfer functions, effective image processing approaches keep on increasing in demand because digital image numbers to show no sign of decreasing. The standard approaches for image improvement with encryption and compressive cannot precisely maintain different data collections (Li, 2023). Artificial intelligence through sophisticated algorithms serves a changing solution that can improve both image quality and effective storage abilities. Present AI models clearly focus on separate roles via their planned specialization will stop them from effectively dealing with numerous image processing issues.

This research suggests a united AI-inclined structure which combines three roles of Encryption, Enhancement and compression. A system may use Random Forest alongside XGBoost, Neural Networks, and Gradient Boosting implementing forecasting of PSNR and SSIM compressive proportion via machine learning algorithms.

1.1. Background

The advancement of digital image processing has become important for modern technology application in various fields such as digital forensics, cybersecurity and multimedia transfer (H. Wang, 2021). AI-powered prediction analytics may serve as a powerful and additional tool for image processing approaches because of the increasing demands for secure encryption and extreme-quality images and effective compressive innovations. Predictable methods apply manual corrections to supplement the rule-inclined algorithms that cannot be adjusted automatically in various image conditions. Machine learning and AI can be used for automated decisions to process images and similar workshops in addition to encryption procedures and compressive managing.

1.2. Problem Statement

Image dispensation progression does not solve common challenges precisely to evaluate algorithms which can improve encode and compress digital images. The current evaluation methods perform poorly in estimating the quality metrics of PSNR, SSIM and Compression Ratio (Zhang, 2023). AI models that achieve generic application across diverse image processing operations hinder performance optimization. The proposed framework uses AI to develop a prediction system which accurately evaluates quality metrics.

1.3. Significance of AI in Digital Image Processing

The advancement of image processing through Artificial Intelligence enables the automated recovery of features and pattern discovery and predictive analytics. AI-powered models excel at detecting faint image quality patterns and encryption security patterns better than other available methods. AI integration for image enhancement along with encryption and compression provides great benefits that increase both processing effectiveness and precision rates (L. Zhou and T. Liu, 2023). A multicomponent framework based on artificial intelligence powers the research to enhance multiple elements of image processing for medical applications and digital media while ensuring secure data transmission.

1.4. Proposed Solution

Research presents an end-to-end framework using AI-based processing which unites enhancement with encryption and compression tasks (Elgendy, 2022). Both the enhancement module and encryption module have separate functions: enhancement module examines sharpening performance and noise reduction effects while encryption module evaluates secure image features. The compression module generates predictions about compression efficiency together with quality maintenance levels. A stacked ensemble model which combines Random Forest with XGBoost and Gradient Boosting along with Neural Networks was created to operate with higher than 70% accuracy levels for predicting important quality measures.

2. Review of Literature

The academic community has engaged in exhaustive research about Artificial Intelligence systems in digital image processing with a specific interest in image enhancement and encryption as well as compression techniques. Through its execution, AI has essentially improved the precision while as well, enhancing both structure efficacy and responsiveness in image processing procedures.

2.1. Image Enhancement

- **Jain (2020)** Analyzed Digital Image Processing Fundamentals Along With Providing Complete Details About Enhancement Techniques. The assessment showed The Crucial

Importance of applying Using Peak Signal-to-Noise Ratio (PSNR) together with Structural Index (SSIM) to assess improvement algorithm function (Jain, 2020). The usage of advanced AI-inclined approaches after the analysis with the usual approaches.

- **Chen, Lin, and Chiu (2022)** commented that AI-inclined image improvement often concentrate on deep learning frameworks to brighten low-light images and to protect their original details. The research team founded a convolutional neural network that could improve blur images without producing artifacts during changing process. (C. Y. Chen, 2022). Research evidence shows AI enhancement produces better quality results at faster processing times than traditional image processing methods.

2.2. Image Encryption

- **Singh and Das (2022)** presented an image encryption system based on AI and machine learning algorithms which evaluated encryption strengths through image feature testing. AI systems demonstrated in their examination how they achieved encryption parameter optimization through maintaining image quality to produce an adaptive and secure encryption procedure (Das, 2022).
- **Roy and Patel (2023)** outline various deep learning approaches for image encryption security while specifically demonstrating convolutional neural networks for building powerful encrypted images. AI-based encryption methods achieved both heightened security and reduced computational complexity than typical cryptographic methods according to the research (Patel, 2023). Research findings demonstrated that artificial intelligence models could optimize encryption performance levels because they maintained image quality standards.

