Low Dose Fluoroscopy for Orthopedic Surgery

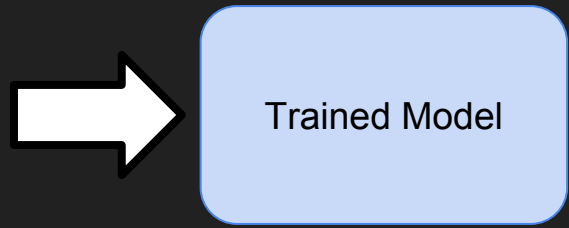
Midpoint Presentation

Team Members: Mariya Kazachkova, Michael Mudgett
Mentors: Mathias Unberath, PhD, Bastian Bier, Nico Zaech, Nassir Navab, PhD, Greg Osgood, MD

Project Recap

- Big picture: reduce total radiation inflicted on patient through x-ray imaging during orthopedic surgery while increasing the temporal resolution of X-ray imaging
- Enable use of low-dose live fluoroscopic video in orthopedic surgery
- Project goals:
  - Develop low dose profile for taking fluoroscopic video
  - Develop method for improving image quality of low dose fluoroscopy given initial high dose image

Project Recap

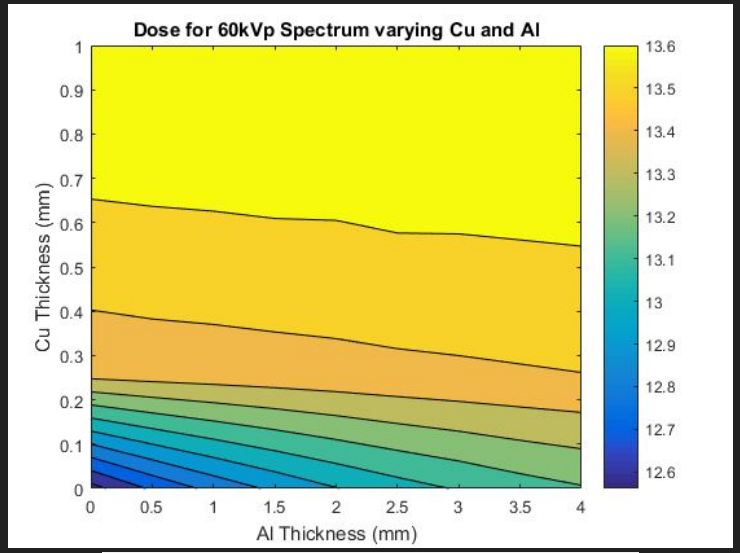


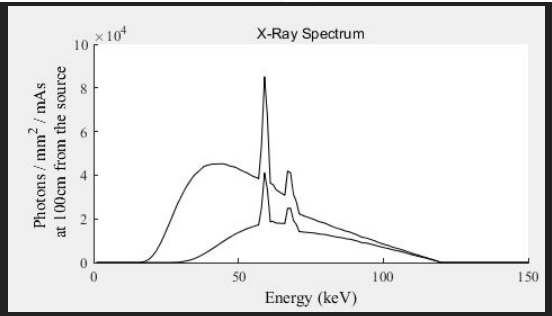
- Noisy image
- Hard to resolve bone/instrumentation
- Low dose to patient
- Continuous video feed (max deliverable)

