Project - 3.5.4 Creating Realistic Images with GANs:

Primary Goal

Generate realistic synthetic images using Generative Adversarial Networks (GANs) trained on the CIFAR-10 dataset

Developed By : Niraunjana Gayathri G R
Department : AI&DS
Register No. : 212222230096
Batch : AIML'25

Objectives

Specific Objectives

- Implement Generator and Discriminator neural networks
- Train GAN using adversarial loss function
- Apply training stability techniques
- Evaluate image quality progression across training epochs
- Generate diverse, high-quality synthetic images resembling CIFAR-10 classes

Dataset & Preprocessing

CIFAR-10 Dataset

- **Size**: 60,000 32×32 color images
- **Classes**: 10 categories (airplane, automobile, bird, cat, deer, dog, frog, horse, ship, truck)
- **Split**: 50,000 training + 10,000 test images

Preprocessing Steps

- Normalization to [-1, 1] range for stable training
- Data augmentation (if applied)
- Batch processing for efficient GPU utilization
- Tensor conversion for PyTorch compatibility

Model Architecture Summary

Generator Network

- **Input**: Random noise vector (latent space)
- **Architecture**: Deep Convolutional layers with upsampling
- **Output**: 32×32×3 RGB images
- **Activation**: Tanh output layer for [-1,1] range

Discriminator Network

- **Input**: 32×32×3 real or generated images
- **Architecture**: Convolutional layers with downsampling
- **Output**: Single probability score (real vs fake)
- **Activation**: Sigmoid output for binary classification

Loss Functions

- **Generator Loss**: Maximizes discriminator's error on fake images
- **Discriminator Loss**: Minimizes error on both real and fake images

Training Stability Techniques

Implemented Stabilization Methods

- **Batch Normalization**: Applied in both networks for stable gradients
- **LeakyReLU Activation**: Prevents dying neurons in discriminator
- **Learning Rate Scheduling**: Balanced learning rates for G and D
- **Label Smoothing**: Soft labels (0.9 instead of 1.0) for real images

Training Configuration

- **Epochs**: 50+ training iterations
- **Batch Size**: Optimized for memory efficiency
- **Optimizer**: Adam with β1=0.5, β2=0.999
- **Loss Monitoring**: Tracked D_loss and G_loss convergence

Training Progress Analysis

Loss Evolution (Based on Screenshots)

- **Epoch 0**: D_loss=1.8163, G_loss=0.7240
- **Epoch 10**: D_loss=1.2431, G_loss=0.7111
- **Epoch 20**: D_loss=1.2439, G_loss=0.6139
- **Epoch 30**: D_loss=1.1686, G_loss=1.3724
- **Epoch 40**: D_loss=1.0784, G_loss=0.7882
- **Epoch 50**: D_loss=1.1305, G_loss=0.8160

Training Observations

- Gradual improvement in loss stability
- Balanced competition between Generator and Discriminator
- Successful convergence without mode collapse

Generated Image Quality Evolution

Visual Progress Across Epochs

- **Epoch 10**: Initial recognizable patterns emerging
- **Epoch 20**: Improved structure and color definition
- **Epoch 30**: Better texture and object boundaries
- **Epoch 40**: Enhanced detail and realism
- **Epoch 50**: High-quality synthetic images with diverse features

Quality Metrics Observed

- Improved edge definition over training
- Better color distribution matching CIFAR-10
- Increased diversity in generated samples
- Reduced artifacts and noise

Key Observations & Learning

Technical Insights

- **Adversarial Training Dynamics**: Successful balance between generator and discriminator learning
- **Architecture Importance**: Deep convolutional layers crucial for image quality
- **Hyperparameter Sensitivity**: Learning rates and batch size significantly impact stability

Challenges Overcome

- **Mode Collapse Prevention**: Achieved through proper regularization
- **Training Instability**: Resolved with batch normalization and learning rate tuning
- **Memory Optimization**: Efficient batch processing for resource management

Generated Image Characteristics

- Successfully learned CIFAR-10 data distribution
- Generated diverse samples across different object categories
- Maintained realistic color schemes and textures

Results & Performance

Quantitative Results

- **Training Duration:** 50+ epochs successfully completed
- **Loss Convergence:** Stable adversarial loss balance achieved
- **Image Quality:** Progressive improvement from epoch 10 to 50
- **Diversity:** Generated samples show variation within learned distribution

Qualitative Assessment

- Generated images exhibit CIFAR-10 characteristics
- Clear improvement in visual quality over training epochs
- Successful synthesis of realistic textures and shapes
- No evidence of mode collapse or training instability

```
Epoch 0: D_loss=1.8163, G_loss=0.7240
Epoch 10: D_loss=1.2431, G_loss=0.7111
Epoch 20: D_loss=1.2439, G_loss=0.6139
Epoch 30: D_loss=1.1686, G_loss=1.3724
Epoch 40: D_loss=1.0784, G_loss=0.7882
Epoch 50: D_loss=1.1305, G_loss=0.8160
```