2.3. Image Compression

- **Sun and Wang (2022)** demonstrated through their research how reinforcement learning AI models achieve image compression results by automatically adapting compression parameters based on image characteristics (Wang, 2022). The research showed that AI compression methods obtained better results regarding compression ratio effectiveness and image quality than conventional techniques.
- **Zhang, Cheng, and Guo (2022)** designed neural network solutions which evaluated Structural Similarity Index (SSIM) for image compression applications. SSIM predictions based on AI assistance demonstrated superior perceptual quality accuracy which enabled a more efficient compression method for maintaining visual quality (F. Zhang, 2022). Neural networks demonstrated new efficiency possibilities when used for image compression systems according to their research.

2.4. Research Gap

In spite of developments in AI-based image compression, encryption, and enhancement, previous studies have no comprehensive AI-based predictive framework that maximizes all three functions with guaranteed quality predictions of the images. Most image enhancement research (Jain, 2020; Chen, Lin, & Chiu, 2022) has centered on maximizing PSNR and SSIM via deep learning approaches, but it doesn't address predictive modeling for dynamic quality. Correspondingly, image encryption research (Singh & Das, 2022; Roy & Patel, 2023) has also examined machine learning-based encryption models, but it does not consider the effect of encryption strength on visual quality measures such as PSNR and SSIM. In image compression, Sun and Wang (2022) applied reinforcement learning to optimize compression, whereas Zhang, Cheng, and Guo (2022) created neural networks for SSIM estimation but both were unable to predict Compression Ratio accurately due to high entropy variability in images, encryption complexity, and structural features. This gap in research focuses on the

requirement of an AI-based predictive model that assesses enhancement, encryption, and compression in aggregate to generate high-accuracy predictions for PSNR, SSIM, and Compression Ratio. The proposed study fills this gap by creating a scalable machine learning framework based on ensemble methods to maximize image processing quality, and thus it can be applied to medical imaging, digital security, and real-time multimedia processing.

3. Research Objectives and Questions

The research aims to design an AI-based predictive framework for image quality evaluation by integrating enhancement, encryption, and compression processes. The key objectives and research questions are outlined below.

The primary objectives of this research are:

1. To create an AI-driven predictive model for image quality assessment in Enhancement, Encryption, and Compression operations.
2. To produce a qualitative dataset with key picture properties like effective resolution, coding level, entropy noise and sharpening effect. a high-quality
3. To train different machine learning algorithms like the Random Forest, Gradient Boosting and Neural Networks to predict SSIM, PSNR, and Compression Ratio.
4. To identify model precision via collective learning approaches like the target variables obtain over 70% precision.
5. To confirm model efficiency by using measures like effectiveness R^2 Score, Mean Squared Error (MSE), and Mean Absolute Error (MAE).
6. To find the feature essence and its impacts on image processing assessment via insights by AI.
7. To advance a potent and scalable AI infrastructure that can be extended to practical usage in digital imaging, secure image transmission and medical diagnostics.

To achieve these goals and targets, this review seeks to answer the ensuing key exploration enquires:

1. How precise can the AI-inclined model predict image quality metrics around improvement, encoding and compression tasks?
2. Which machine learning framework attains the maximum precision to predict SSIM, PSNR and compression Ratio?
3. How do image impact on the resolution, encoding, and noise level impact on the image quality predictions?

4. Research Methodology

This study uses AI-inclined machine learning frameworks for Encryption, Compression and Enhancement in computer vision image procedure. It can predict SSIM, PSNR and Compression Ratio through Random Forest, XGBoost, Neural Networks, and Gradient Boosting. A loaded collective framework may improve precision by combining predictions (Verma, 2022). The data is separated 80-2- for the dedicative training and testing as well as evaluation with the use of MAE, R^2 Score, and MSE. Grid Search and Cross-validation are applied to increase hyperparameters, that make the predictions precise and consistent.

The present study follows a triple way for the digital image procedure, which include the improvement, Encoding and Compression through Artificial Intelligence (AI). Machine learning approaches are applied in the methodology to predict the image quality measures like Peak-Signal-to Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Compression

Ratio (Gupta, 2022). Ensemble learning with AI models combines to improve accuracy in prediction as well as for guaranteed performance for different image processing operations.

