Knee Magnetic Resonance Image Synthesis with 3D CycleGAN

CycleScan
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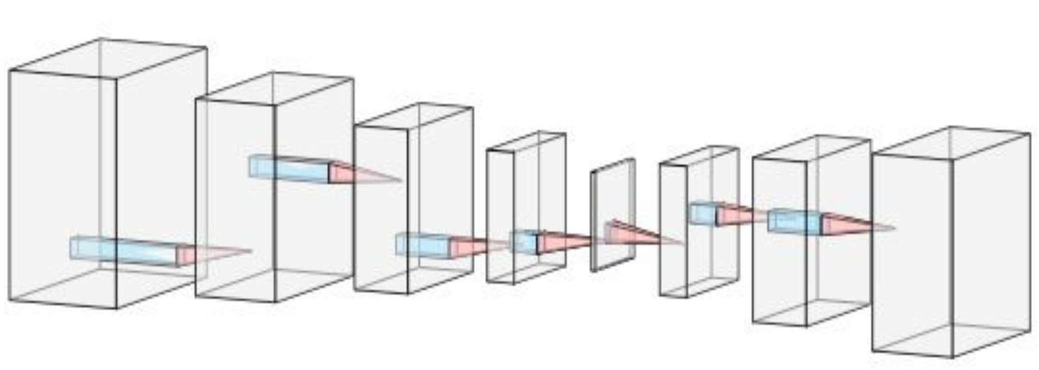
Introduction

- MRI is a noninvasive way to track the integrity of ACL tissue after surgery. High signal intensity can be a sign of inflammation or injury
- There are many MRI modalities that are used to highlight specific structures changing the overall signal intensity
- **Goal**: Implement a deep learning based image generation to transform between MRI modalities
- The focus will be on knee MRIs from patients in two clincal trials *(Murray AJSM 2020)* using two MRI modalities:
  (1) Constructive Interference in Steady State (CISS)
  (2) Double Echo Steady State (DESS)

