Progress Report

ControlNet + DPS

Saruultugs Batbayar

10/9/2025

UNIVERSITY of ROCHESTER

Problem Statement & Motivation

Light Sheet Microscopy (LSM):

- Captures thin optical sections of a specimen.
- Trade-off between **acquisition speed** and **phototoxicity**.

*Fast and safe for live samples, but results in **severe structured missing data**.*

Our Goal

Reconstruct complete, high-quality volumes from these striped measurements.

Preserve **global structure** under extreme information loss.

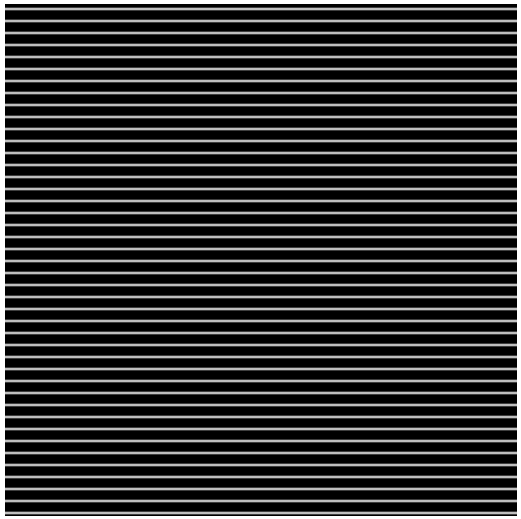
sampling strategies.

Problem Statement & Motivation

Why Diffusion Models?
Striped masks mimic the actual physical acquisition process in LSM.

Diffusion models are well-suited because:

1. They can **condition on known measurements** (the skip-row stripes).
2. Provide strong **data priors** to fill in missing regions.
3. Flexible: same framework can adapt to different domains.



Models We Tested

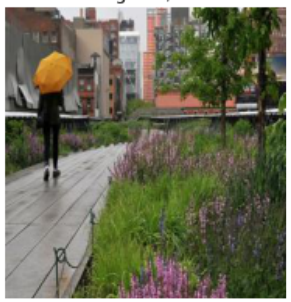
1. **RePaint:** Baseline DDPM-based inpainting
2. **CoPaint / Tiramisu:** Conditioning-guided inpainting
3. **DPS (Diffusion Posterior Sampling):** Likelihood-based conditioning, no retraining required
4. **ControlNet + DPS:** Our proposed direction. Explicit conditioning on striped mask + DPS flexibility

Models We Tested

- **RePaint**: Masked input + noise → iterative denoising → filled image
- **CoPaint**: Masked input + conditioning encoder → diffusion sampling → output
- **DPS**: Forward operator (striped mask) + noisy measurement → posterior sampling → restored image
- **ControlNet + DPS**: more robust reconstructions with less data/ training.
    1. ControlNet encodes structural guidance from the striped mask (measurement).
    2. DPS ensures consistency with measurement operator.

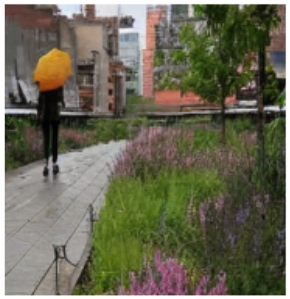
Visual Comparison On The Results

Original / GT

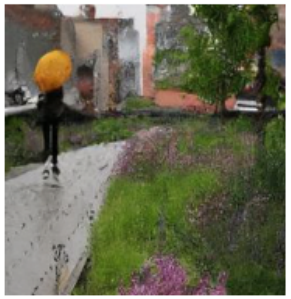


Masked (skip=6, start_row=None)

ControlNet
SSIM=0.419
PSNR=19.98
LPIPS=0.155



RePaint
SSIM=0.468
PSNR=19.71
LPIPS=0.280



CoPaint
SSIM=0.489
PSNR=19.26
LPIPS=0.330

Original / GT

Masked (skip=6, start_row=None)

ControlNet
SSIM=0.697
PSNR=25.09
LPIPS=0.198

RePaint
SSIM=0.655
PSNR=22.36
LPIPS=0.221

CoPaint
SSIM=0.658
PSNR=22.65
LPIPS=0.203

Visual Comparison On The Results

Original / GT

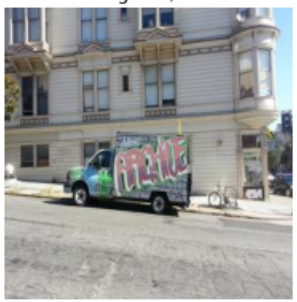
Masked (skip=6, start_row=None)

ControlNet
SSIM=0.672
PSNR=22.35
LPIPS=0.131

RePaint
SSIM=0.664
PSNR=20.84
LPIPS=0.234

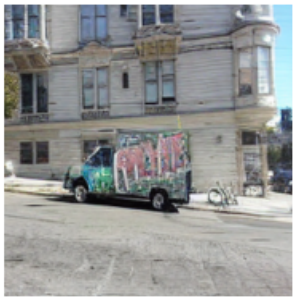
CoPaint
SSIM=0.702
PSNR=21.18
LPIPS=0.201

Original / GT



Masked (skip=6, start_row=None)

ControlNet
SSIM=0.572
PSNR=21.70
LPIPS=0.133



RePaint
SSIM=0.485
PSNR=19.27
LPIPS=0.327

CoPaint
SSIM=0.509
PSNR=19.45
LPIPS=0.327

Models: Pros And Cons

Model	Pros	Cons
RePaint	Simple, effective in 2D	Struggles on severe loss, high compute
CoPaint	Conditioning improves fidelity	Needs large dataset for training
DPS	No retraining needed, flexible to measurement operators	Slower sampling, guidance tuning sensitive
ControlNet + DPS	Explicit conditioning + robust posterior sampling; works with limited data	Slightly higher complexity; ControlNet requires light training/fine-tuning

Future Directions

Short-Term
- Generate a complete DPS result set for striped-mask measurements.
- Compare against RePaint, CoPaint baseline models.

Mid-Term
- Implement ControlNet + DPS hybrid for structured conditioning.
- Optimize sampling speed (reduce steps while preserving quality).

Long-Term
- Extend pipeline to LSM data.
- Evaluate robustness under different skip-patterns (e.g., every 2nd, 4th, 8th row).
- Potential integration with real experimental data from LSM.

UNIVERSITY of ROCHESTER