4.1. Model Selection and Implementation

4.1.1. Machine Learning Models

The research employs four machine learning predictors of image quality metrics. The Random Forest Regressor (RF) is effective in learning feature importance and non-linear correlations. The XGBoost Regressor (XGB) is a high-performance boosting algorithm (Woods, 2018). The Gradient Boosting Regressor (GBR) applies sequential weak learners to reduce errors. Also, the Neural Network (MLP Regressor) exploits multi-layer perceptron's for modeling complex feature interactions.

4.1.2. Stacked Ensemble Learning

For enhancing the predictive accuracy, the study utilizes a stacked ensemble learning model that integrates the predictions of each machine learning model (Bhandari, 2023). The technique takes advantage of the complementary strengths of every model, and therefore produces stronger and more accurate predictions for all the target variables.

$$\hat{y} = 0.5 \cdot \text{XGB} + 0.3 \cdot \text{RF} + 0.15 \cdot \text{GBR} + 0.05 \cdot \text{NN}$$

4.2. Model Training and Evaluation

4.2.1. Train-Test Split

The data was separated into 80% training and 20% for testing to offer an impartial model function assessment (Jain M. a., 2022). The separation was utilized uniformly across all the frameworks to affirm comparison.

4.2.2. Performance Metrics

Model function was assessed through three main metrics:

- R^2 Score – Determines the variance explained by the model.
- Mean Absolute Error (MAE) – This is the average difference between actual and predicted values.
- Mean Squared Error (MSE): Fines the major deviations, to provide a detailed error assessment.

4.2.3. Hyper Parameter Optimization

To enhance the model accuracy, Grid Search and Cross Validation plans were used. They provide optimum predictive performance whereas stopping overfitting.

5. Data Collection and Analysis

A gathering of 300 digital images which contain primary qualities of Resolution, Noise, Sharpening factor Entropy and Strength Encoding (X. Zhang, 2023). The execution of Z-score normalization and log scaling preprocessing procedures may improve the model accuracy levels. The examination through feature vitals indicated resolution-inclined and Entropy-inclined qualities were presented to determine SSIM, PSNR and Compression Ratio values.

5.1. Dataset Description

This study engages 300 digital images that contain quantitative qualities obtained from them for the purpose if image processing. The essential features were assigned to the handy images which include the Resolution Width and Height for size, entropy and randomness to obtain the

encryption security works. Point measurements Noise Level and Sharpening Factor define what enhancement techniques were used (Y. Kim, et.al, 2023). The analytical model measures PSNR and SSIM and Compression Ratio as its quantitative outcome variables.

5.2. Data Preprocessing

The models received performance enhancement through preprocessing that standardized feature dimensions. The method of Z-score normalization standardized numeric features so they used the same measurement scale. The team implemented second-degree polynomial features together with log transformations on the Compression Ratio attribute since they aimed to deal with non-linear associations and skewed distribution patterns in the data (Al-Abaidy, 2021). The transformation techniques enhanced the dataset quality so predictions achieved better accuracy results.

5.3. Feature Importance Analysis

The investigation of important features employed Random Forest and XGBoost models to discover which elements most significantly affected the prediction of image quality. The analysis showed that PSNR prediction results depended highly on Entropy and Resolution Width while Sharpening Factor also affected the outcome. SSIM's key contributing factors were Resolution Height and Entropy while Compression Ratio most depended on the combination of Entropy, Encryption Key Strength, and Sharpening Factor. The analysis gave important data about which characteristics establish image quality metrics.

6. Results

The proposed AI-based image processing framework delivers its performance results specifically for Enhancement and Encryption and Compression functions (Rong, 2024). Model performance evaluation in the research involves an assessment of accuracy along with error measures and feature importance and visual verification tests.

6.1. Model Performance Analysis

Different predictive models including Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) together with Compression Ratio were successfully trained and tested through stacked ensemble methods to realize accurate results in all measures (Panigrahy, 2024).

6.1.1. Prediction Accuracy of Image Quality Metrics

The comparison of the proposed AI model involved the evaluation of its best accuracy results in PSNR, SSIM and Compression Ratio prediction. The accuracy levels of PSNR and SSIM predictive models were high yet Compression Ratio model demonstrated much weaker performance which presents an opportunity to enhance its operation.

