# Assessment of Breast Density via Supervised and Unsupervised Algorithms

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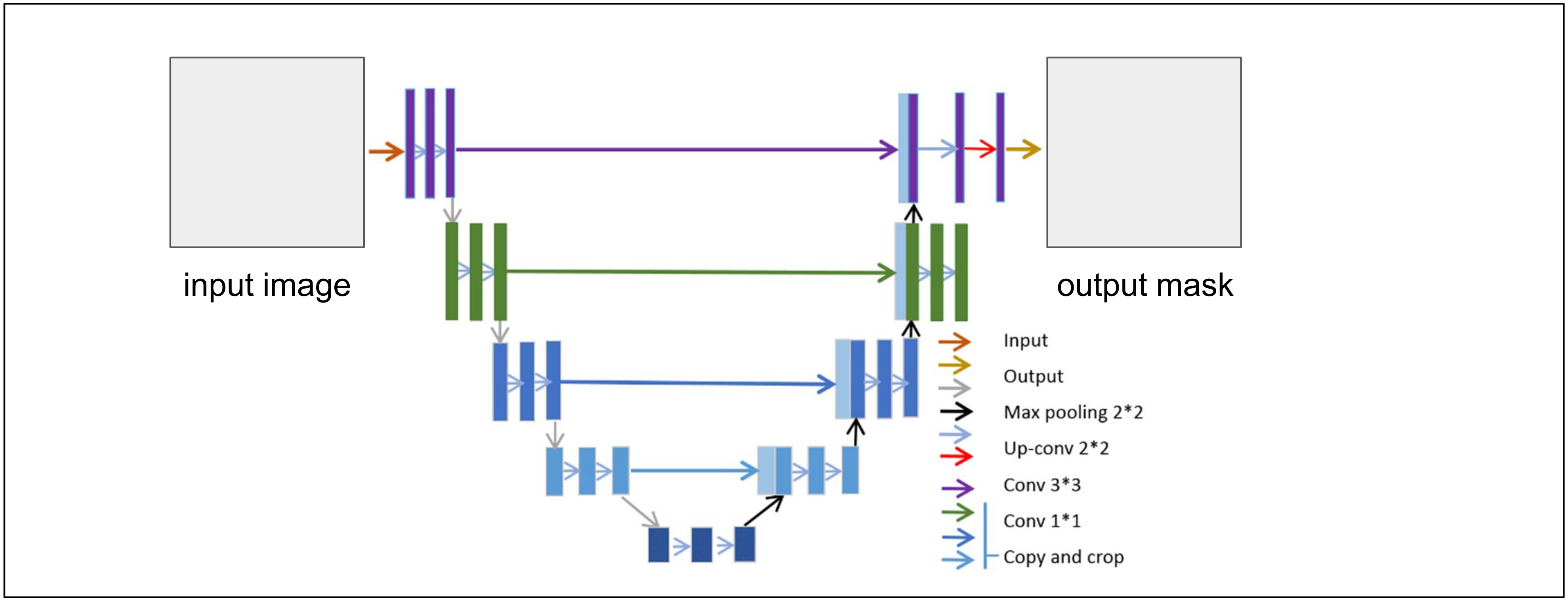
# U-Net Segmentation

# U-Net Architecture



# U-Net Performance

Input:

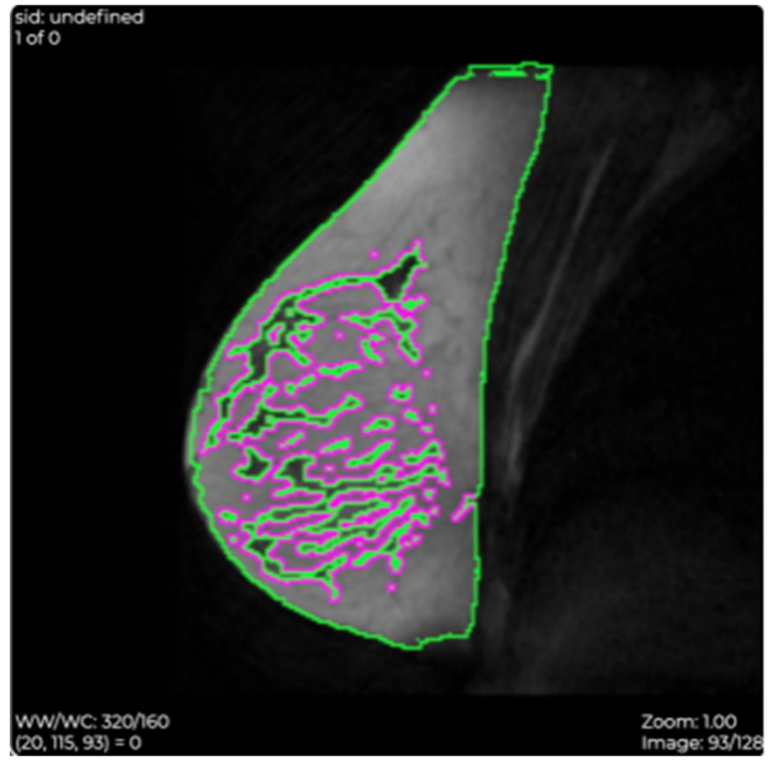
- 238 individual patient MRIs
- Uniform (128, 256, 256) matrix
- 30,464 2D images

Dice scores:

- Breast: 0.92
- FGT: 0.78

Output:

- FGT/breast ratio as ground-truth

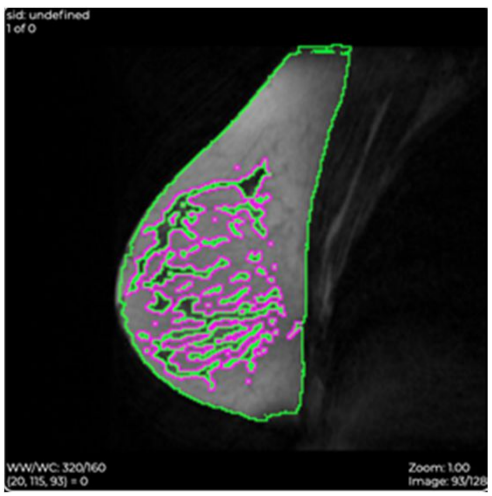



FGT (pink) and breast (green) segments

# Convolutional Neural Networks (CNN)

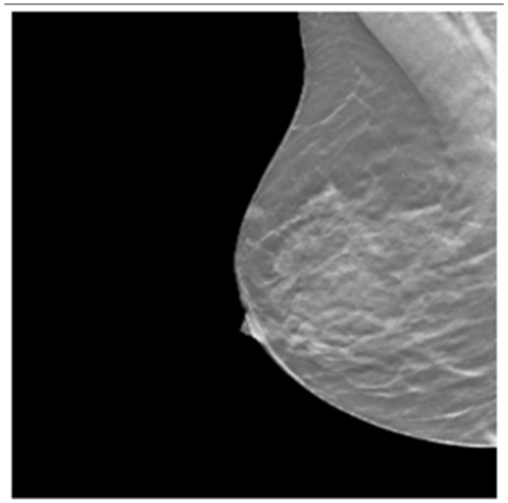
# MRIs to Mammograms

MRI



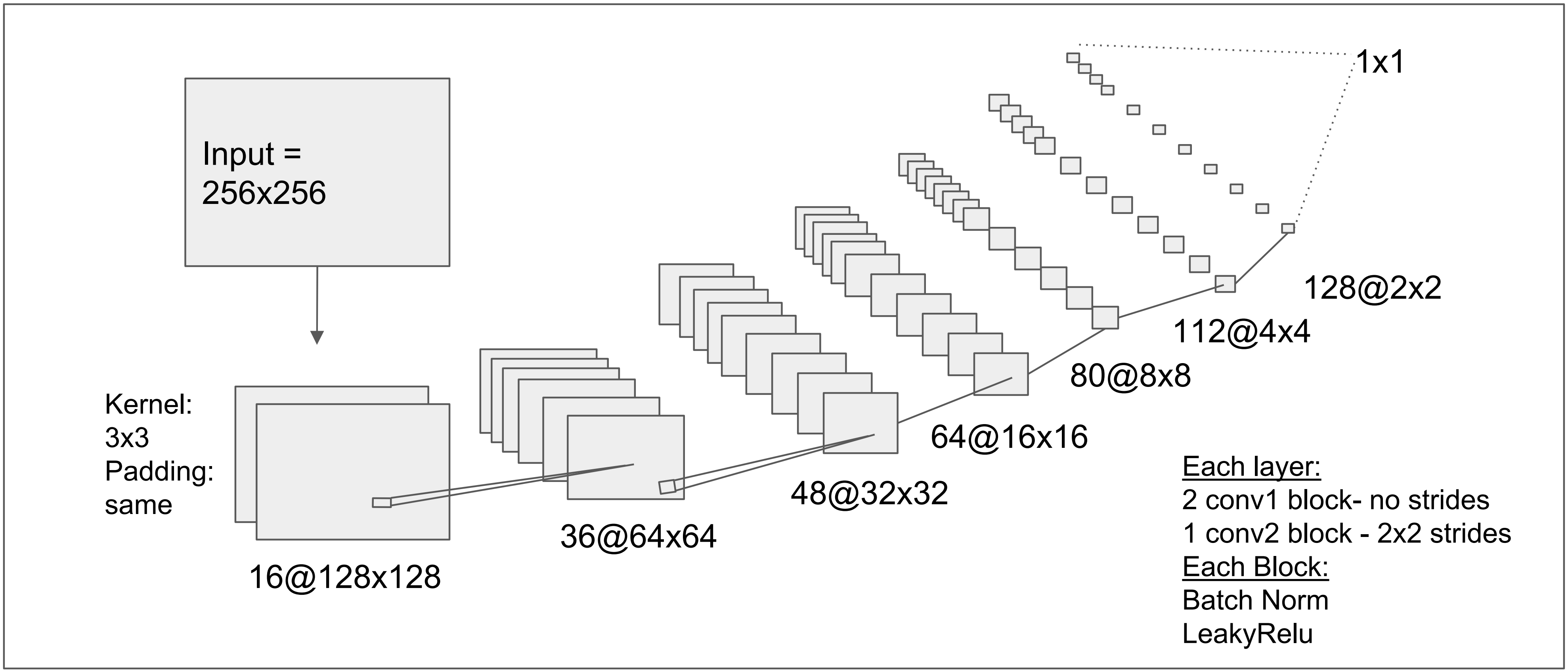

Use FGT segmentation tool to predict density

Mammogram

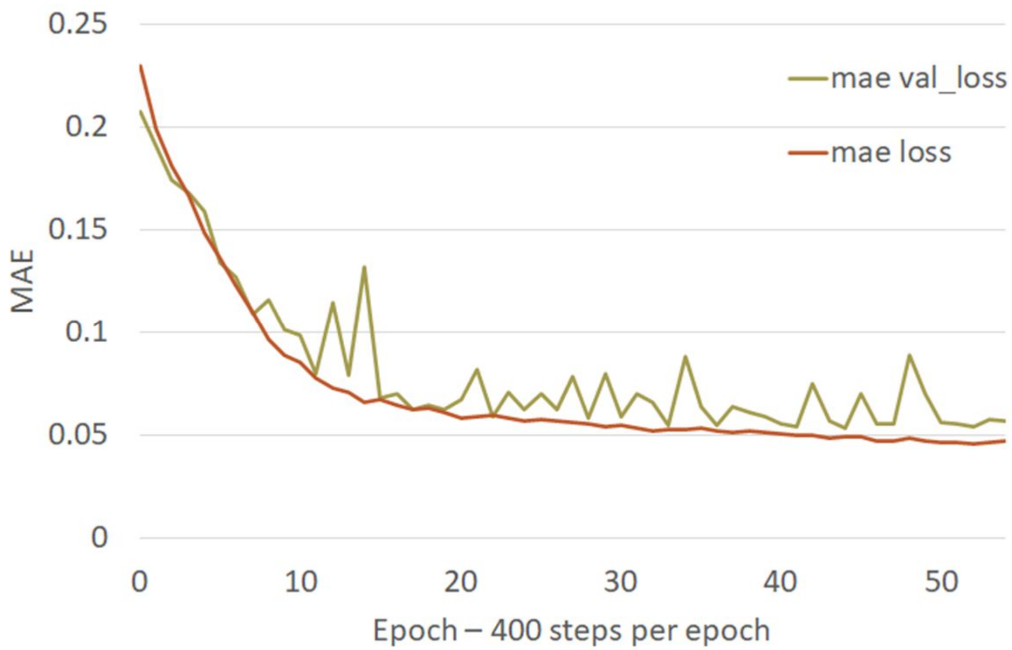


GT = 0.3847

# CNN Architecture for Linear Regression



# Initial Performance




LR = .0005
Batch Size = 12
Implemented EarlyStopping
Mean Absolute Error = **0.04-0.05**