- Clean image
- Would normally give large dose to patient

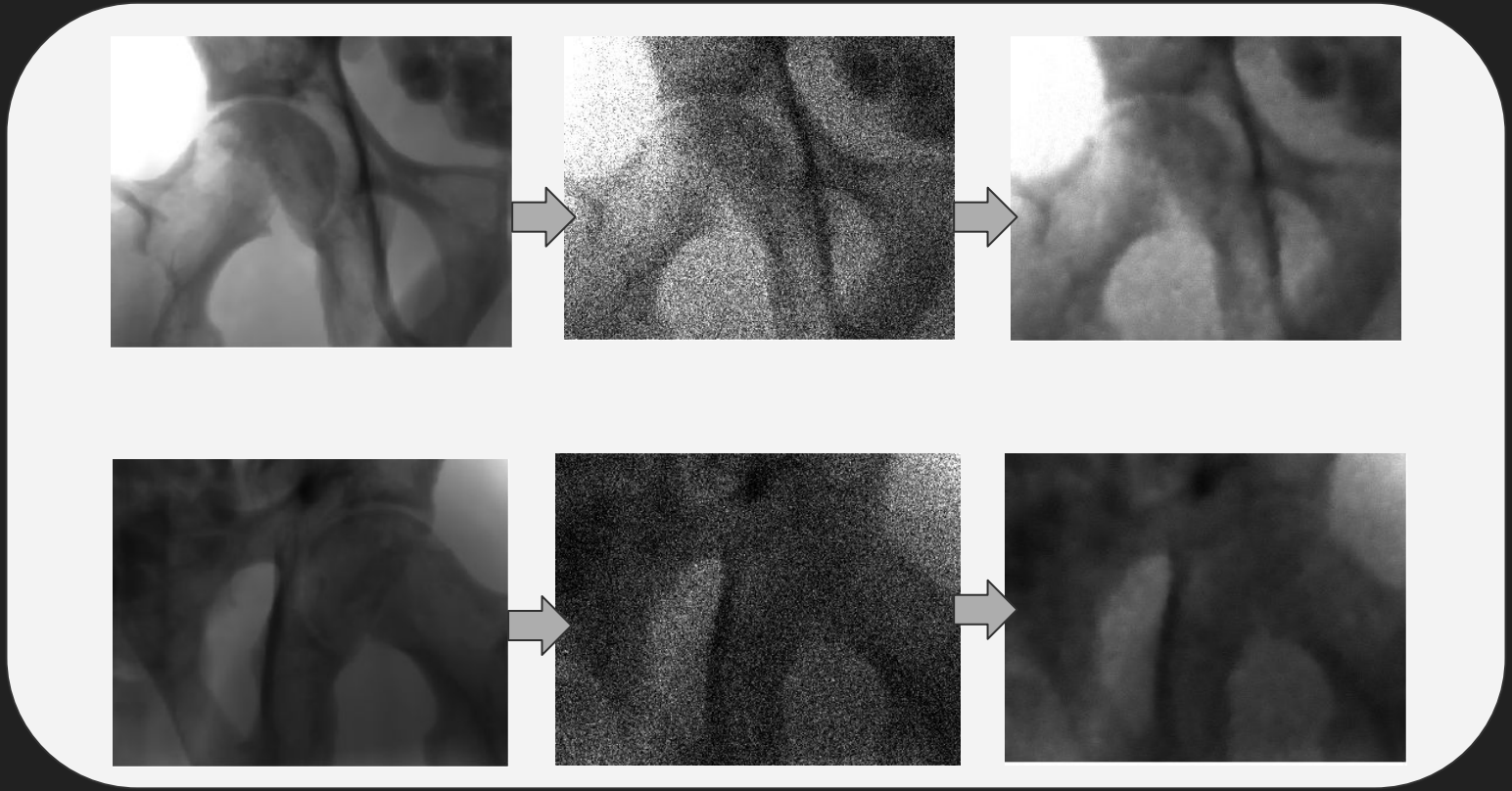
Project Progress - Image/Dose Simulation (Mike)

- Two techniques
  - Monte Carlo GPU
    - Slow
    - Dose Simulation
  - DeepDRR
    - Fast
    - Image generation
- Analyzing effects of filtration
  - Dose and image quality
- Developing methods for mass production
- Lots of time setting up, automating, manipulating program





Project Progress - Deep Learning (Mariya)