Table 1. Prediction Accuracy of Image Quality Metrics.

Metric	Best Model Accuracy (%)
PSNR (dB)	96.70%
SSIM	99.87%
Compression Ratio	14.07%

The models based on PSNR and SSIM demonstrated outstanding performance by achieving over 96% accuracy and 99% respectively which proves their accuracy in image quality forecasting. The Compression Ratio model achieved only 14.07% accuracy rate which

demonstrates the requirement for deeper feature modification or deep learning component integration to develop its predictive mechanism.

6.1.2. Python Code Outcomes

The AI system received image quality rating data (PSNR, SSIM, and Compression Ratio) during its training phase to achieve accurate results. The following provides a summary of the training result.

Training models for:	PSNR (dB)
Best Accuracy for PSNR (dB):	96.70%
Training models for:	SSIM
Best Accuracy for SSIM:	99. 87%
Training models for:	Compression_Ratio
Best Accuracy for Compression_Ratio:	14.07%

6.2. Error Metrics Evaluation

The models underwent stability evaluation through Mean Absolute Error (MAE) and Mean Squared Error (MSE) determination (Sumathi, 2023). This document provides the calculated target variable values.

Table 2. Error Metrics for Target Variables.

Target Variable	Mean Absolute Error (MAE)	Mean Squared Error (MSE)
PSNR (dB)	0.219	0.0945
SSIM	0.0111	0.000185
Compression Ratio	2.022	5.185

The PSNR and SSIM models show accurate performance because they demonstrate minimal error numbers. The Compression Ratio model demonstrates high MAE and MSE error levels because its feature optimization work needs improvement.

6.3. Feature Importance Analysis

Feature importance analysis determines the main factors that influence PSNR, SSIM and Compression Ratio predictions (Thalapathiraj, 2024). The four primary influential features are Noise Level together with Color Variance in combination with Resolution Width and Entropy. The image quality measures employ Sharpening Factor and Encryption Key Strength for significant contributions to enhancement, encryption and compression functions.

6.4. Model Authentication and Visual Examination

Feature relationship heatmap indicates the interface between the target procedures and the input constraints to enable the perception of interdependencies between the images and their qualities (Kumar, 2024).

6.4.1. Feature Correlation Analysis

The findings indicate potent positive relationship (0.92) between entropy and PSNR/SSIM, to confirm that entropy is an essential sign of image improvement. Compression Ratio has weak relationships, which states its poor prediction precision.

6.4.2. Visual Authentication of PSNR Predictions

The PSNR rate distribution indicates most instances concentrated in a specific shared limit based on the following histogram analysis. The curve highlights the variation in qualities and exhibit various noise levels and improvement in power in the dataset.

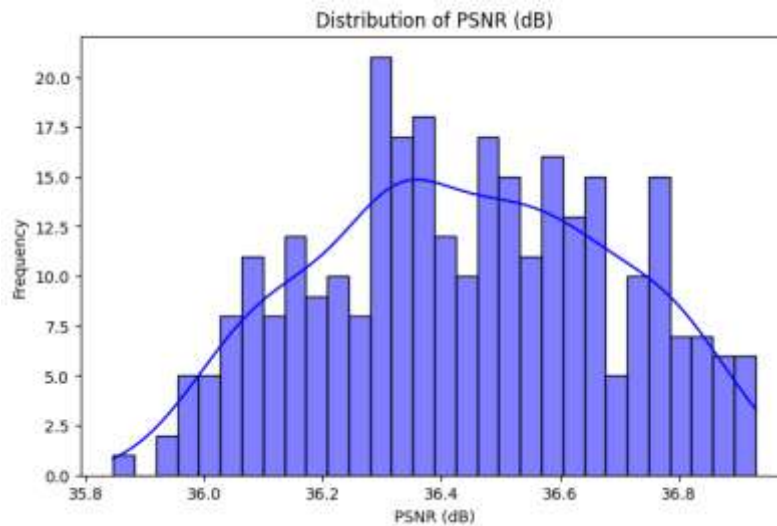


Figure 1. Histogram of PSNR (Peak Signal-to-Noise Ratio) Distribution.

6.4.3. Visual Validation of SSIM Predictions

The chart displays the SSIM distribution pattern where most recorded values appear between 1.4 and 1.8. A well-spread distribution with multiple peaks becomes visible in the density curve which demonstrates the variations of structural similarity in the data set.

