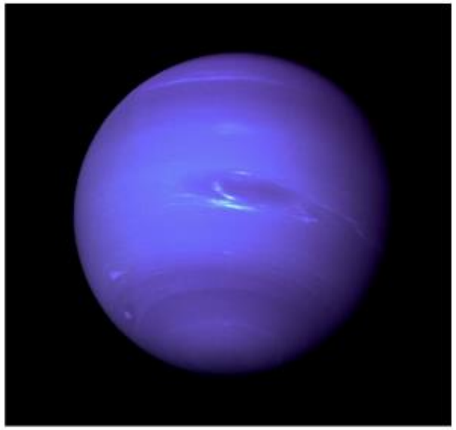
Image Super-Resolution using Enhanced Sub-Pixel Convolutional Networks (ESPCN)

Abstract

- **Problem Statement:** Super-resolution is crucial in enhancing image quality for applications like medical imaging, satellite photos, and security.
- **Existing Methods:**
  - **Traditional Interpolation:** Bicubic, Bilinear – Fast but poor quality.
  - **State-of-the-Art (e.g., Real-ESRGAN):** High quality but computationally expensive.
- **Our Approach:**
  - We implement **Efficient ESPCN**, which balances performance and speed.
  - We compare results across different **scaling factors (2x, 3x, 4x)**.
  - Also compare **with and without augmentation** for scale=2.

Picture of a planet 4 billion kilometres away



Security camera

1. Introduction

- **Existing Methods**:
  - Bicubic/Bilinear → Simple but low-quality
  - Real-ESRGAN / EDSR → High quality, high cost
- **ESPCN Motivation**:
  - Lightweight, real-time
  - PixelShuffle-based upsampling
  - Great for mobile, video,embedded or web use-cases.

2. Dataset – DIV2K (from Kaggle)

- **DIV2K Dataset**: Large, diverse collection of 2K resolution RGB images
- **Train set**: 800 HR images → LR pairs for ×2, ×3, ×4
- **Validation set**: 100 HR images, for feedback evaluation
- **Test set**: 100 diverse images (HR released post-challenge)
- **Use case in this project**:
  - Only the **training HR images** used to synthesize LR-HR pairs
  - Enables training of SR models on a wide variety of natural scenes