Project Progress - Deep Learning

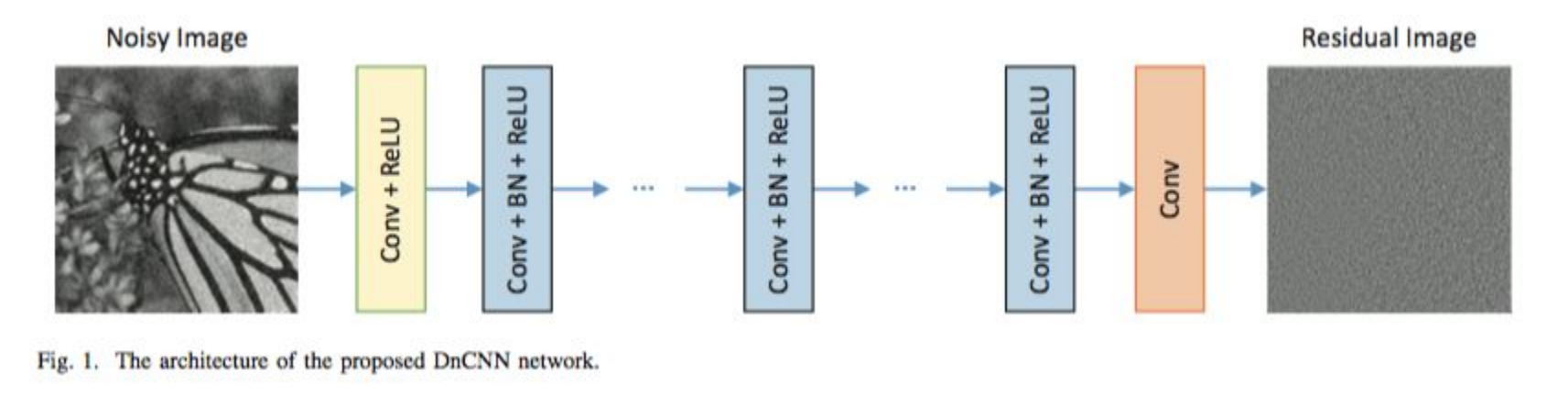
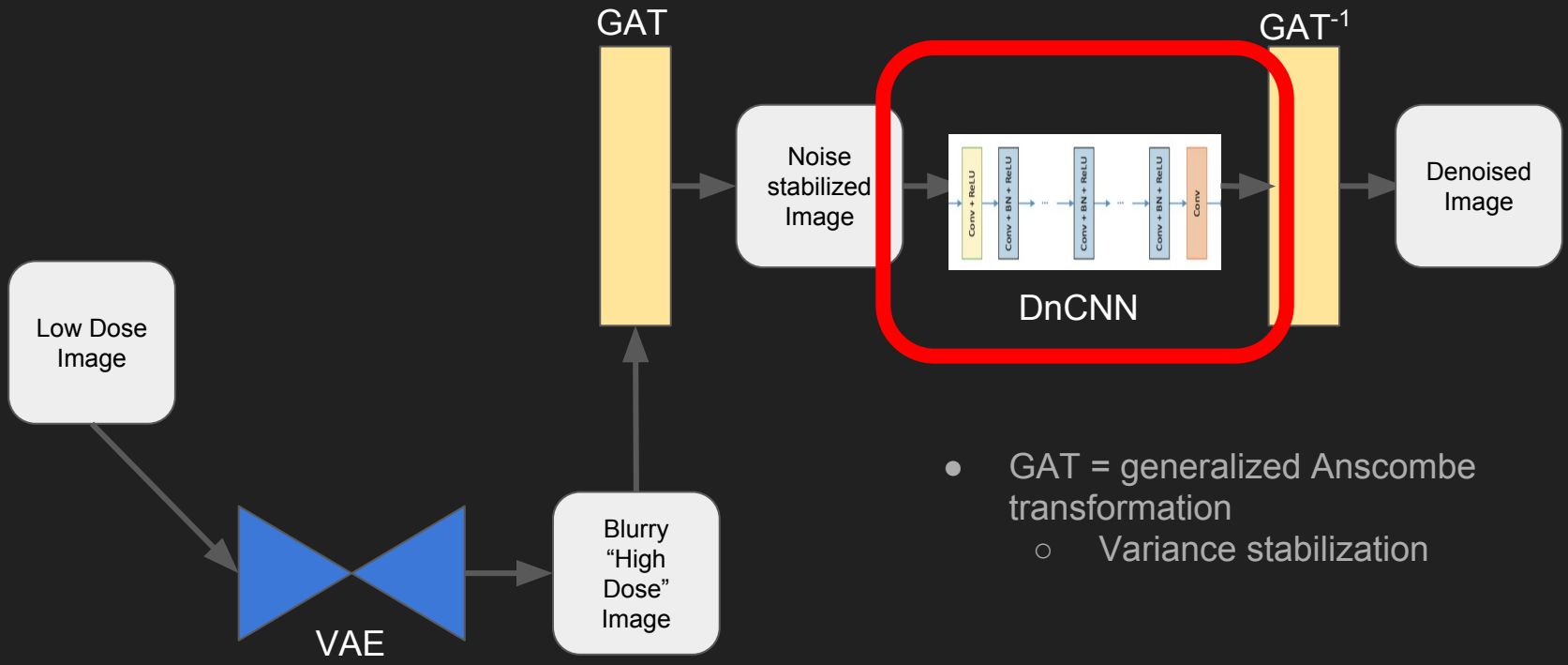