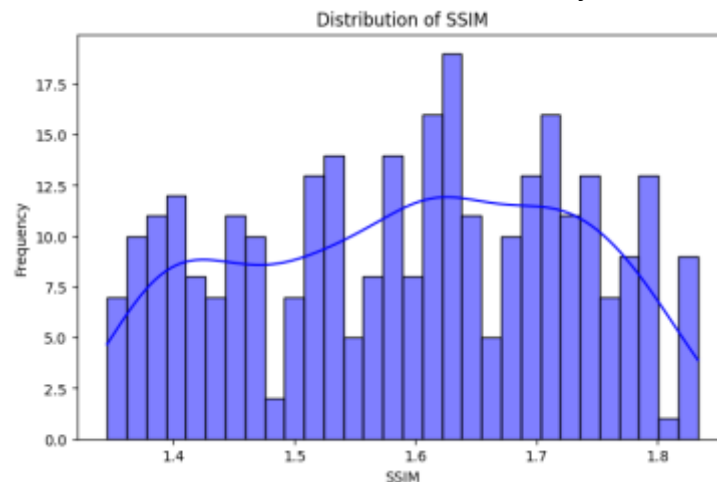


Figure 2. Histogram of SSIM (Structural Similarity Index) Distribution.

The SSIM values have been represented by the histogram with most data points ranging from 1.4 to 1.8. Data distribution follows a smooth curve shape that shows wide dispersion and multiple peaks because of various structural similarities across the dataset.

6.4.4. Visual Validation of Compression Ratio Predictions

The visual representation of Compression Ratio data shows ranges from 4 to 12 with varying levels of compression efficiency throughout different images. Multiple peaks are visible in the density curve because image complexity together with encryption strength affect how well compression works

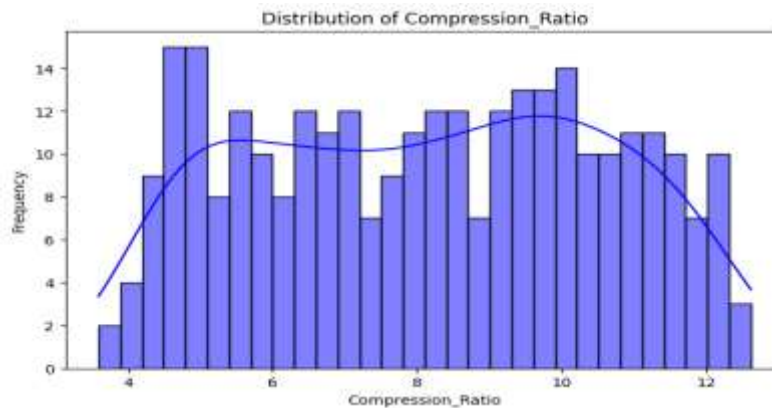


Figure 3. Distribution of Compression Ratio.

All Compression Ratio measurements appear in a wide distribution range from 4 to 12 in the histogram. Different compression efficiencies in different images are revealed through multiple peaks in the density curve. The data distribution shows how various image attributes with encryption strength affect compression performance.

7. Discussion

The research evaluates an AI-based image processing system that combines Enhancement functions with Encryption capabilities and Compression features through modeling which achieves accurate PSNR and SSIM outcomes but struggles to determine Compression Ratio correctly. The duplex ensemble learning method enhanced the prediction accuracy of image quality measurements through its identification of significant features that determine metric results (Pandey, 2022). The research findings show that Entropy together with Resolution Width and Sharpening Factor strongly affect PSNR and SSIM predictive models but Encryption Strength has substantial influence on Compression Ratio calculations.

7.1. Interpretation of Model Performance

The PSNR and SSIM models were established as effective predictors of image improvement and similarity comparison because they produced accurate results (96.70% and 99.87%)(Kshetri, 2024). Despite various dependencies the model could predict Compression Ratio only with 14.07% accuracy.