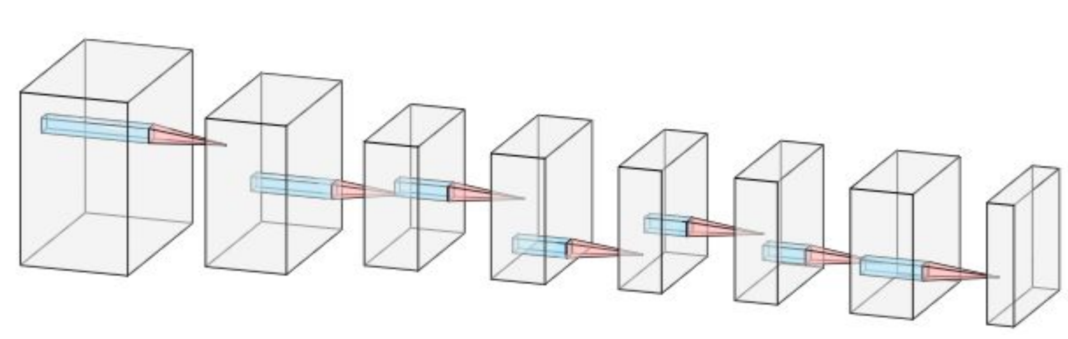
Methodology

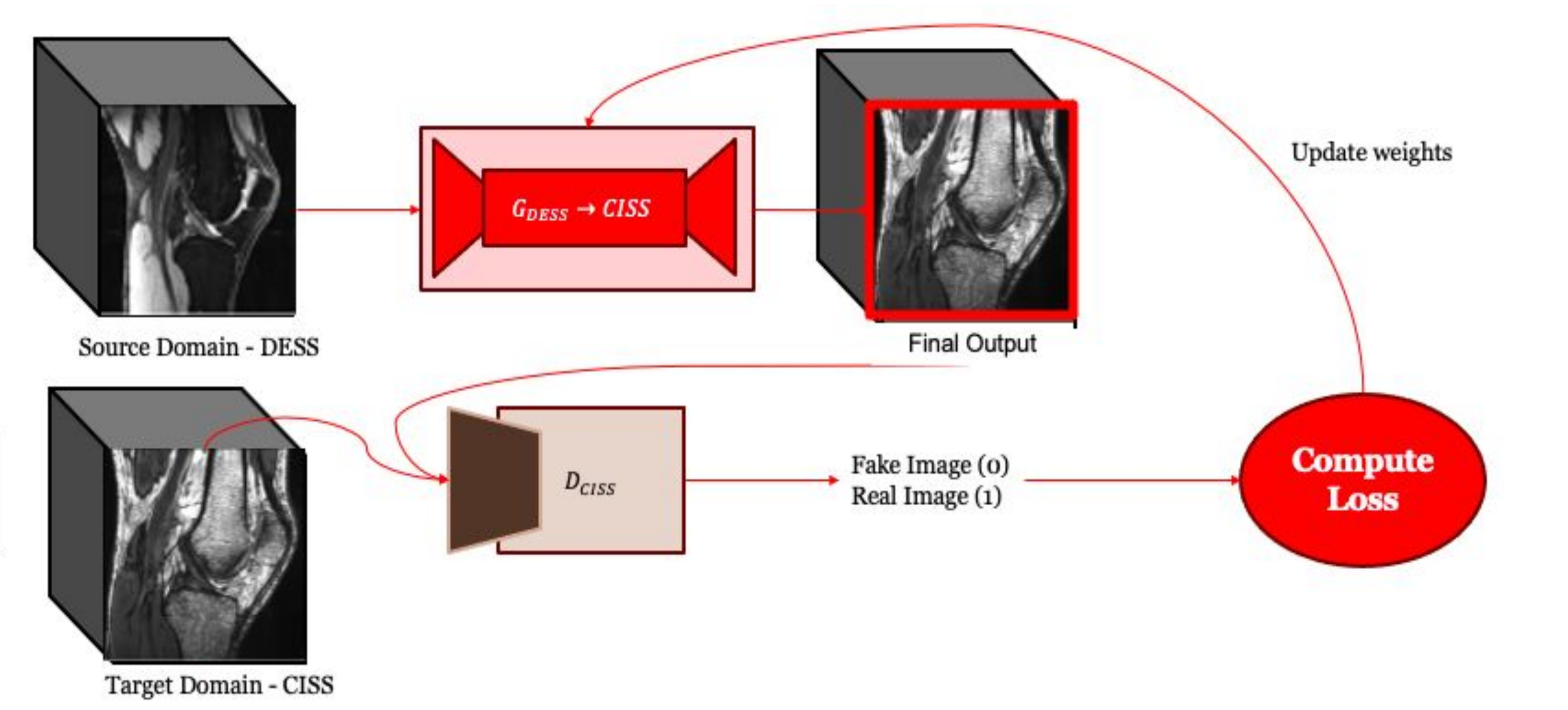
- The original cycleGAN model was introduced by Zhu et al (https://arxiv.org/pdf/1703.10593) with an 2D architecture and respective loss functions
- MRI images are 3D volumes, therefore, the architecture was re-implemented to suit 3D volumes
- **Dataset**: Two ACL clinical trials [1,2]
  - 96 CISS images taken 2 years post-operation
  - 68 DESS images taken 6 years post-operation
- Preprocess: Images were preprocessed by being:
  - Cropped to 256 x 256 with 20 slices
  - Normalized voxel values to [-1,1]
- Model training was conducted using a Google Cloud AI Notebook with an NVIDIA T4 GPU (16 vCPUs, 104 GB RAM)