Fig. 1. The architecture of the proposed DnCNN network.

- y = x + v
  - y is noisy input to network
  - x is clean image
  - v is noise
- Learn R(y) ≈ v
- Can then do x' = y - R(y)

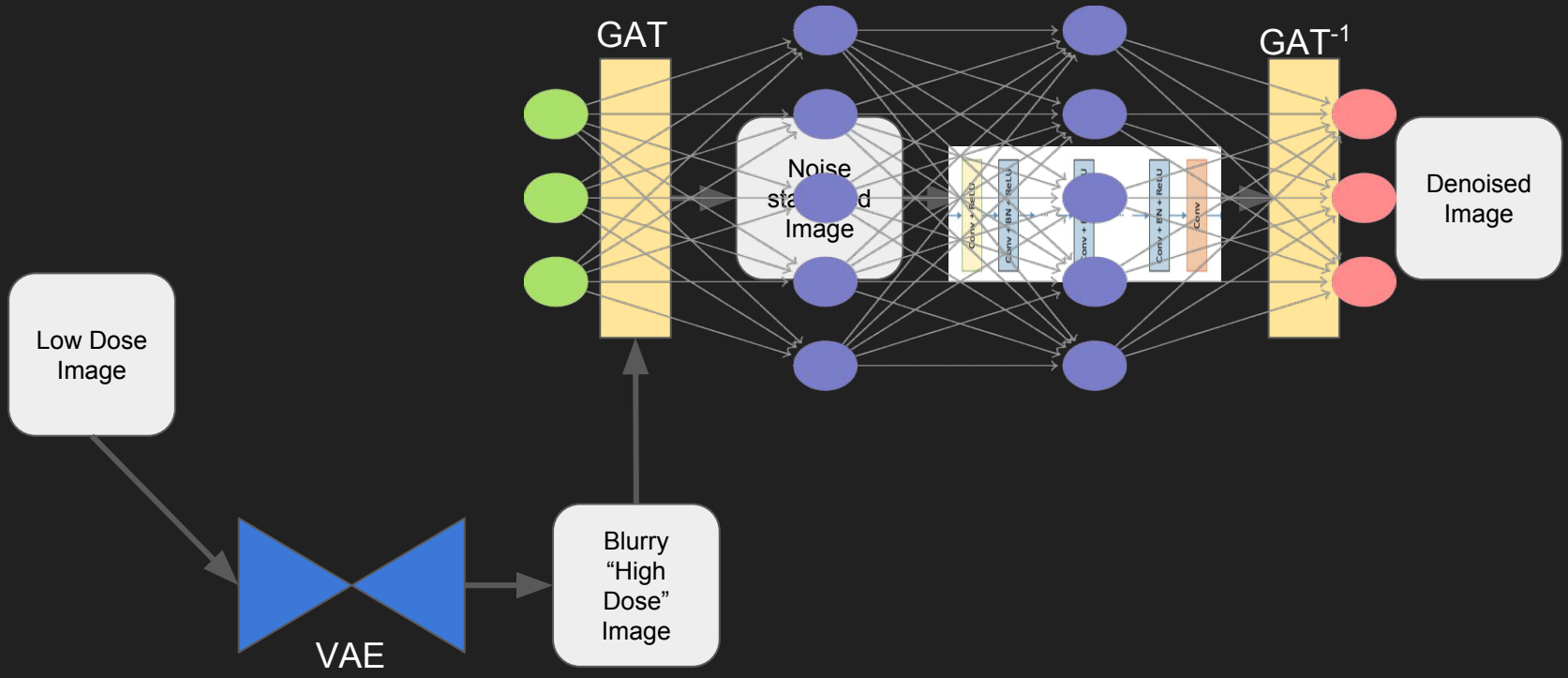
Zhang, Kai & Zuo, Wangmeng & Chen, Yunjin & Meng, Deyu & Zhang, Lei. (2016). Beyond a Gaussian Denoiser: Residual Learning of Deep CNN for Image Denoising. IEEE Transactions on Image Processing. PP. 10.1109/TIP.2017.2662206.