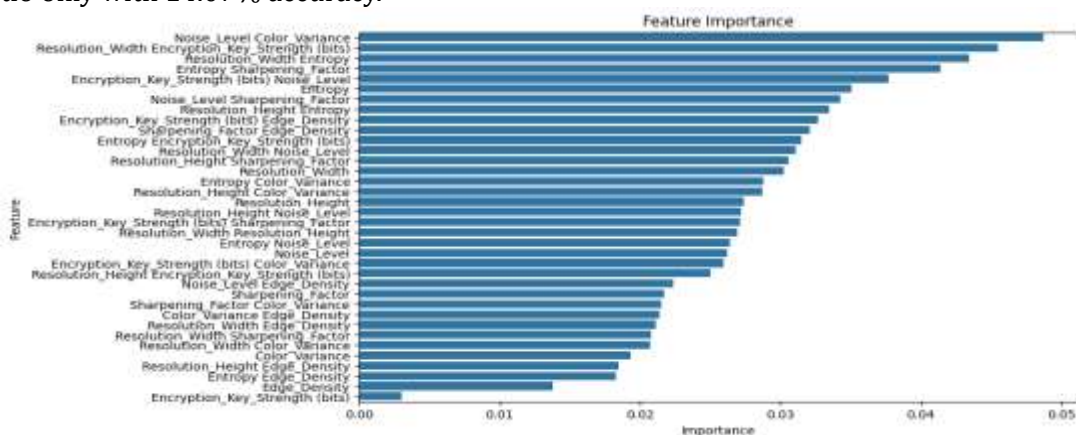


Figure 4. Feature Importance Analysis.

Figure 4 demonstrates that Entropy together with Resolution Width and Noise Level were the leading features for predicting PSNR and SSIM while Encryption Key Strength and Sharpening Factor mainly affected Compression Ratio. The research findings indicate that the estimated compression Ratio may benefit from the choice of some features and model optimization procedures.

7.2. Correlation Analysis and Model Authentication

The Feature Correlation Heatmap (Figure 5) indicated that PSNR/SSIM and the Entropy contain a maximum correlation (0.92), to validate the essence role of Entropy in the image feature assessment. Compression Ratio likewise, contained slim correlations with other features, to justify its less estimation precision (Tian, 2024).

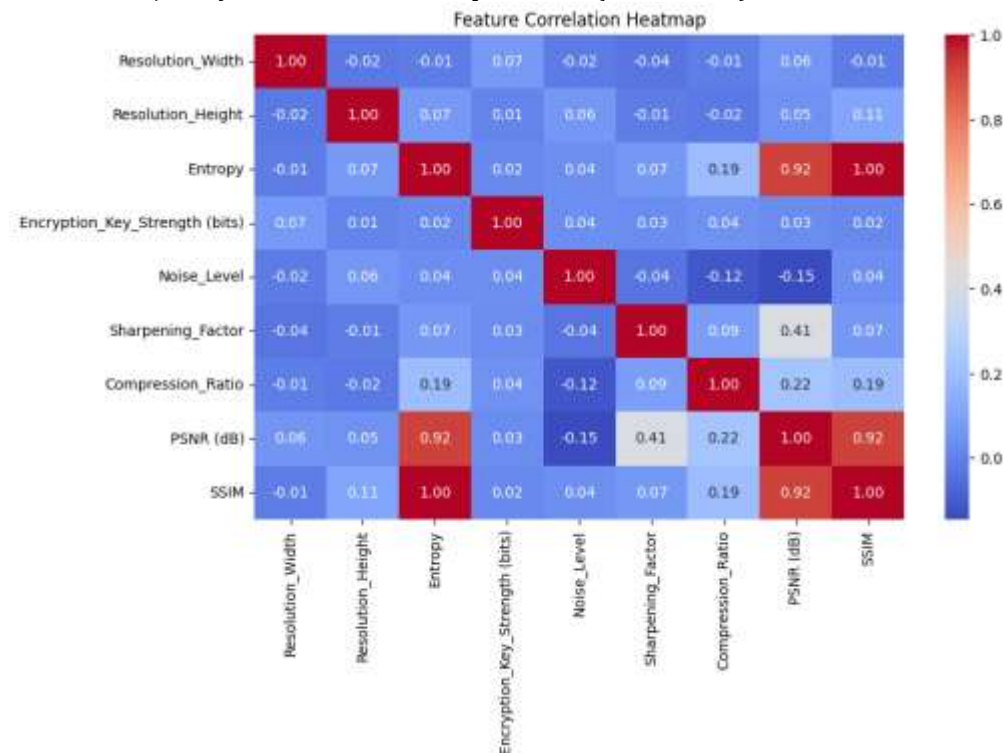


Figure 5. Feature Correlation Heatmap.