U-Net Generator



Discriminator



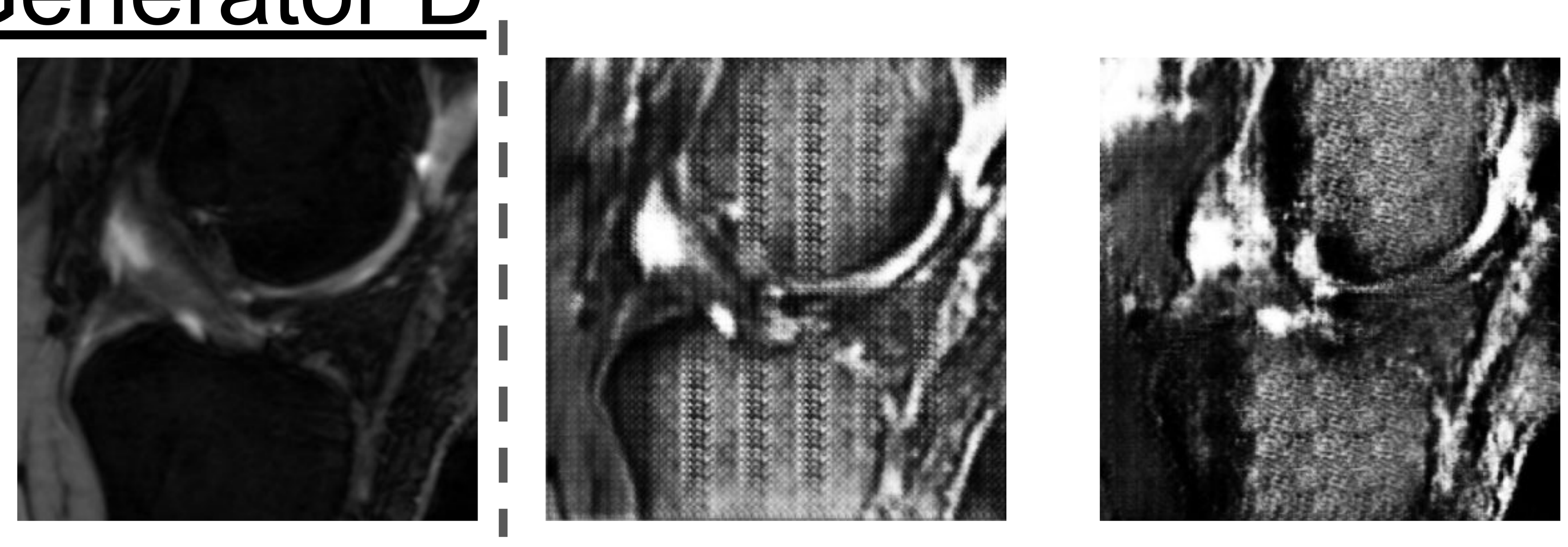


Results

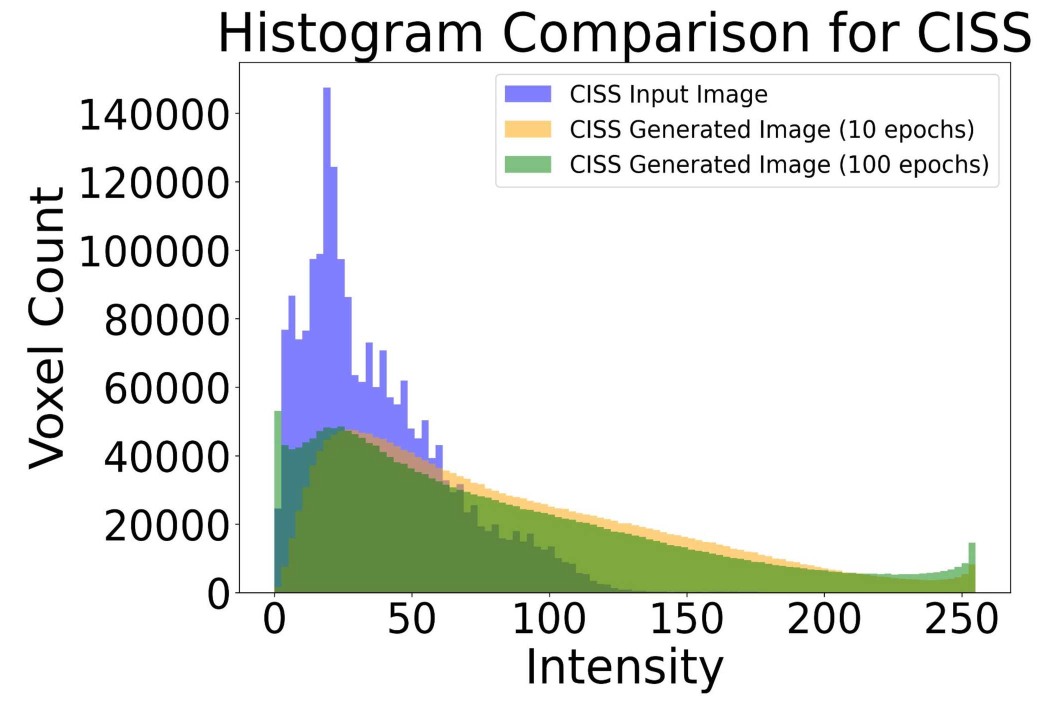
Generator C **10 Epochs** **100 Epochs**