# Experiments

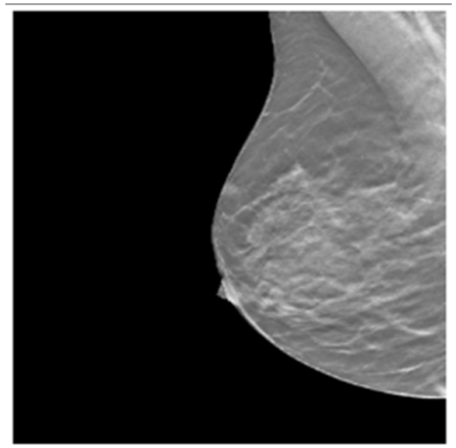
- Learning Rate tuning
  - Starting Learning Rate
  - LR Scheduler
  - ReduceLRon Plateau
- Hyperparameters
  - L1/L2 regularizer
  - Dropout
  - Batch Size
- Other Adjustments
  - Scaling the ground truth
  - Removing Activation Function
  - EarlyStopping vs Defining # of epochs

# Experiments

- Learning Rate tuning
  - Starting Learning Rate
  - **LR Scheduler**
  - ReduceLRon Plateau
- Hyperparameters
  - L1/**L2 regularizer**
  - Dropout
  - Batch Size
- Other Adjustments
  - **Scaling the ground truth**
  - **Remove Activation Function**
  - EarlyStopping vs **Defining # of epochs**

# Best Performance

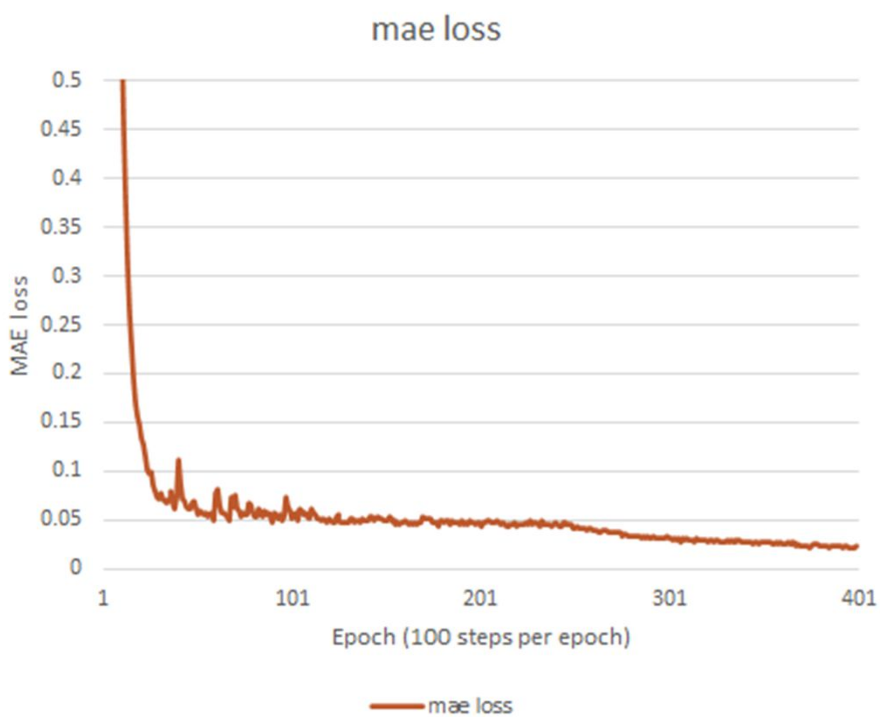
- LR = .0005
- Batch Size = 12
- LR Scheduler: 1% decay rate every epoch
- 100 steps per epoch, 400 epochs
- Scaled the ground truth values [0.0-0.4] => [0.0-1.0]
- Removed sigmoid activation function
- L2 regularizer = .01
- Best MAE loss: **0.025**