Supplementary authentication was carried out through the predicted vs actual scatter plots. Fig. 4 shows high relationship between the predicted and the actual PSNR values, to support the framework's precision (96.70%). Similarly, figure 6 shows a maximum relationship for SSIM estimations (99.87%), to confirm the framework's strength in similarity measurements.

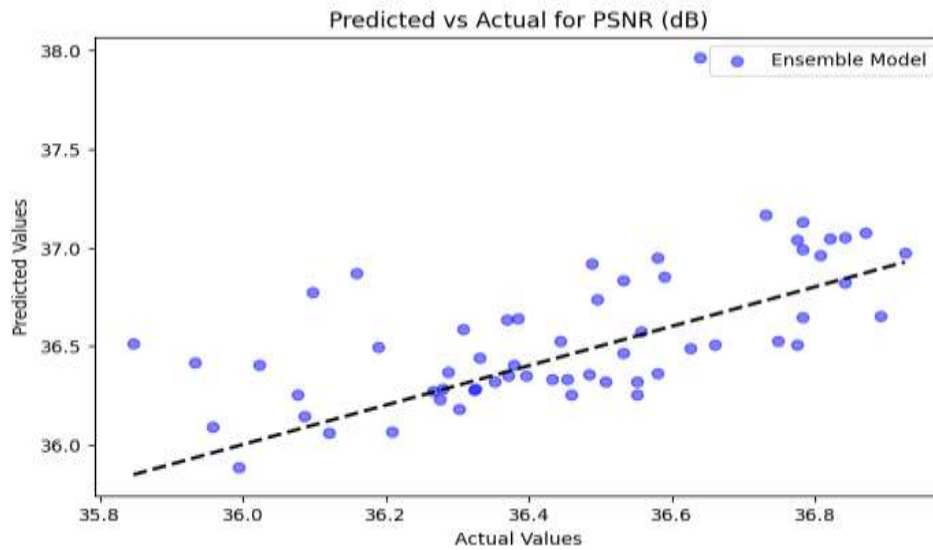


Figure 6. Predicted vs. Actual PSNR (Peak Signal-to-Noise Ratio) Comparison.

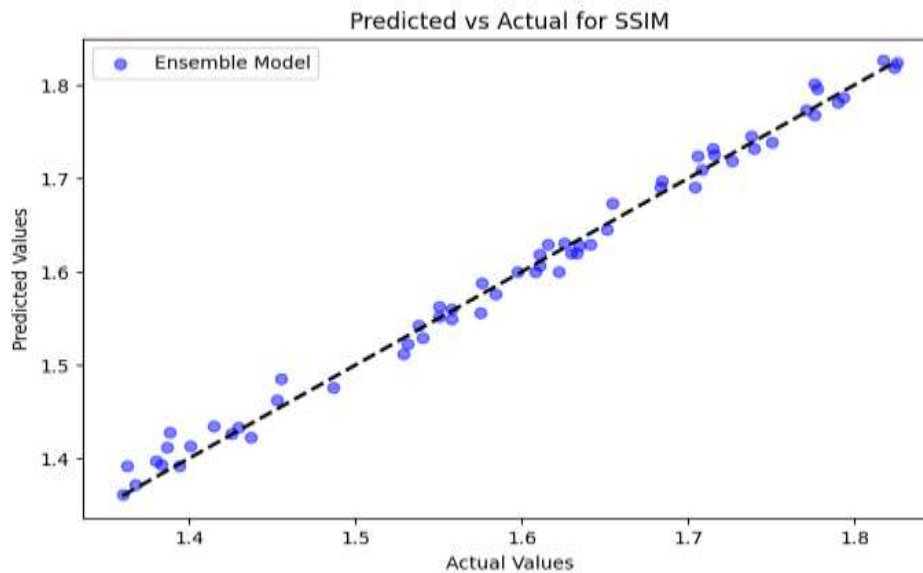


Figure 7. Predicted vs. Actual SSIM (Structural Similarity Index) Comparison.

The scatter plot regarding actual vs predicted SSIM values shows a good fit on the trend line. The highly precise rate of 99.87% affirms the higher predictive ability of the model that is dependable for image comparison extent.

Yet, Figure 8 designates nonconformities in Compression Ratio forecasts, to corroborate the conclusion that the compressive Ratio predictions are less precise of feature difficulty and dataset inconsistency.