Input Image | Generated Image | Generated Image

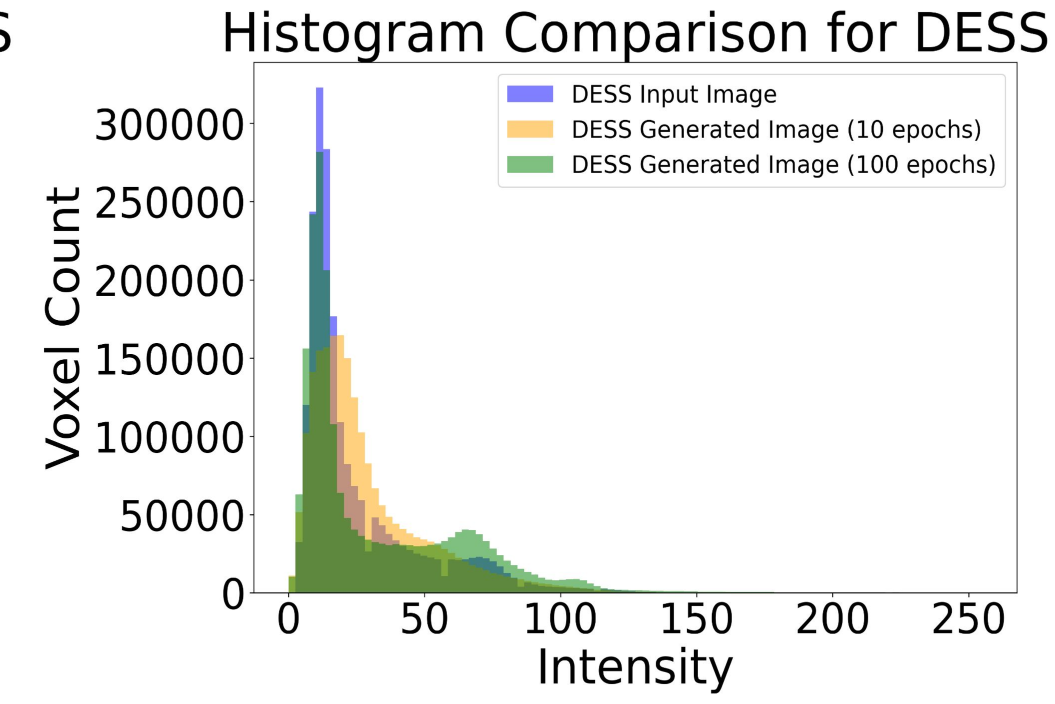
Generator D



Histogram Comparison for CISS



Histogram Comparison for DESS



KL Divergence	CISS	DESS
Input || Generated Image (10 Epochs)	54.169	13.054
Input || Generated Image (100 Epochs)	39.117	8.952

Discussion

A limitation of the current model is the underlying architecture: GANs can be quite unstable in the training process, and our GAN started producing suboptimal results after 100 epochs. Future steps would be to implement a latent diffusion model, which can accomplish the same task as a GAN with more stability. Theoretically, our current GAN can be used to create a good latent representation for a diffusion model, rather than using an autoencoder to find that latent space as suggested in latent diffusion model papers (https://arxiv.org/abs/2311.00265, https://arxiv.org/abs/2408.09315).