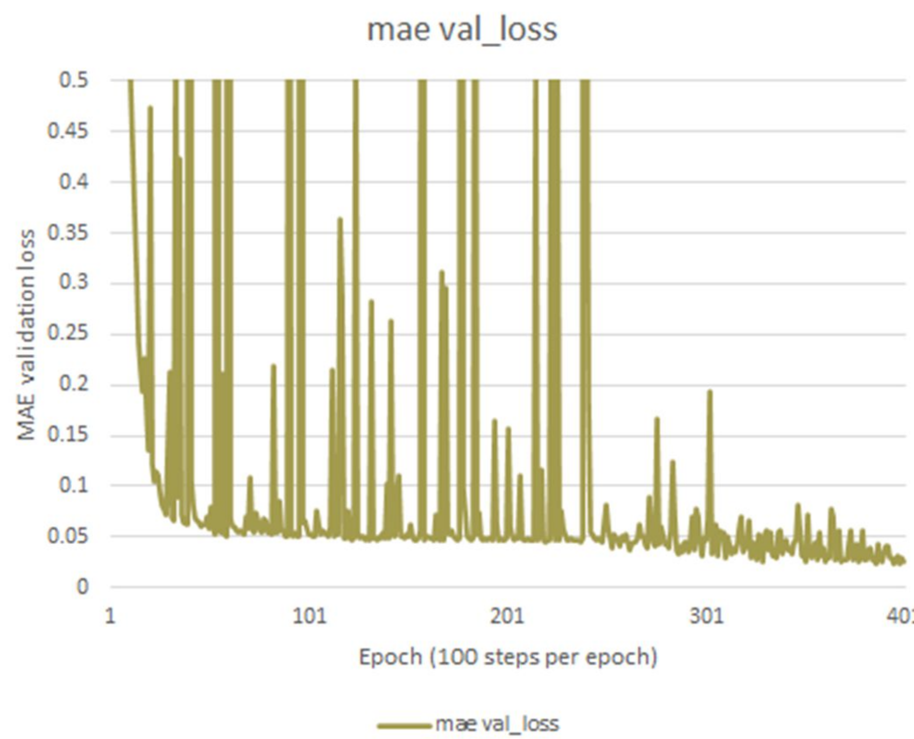


GT scaled by 2.5x
0.3847 => 0.9618

# Remaining Issues...

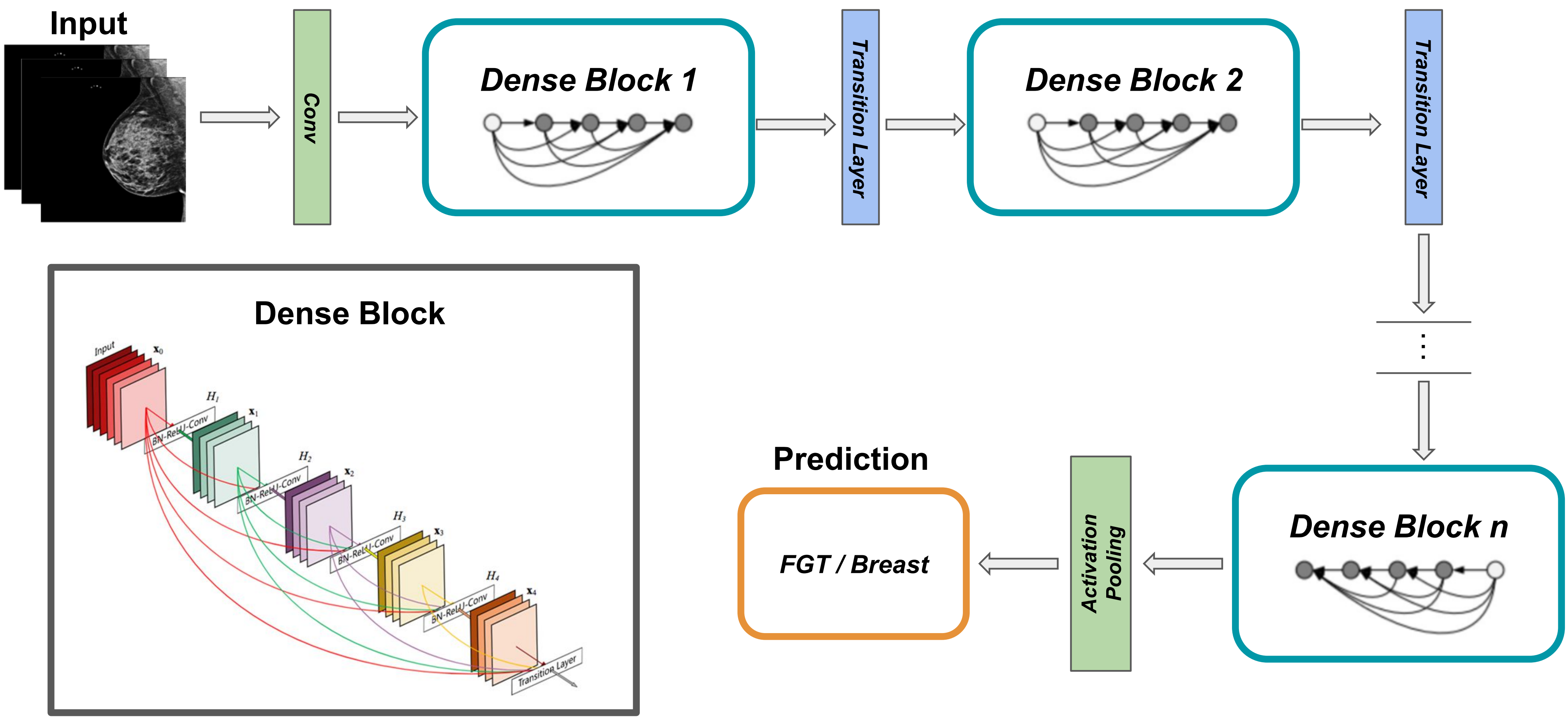
Ideas! Adjust LR Scheduler and/or starting LR



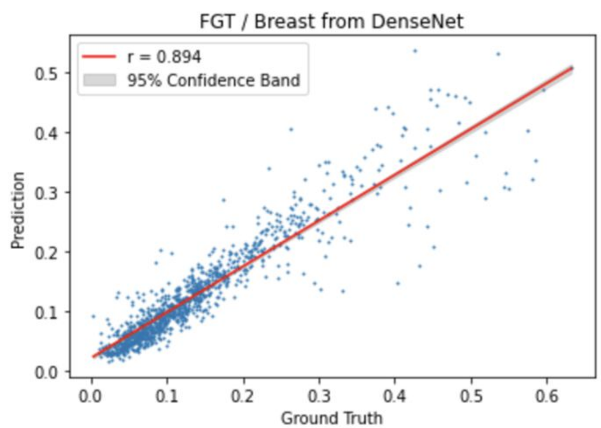
# Densely Connected Convolutional Networks (DenseNet)