Project Progress - Next Steps



- GAT = generalized Anscombe transformation
  - Variance stabilization

Project Progress - Next Steps



Updated Deliverables

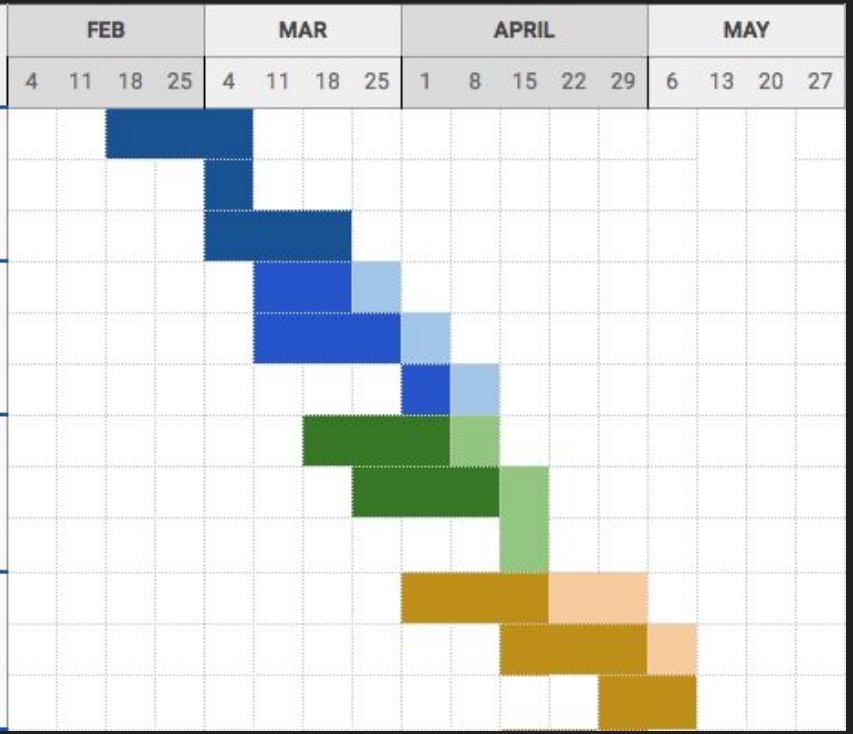
- Minimum:
  - Simulate a set of x-ray images with varying dose parameters
    - Quantify **dose** received by patient and **image quality**
  - 
    Implemented neural network which can denoise a single image - no prior (Python code + doc)
- Expected:
  - Functioning denoising network to improve image quality of a still, low-dose image from a high-dose DR
  - (NEW) Functioning denoising pipeline to improve quality of still, low-dose images without the need for a high-dose DR
  - Chosen dose profile to minimize dose but maximize image quality
- Maximum:
  - LSTM for continuous fluoroscopy (video)