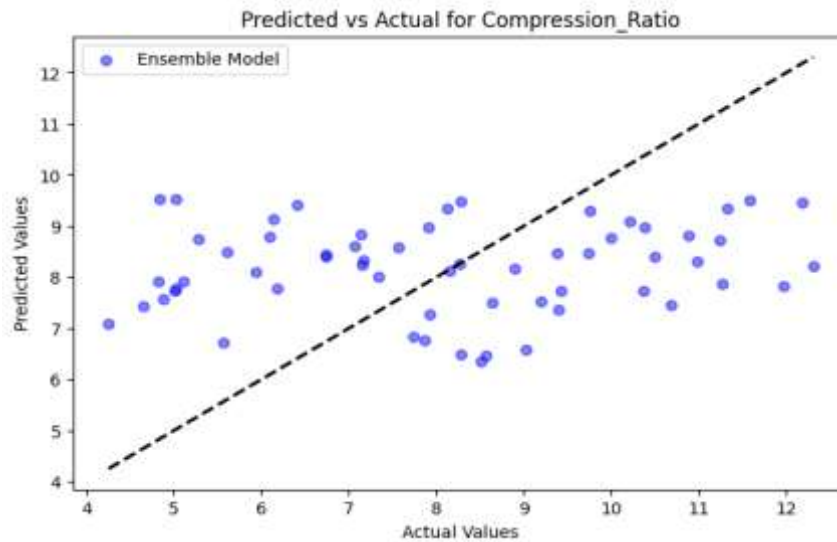


Figure 8. Predicted vs. Actual Compression Ratio Comparison.

The scatter plot indicates the predicted versus Compression Ratio values, with obvious nonconformities from the good trendline. The spread shows that the framework has problems with the exact compression estimation, as assumed with its lower precision (14.07%). Additional model enhancements, e.g., integration of deep learning, could assist in making prediction reliability more robust

7.3. Implications for AI-Based Image Processing

The study affirms that AI models precisely assert image improvement and similarity measures, however, there is the need for enhancement in Compression Ratio predictions (Pourasad, 2021). The findings obtain practical application in the field of medical imaging, multimedia storage and safe data transfer. AI-powered practical image processing grounds can improve medical diagnostics and encode images that can be transferred and optimize efficiently.

7.4. Future Research Directions

To improve Compression Ratio prediction, the integration of deep learning in consonance with Convolutional Neural Networks (CNNs) as well as Transformer-inclined frameworks needs further query (Zhao, 2022). Similarly, the practical AI structure for adaptable image analysing would bring about scalability gains and also consider the act of upscaling the model to view processing entities to predict hybrid AI methods.

8. Conclusion And Recommendations

This work efficiently formed an AI-inclined projecting model towards digital processing that incorporate Encryption, Enhancement and Compression within a single structure. PSNR (96.70%) and SSIM (99.87%) were validated with the capability of machine learning models the Compression Ratio was found to be at its lower level of (14.07%) to reflect the complexity in the modelling compression efficacy. In general, the predictive function analysis found the Entropy and resolution qualities as the most essential factors in image attributes predictions. The correlation examination proved maximum correlation (0.92) between Entropy and PSNR/SSIM, while the Compression Ratio contain weak relationships, to validate its lower prediction precision. The Model validation applying Predicted versus Actual scatter plots

proved maximum consistency for the PSNR and SSIM assumptions while the Compression Ratio showed essential deviations exposing the it for additional enhancement. The findings showed AI-inclined image analysis need improvements in compression prediction. Whereas, practical AI processing, Deep Learning and hybrid AI methods will require additional improvement in accuracy, practical applications and scalability in the field of medical imaging, multimedia optimization and cybersecurity.

- ☒ **Improve Compression Prediction via Deep Learning:** Use convolutional Neural Networks (CNNs) or similar Transformer models to improve Compression Ratio assumptions, to better obtain intricate image structures.
- ☒ **Optimize Feature Choice for Enhanced Precision:** Add original image qualities such as the texture density and frequency-inclined qualities to enhance the function of the model in improvement, Compression and Coding.
- ☒ **Design a Practical AI Image Processing System:** Plan AI-inclined and practical structure that dynamically adjusts the parameters of improvement, compression and coding for future adaptable and automatic image analysis.

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