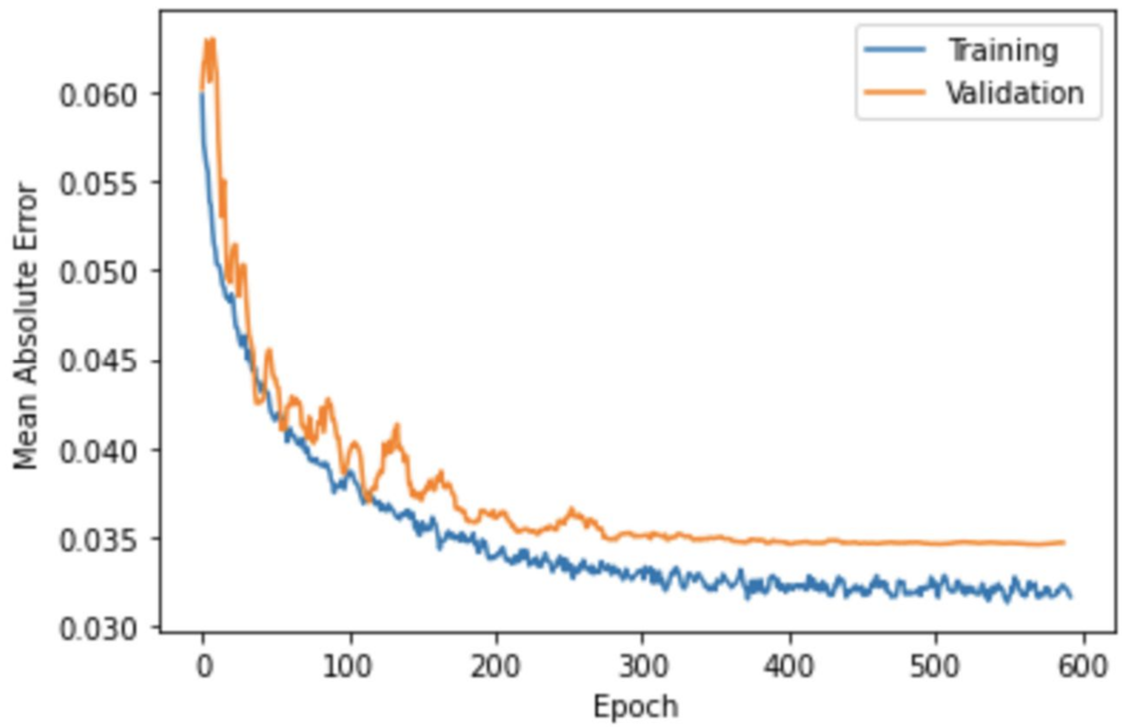
# DenseNet Architecture



# DenseNet Regression Parameters and Results

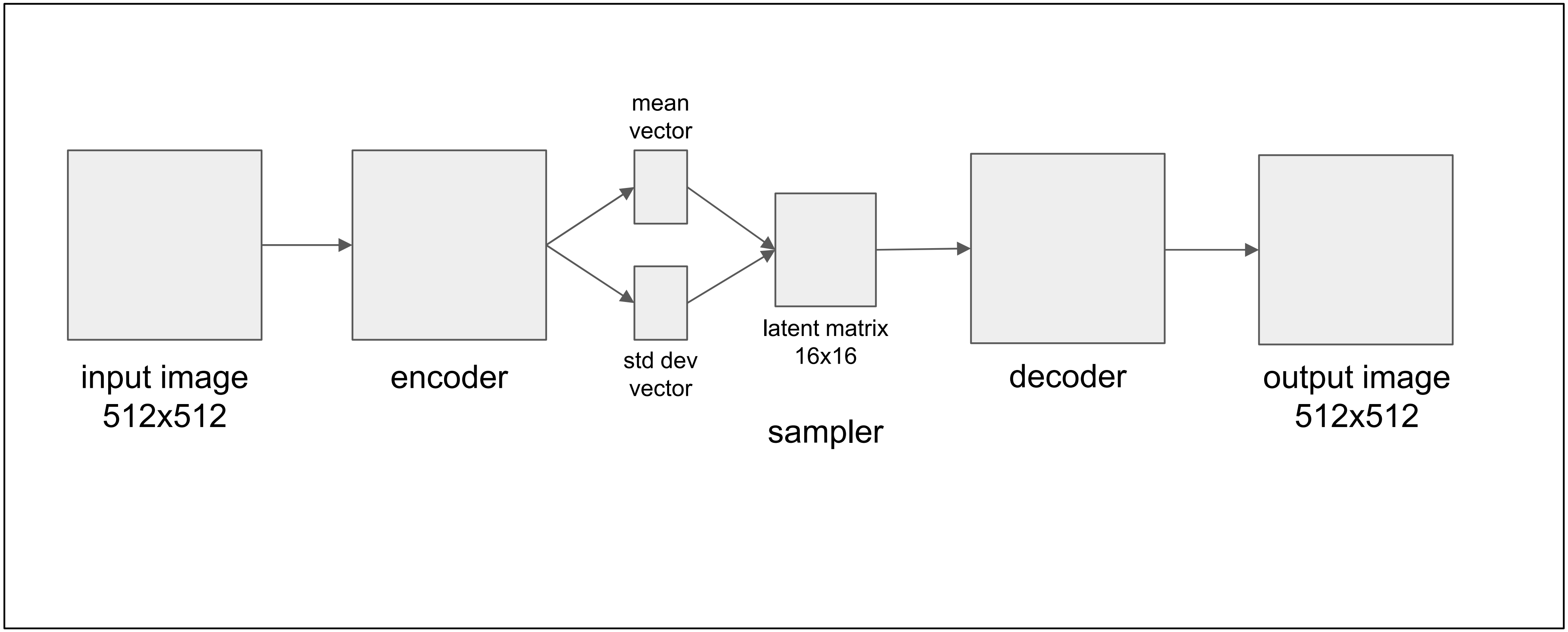
- 3 dense blocks without bottleneck
- 4 dense blocks with transition
    - Growth rate increased
    - Bottleneck 2 * growth rate
- Only 3 layers per dense block
- Loss Function - Huber
- LR scheduling after n epochs
- MAE = 0.0345, MAPE = 30%