Updated Milestones

	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Date	3/18/18	4/1/18	4/2218	5/6/18
Work	- Generate comprehensive set of simulated x-ray images	- Train a NN to denoise one of the low-dose images	- Analyze image quality/dose/improvability and choose the best dose profile	- LSTM for live fluoroscopy
Deliverable (Measurable)	- Bank of images - Quantified dose/quality relationship for each profile	- An improved low-dose image that can be used in a surgical setting - NN code and documentation	- Chosen dose profile that is realistic, lessens dose received by patient, works with NN - NN pipeline that denoises a low dose image without the need for a high-dose DR (+ documentation)	- Set of continuous images improved by the network - Time-analysis of NN performance - Code and documentation
Backup Plan	- Completed	- Completed	- Choose the best profile, go back to milestone 1 and rework parameters	-Improve small sequences of images, move up to video feed

Updated Schedule

	Milestone:	
1	**Setup and Initial Exepriments**	- Read about MCGPU - Access to MCGPU - Preliminary images created
2	**NN Research and Initial Architecture**	- Research on denoising NNs - Code and documentation - Evaluate results
3	**Best dose profile and NN with no high-dose prior**	- Variation of kVp, mAs, filtration - Architecture for NN pipeline - Code and documentation for pipeline
4	**LSTM**	- Research LSTM - Code/train and documentation - Organize produced images + consult physician



Updated Dependencies

Dependency	Plan to Resolve	Date Expected	Date Needed	Contingency Plan
MCGPU/Python Software	Downloaded (Free)	Complete	-	-
GPU Access for Running MCGPU/Neural Net	Machines (with software) in Navab lab	Complete	-	-
CT Volumes for Generating X-Ray Images	Downloaded from NIH Cancer Imaging Archive	Complete	-	-
Video for LSTM	Mentor acquiring	4/20/18	4/22/18	Photoshop instrumentation

Management Plan

- Weekly meetings with Mathias (when available) and Nico
  - Wednesday at 10am
- Team meetings -- biweekly (Monday and Friday)
  - Bitbucket for code management
- Meeting with Prof. Navab/Dr. Osgood when expert knowledge is required
  - i.e. determining whether an image is clear enough for use in surgery

Reading List

- H. Chen et al., "Low-dose CT denoising with convolutional neural network," 2017 IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017), Melbourne, VIC, 2017, pp. 143-146.
- J. M. Wolterink, T. Leiner, M. A. Viergever and I. Išgum, "Generative Adversarial Networks for Noise Reduction in Low-Dose CT," in IEEE Transactions on Medical Imaging, vol. 36, no. 12, pp. 2536-2545, Dec. 2017.
- Dong C., Loy C.C., He K., Tang X. (2014) Learning a Deep Convolutional Network for Image Super-Resolution. In: Fleet D., Pajdla T., Schiele B., Tuytelaars T. (eds) Computer Vision – ECCV 2014. ECCV 2014. Lecture Notes in Computer Science, vol 8692.
- Badal, A. and Badano, A. (2009), Accelerating Monte Carlo simulations of photon transport in a voxelized geometry using a massively parallel graphics processing unit. Med. Phys., 36: 4878–4880.
- A. Badal and A. Badano, "Monte Carlo simulation of X-ray imaging using a graphics processing unit," 2009 IEEE Nuclear Science Symposium Conference Record (NSS/MIC), Orlando, FL, 2009, pp. 4081-4084.
- J. Baro, J. Sempau, J.M. Fernandez-Varea, F. Salvat, “PENELOPE: An algorithm for Monte Carlo simulation of the penetration and energy loss of electrons and positrons in matter,” Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Volume 100, Issue 1, 1995, Pages 31-46.
- L. Gondara, "Medical Image Denoising Using Convolutional Denoising Autoencoders," 2016 IEEE 16th International Conference on Data Mining Workshops (ICDMW), Barcelona, 2016, pp. 241-246.