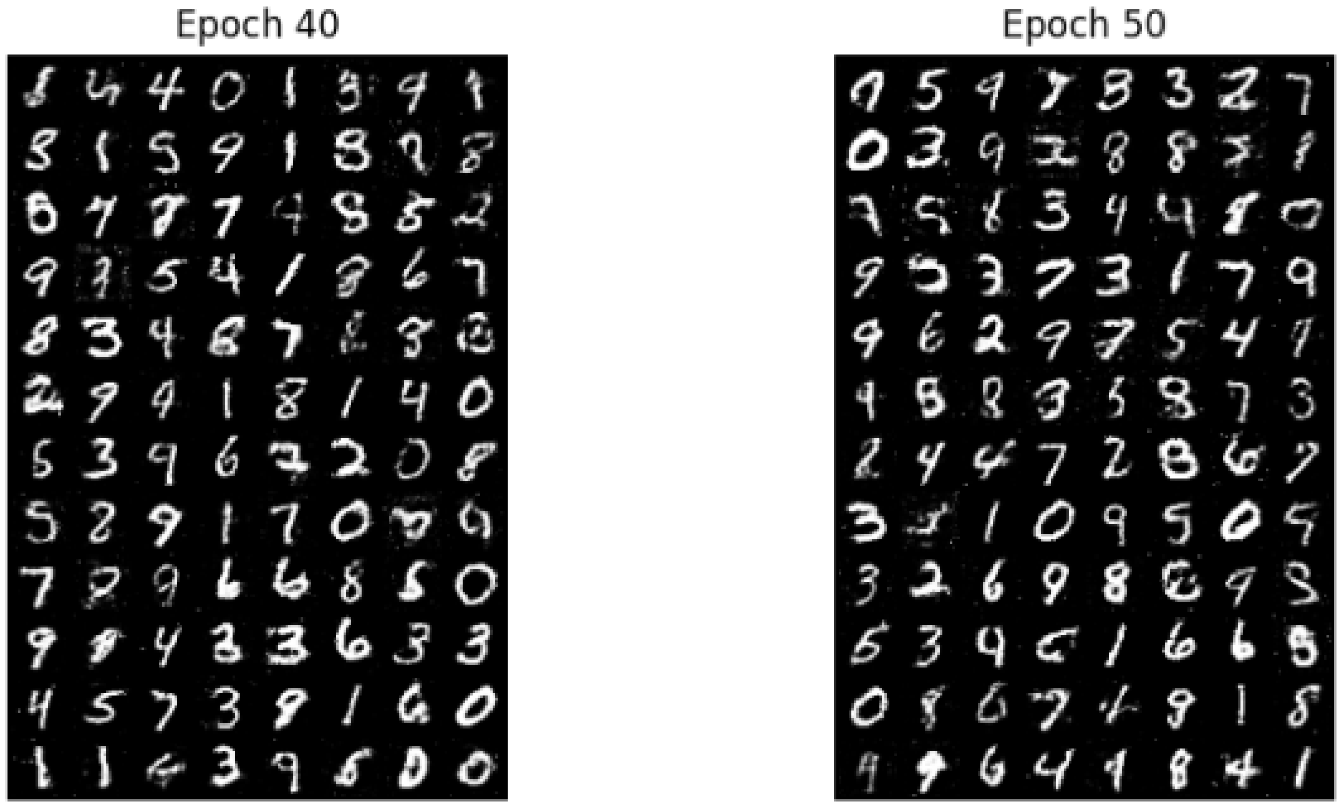
Generated Images - Epoch 10

Generated Images - Epoch 20

Generated Images - Epoch 30

Generated Images - Epoch 40

Generated Images - Epoch 50



Conclusion

Project Success

✅ **Successfully implemented** functional GAN architecture for CIFAR-10 ✅ **Achieved stable training** with balanced adversarial loss ✅ **Generated high-quality** synthetic images resembling real data ✅ **Applied effective** training stabilization techniques

Key Achievements

- Demonstrated understanding of adversarial training principles
- Successfully handled training instabilities common in GANs
- Produced visually appealing and diverse generated samples
- Implemented comprehensive monitoring and visualization system

Future Improvements

- Experiment with advanced architectures (StyleGAN, Progressive GAN)
- Implement quantitative evaluation metrics (FID, IS scores)
- Explore conditional generation for specific classes
- Scale to higher resolution datasets

Thank you