3. Proposed Methodology

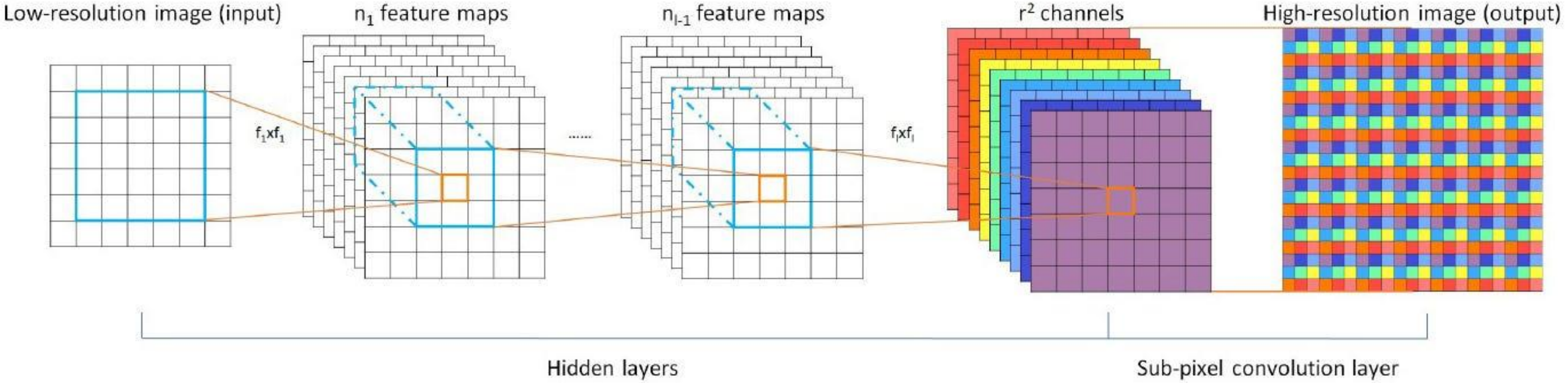
Preprocessing & Augmentation

- **Bicubic downsampling** to create LR images from HR
- **Augmentation**:
  - **HorizontalFlip (p=0.5)**
    → Flips the image horizontally with 50% probability.
  - **RandomBrightnessContrast (p=0.3)**
    → Randomly adjusts image brightness and contrast (30% chance).
  - **GaussNoise (var_limit=(5.0, 20.0), p=0.3)**
    → Adds Gaussian noise with variance between 5–20 (30% chance).
  - **ImageCompression (quality_lower=85, quality_upper=100, p=0.4)**
    → Simulates JPEG compression artifacts with 85–100% quality (40% chance).
  - **RandomGamma (p=0.3)**
    → Applies gamma correction to change brightness non-linearly (30% chance).
  - **HueSaturationValue (p=0.3)**
    → Randomly modifies hue, saturation, and value (HSV) channels (30% chance).

3. Proposed Methodology

ESPCN Model Architecture

- Input → Conv (ReLU) → Conv (ReLU) → Conv → Pixel Shuffle
- Uses **depth-to-space** rearrangement (efficient upscaling)
- Trained separately for **scale=2, 3, 4**
- Optimized using Adam, Loss: MSE



4. Evaluation Metrics

PSNR (Peak Signal-to-Noise Ratio)

PSNR measures the **pixel-level fidelity** between the original (ground truth) and a distorted (processed) image. It's based on the **Mean Squared Error (MSE)** between the two images.

A **higher PSNR** generally indicates that the reconstructed image is closer to the original.

Characteristics:

- **Range**: Typically between 20 and 50 dB for lossy image compression.
- **Higher is better**: PSNR $\geq$ 30 dB is considered good.
- **Limitations**:
  - Doesn’t consider human visual perception.
  - Sensitive to small pixel-level changes.
  - Two images may have high PSNR but look perceptually very different.

4. Evaluation Metrics

SSIM (Structural Similarity Index Measure)

SSIM evaluates the **perceptual similarity** between two images by considering:

- **Luminance (brightness)**
- **Contrast**
- **Structure**

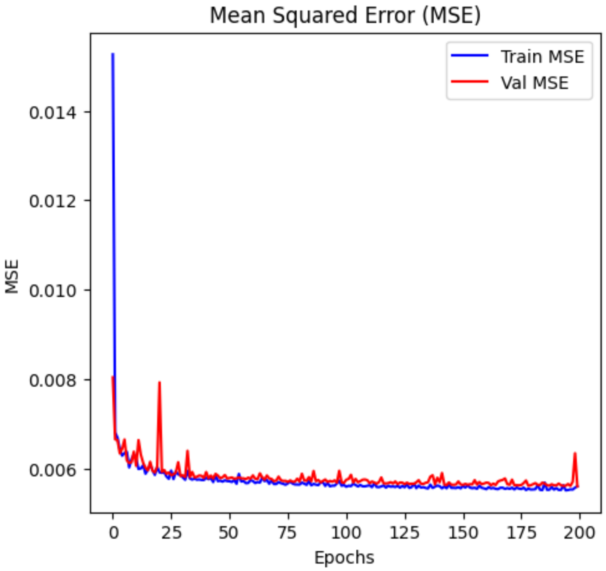
Unlike PSNR, it aligns more closely with how **humans perceive image quality**.

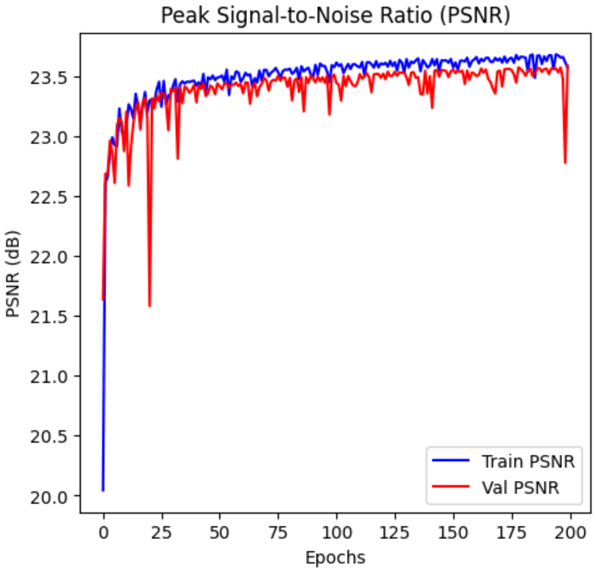
Characteristics:

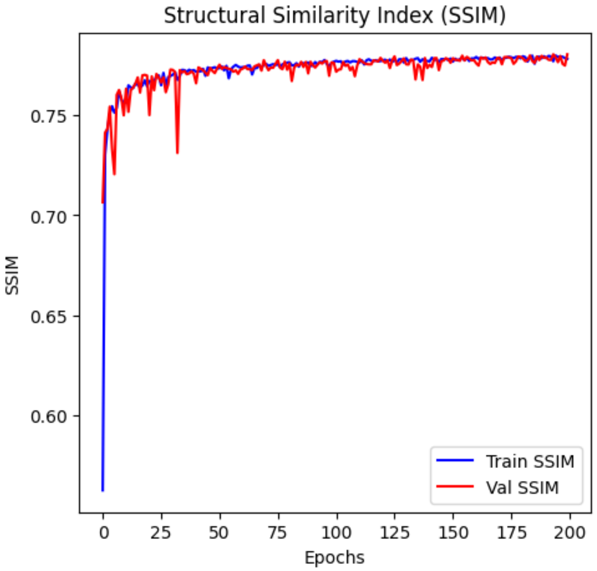
- **Range**: [-1, 1] (Usually reported between 0 and 1)
- **Higher is better**: SSIM = 1 means perfect structural similarity.
- **More perceptually aligned** than PSNR.

5. Results and Comparison

Without Augmentation:

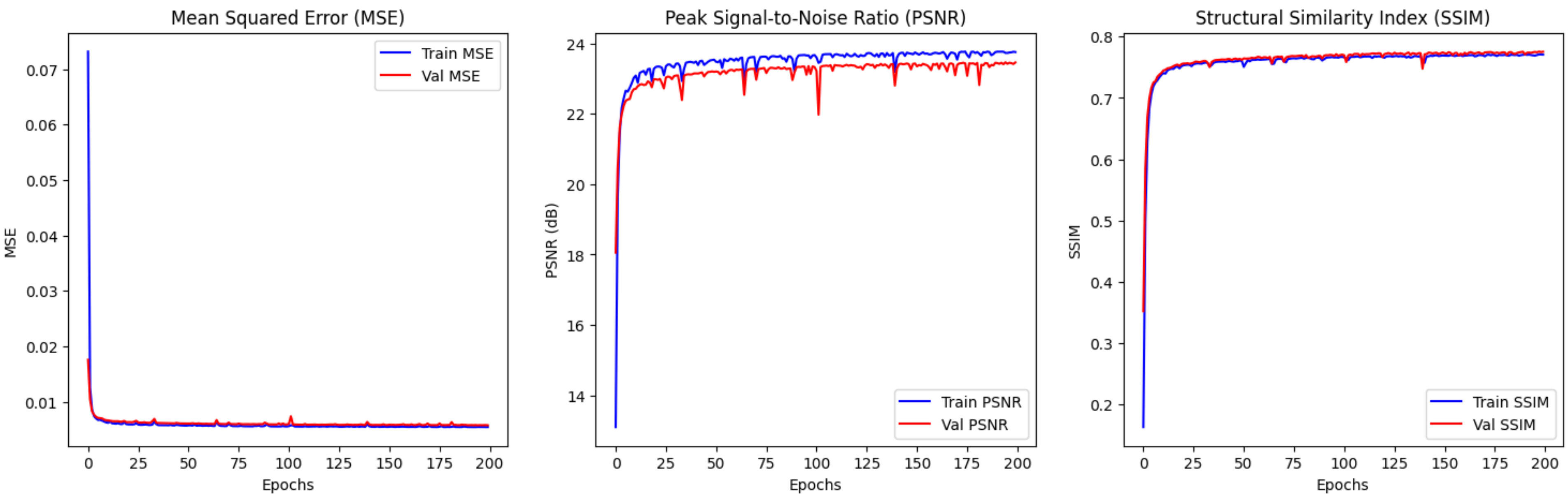






5. Results and Comparison

With Augmentation:



5. Verdict

Metric	Before Augmentation	After Augmentation	Verdict
MSE	Low, stable	Low, slightly smoother	Equal / Slightly better
PSNR	Slightly noisy, larger gap	Smoother, reduced gap	Improved generalization
SSIM	More variance, lower early on	Smoother, higher convergence	Improved structural quality

THANK YOU

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