Performance Analysis for Projection-Correction Methods in Motion Deblurring Problems

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Problem Description

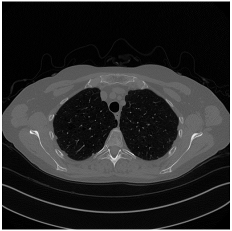
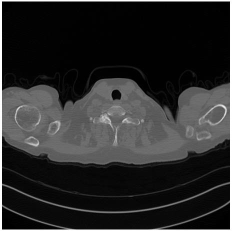
- The project analyzes the performance of two **Projection-Correction** algorithms for reconstructing medical images affected by **motion blur**.
- The studied algorithms are:
  - **Diffusion Posterior Sampling (DPS)**
  - **Regularization by Denoising with Diffusion (RED-Diff)**
- Both methods are based on **pre-trained diffusion models**.
- Objective: evaluate the effectiveness of these methods in recovering degraded images.

Approach to the Problem

- **Objective**: Analyze the performance of *Projection-Correction* methods **DPS** and **RED-Diff** for motion blur removal on medical images
- **Phase 1**: Dataset preprocessing (128x128)
- **Phase 2**: Data augmentation to increase dataset diversity
- **Phase 3**: Training a DDIM diffusion model on medical data
- **Phase 4**: Simulation of motion blur and its removal
- **Phase 5**: Implementation and comparison of *Projection-Correction* methods: **DPS** and **RED-Diff**
- **Phase 6**: Quantitative evaluation of performance using metrics such as **PSNR** and **SSIM**

Mayo Clinic CT Dataset

- Released by the **Mayo Clinic** for research purposes.
- Contains chest **Computed Tomography (CT)** scans.
- Images are in **grayscale (black and white)** format.
- Focus on **lung nodules** and early detection of **lung cancer**.
- Widely used in machine learning and AI medical imaging research.


- All CT images were preprocessed and resized to a fixed dimension of **128 × 128 pixels**.
- This standardization ensures consistency for input into deep learning models.
- The dataset was **augmented** to avoid overfitting and improve model generalization (detailed later).

Sottosezione 2.1

Sottosezione 2.1

Training Pipeline

- **Obiettivo**: Train a denoising diffusion model (DDIM U-Net) su immagini in scala di grigi
- **Componenti principali**:
  1. Data Augmentation
  2. DataLoader
  3. Compilazione del modello
  4. Loop di training con mixed-precision

Data Augmentation

- **Base Dataset**: Dataset Mayo
  - Grayscale → 1 channel
  - Resize images to 128 × 128
- **Augmentations** (8 types):
  - *None*: no transformation
  - `Rotation` ±5° (rotation + centering)
  - `Flip` horizontal
  - `Gaussian noise` (mean=0, std=10)
  - `Salt and pepper noise` (prob=2%)
  - `Brightness` (factor=1.2)
  - `Contrast` (factor=1.3)
- **Implementazione essenziale**:

Schedulers for Diffusion

- **DDPMScheduler** for training diffusion process
  - `Timesteps` 1000
- **DDIMScheduler** for sampling
  - `Timesteps` 1000

Compiling the Model

- **Why**: optimize the model for better performance
- **Usage**:

```
model = torch.compile(model)
```

- **Benefits**: improved batch throughput

Mixed-Precision with AMP

- **GradScaler amd autocast**:
  - `GradScaler` for scaling gradients
  - `autocast` for automatic mixed precision
- Reduce memory usage and speed up training

Training Loop

1. Loss function: `MSE`
2. Start the training `model.train()`
3. For each epoch:
    - Move images to GPU (if available)
    - Generate noise and timesteps
    - Compute noise prediction on the input data
    - Prediction + MSE loss
    - Optimization + `scheduler.step()`
4. Save validation samples to visualize the model performance during training
5. Compute and log average losses
6. Save model weights each epoch

Validation and Checkpointing

- **Validation**:
  - `model.eval()` to set the model to evaluation mode
  - MSE loss on validation set
- **Checkpoint**:
  - Save the model weights to a `.pth` file
  - Update loss, PSNR and SSIM history in `history.txt`
- Monitor train vs validation loss over epochs aswell as PSNR and SSIM between the generated and original images
  - For each epoch sample 10 images from the validation set and compute the metrics

Loss Plot

- **Loss Plot**: visualizes the training and validation loss over epochs
- **Purpose**:
  - Monitor the model's performance

Sottosezione 2.1

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Conclusioni

Grazie per l'attenzione