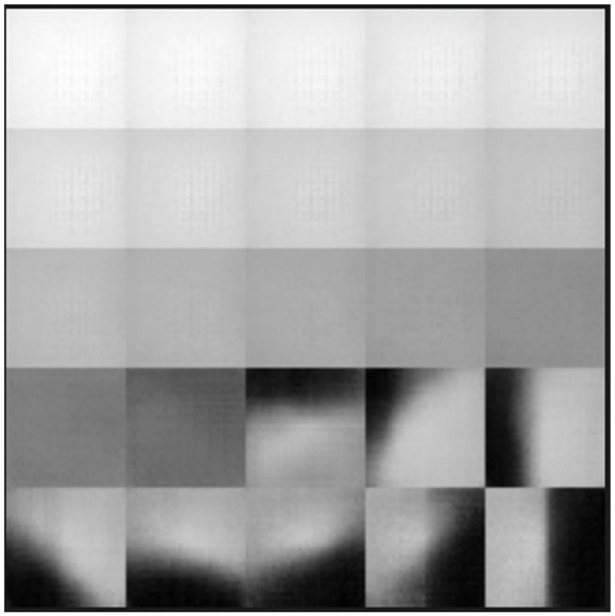



# Variational Auto-Encoders (VAE)

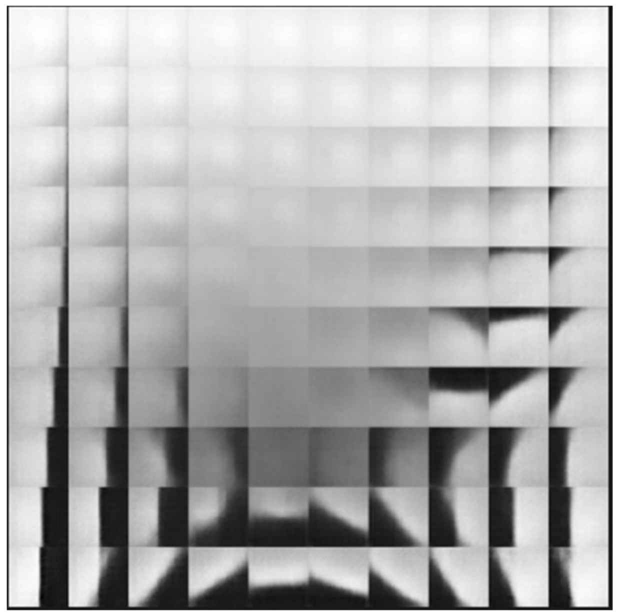
# VAE Architecture



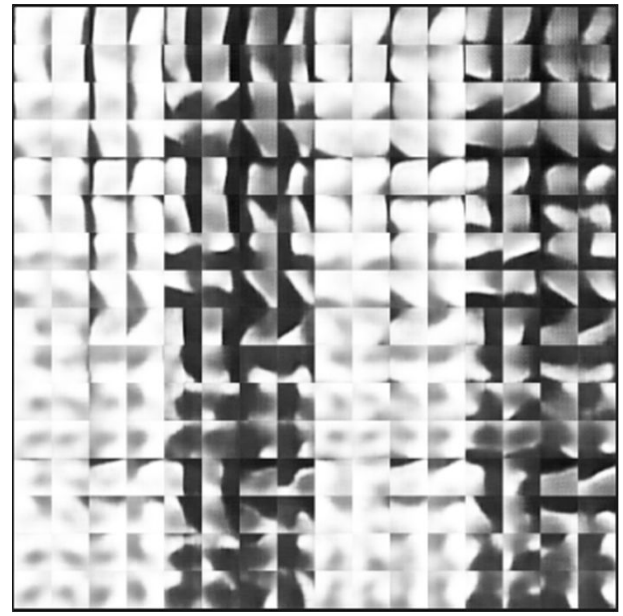
# Decoder Prediction



1 feature



2 features

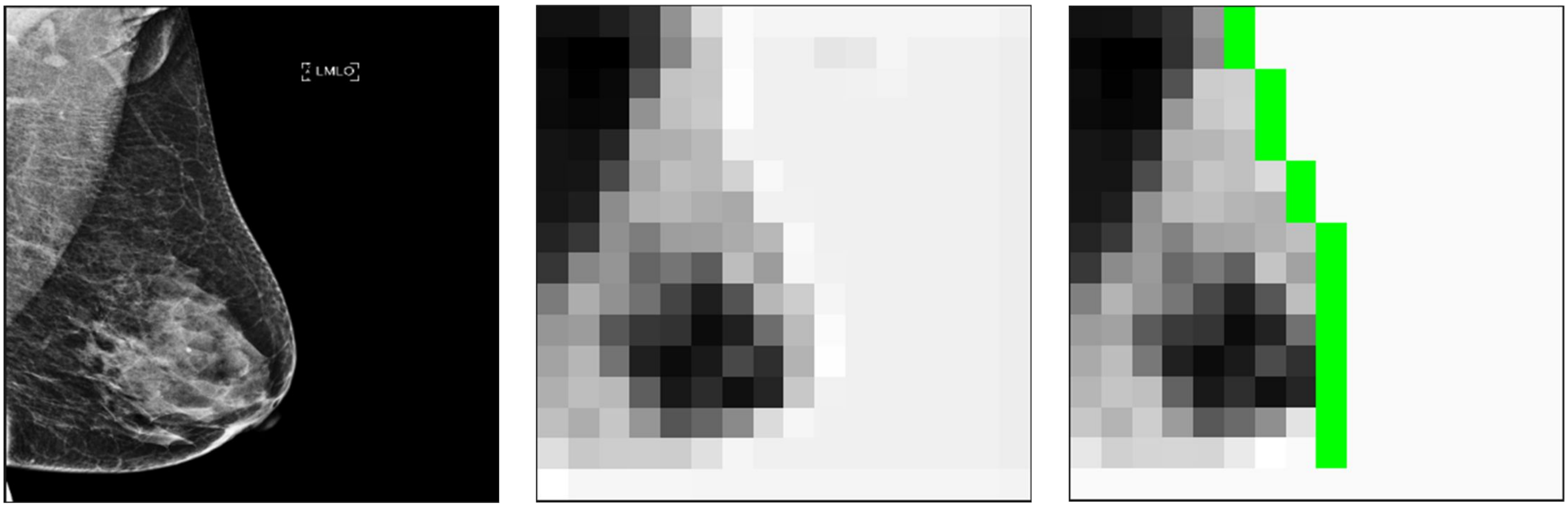


8 features

# Process Workflow

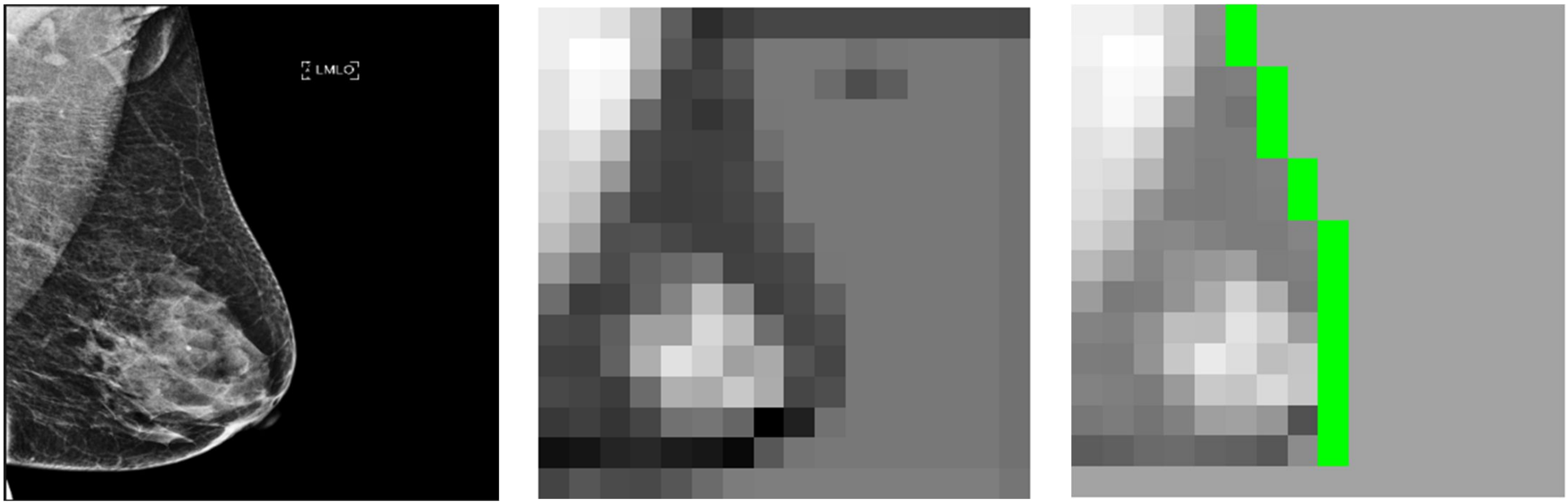
- Run encoder prediction on a 512x512 input image
- Generate a 16x16 latent feature matrix for a patch shape of 32x32
- Clean up latent feature matrix by removing predictions outside the breast
- Collapse latent feature matrix into mean, variance, and weighted mean
- Correlate them with the ground-truth FGT/breast ratio from U-Net

# Encoder Prediction (1 feature)




original image | latent matrix | masked breast

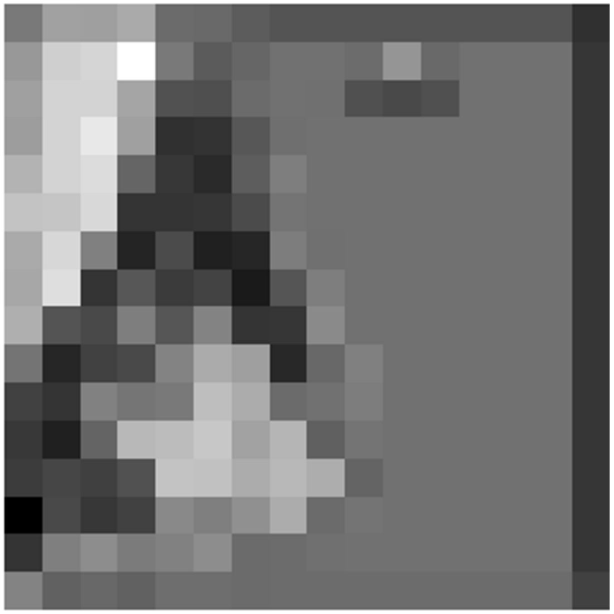
# Encoder Prediction (2 features)



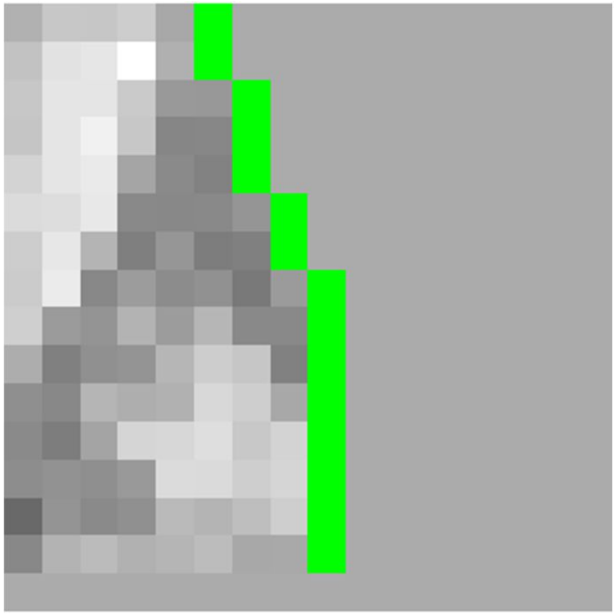

original image | latent matrix | masked breast

# Encoder Prediction (10 features)


original image



latent matrix



masked breast

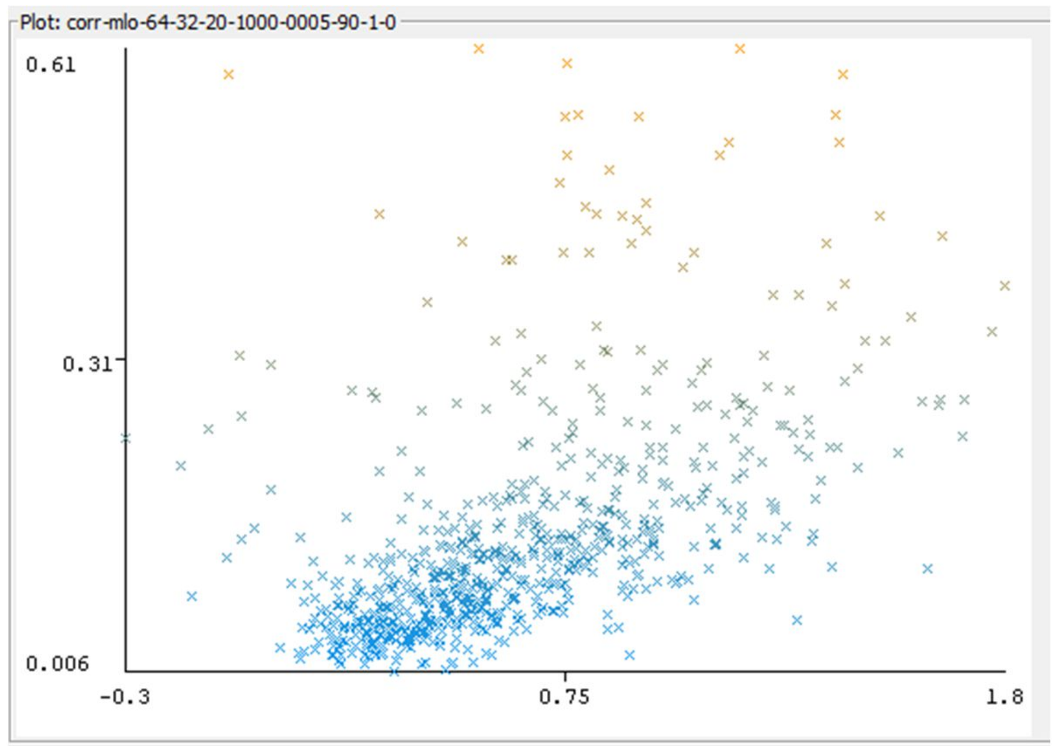
# Results (1 feature)

Single variable linear regression:

- Correlation: 0.53
- gt = 0.17wm + 0.03
- Mean abs error: 0.06

Multi-variable linear regression:

- Correlation: 0.56
- gt = 0.17wm - 0.18mean + 0.08
- Mean abs error: 0.06



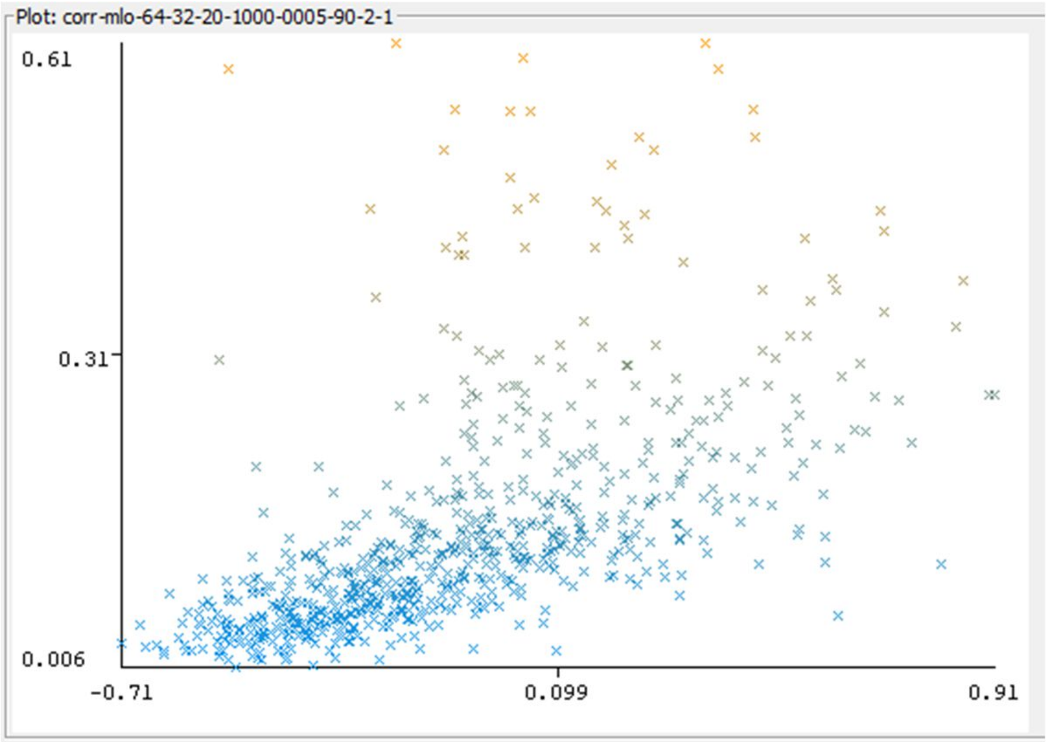
# Results (2 features)

Single variable linear regression:

- Correlation: 0.59
- gt = 0.21wm + 0.15
- Mean abs error: 0.06

Multi-variable linear regression:

- Correlation: 0.63
- gt = 0.18wm + 0.14mean - 0.11var + 0.22
- Mean abs error: 0.06



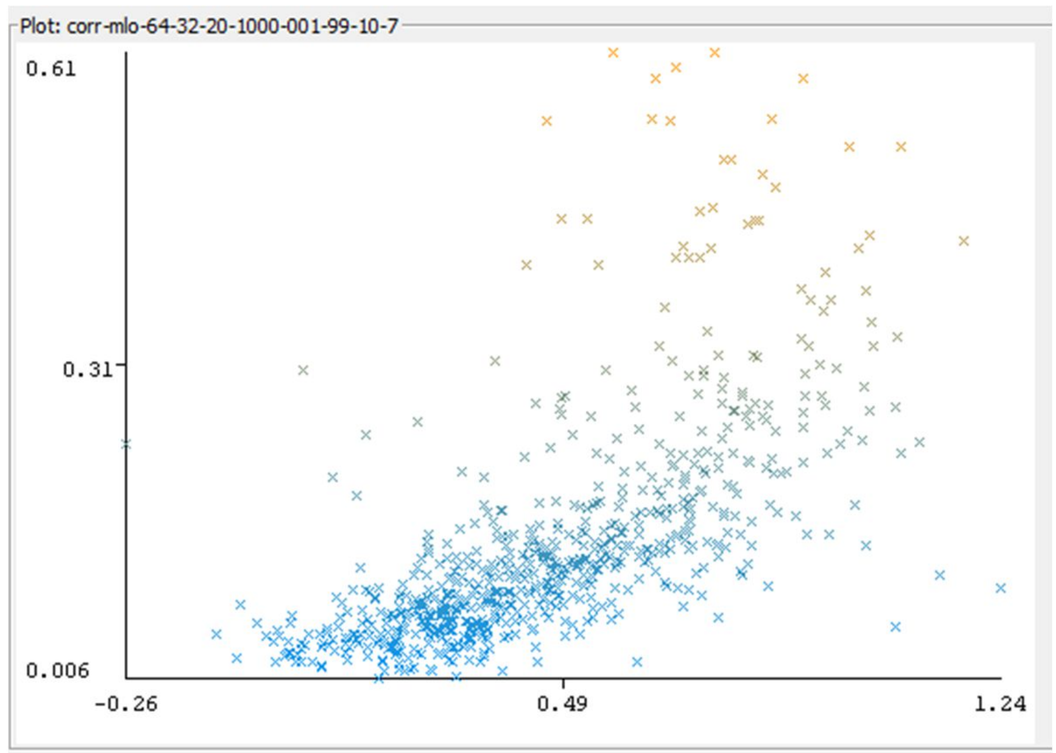
# Results (10 features)

Single variable linear regression:

- **Correlation: 0.66**
- **gt = 0.29wm**
- **Mean abs error: 0.05**

Multi-variable linear regression:

- Correlation: 0.66
- gt = 0.28wm - 0.07mean
  - 0.07var + 0.05
- Mean abs error: 0.05



# Conclusion

- VAE can be used as an unsupervised approach
- More features provide higher correlation for weighted mean
- Trade-off between more features and multi-variable regression
- Correlation can be improved by considering:
  - More features to find saturation
  - Non-linear regression models
  - A better breast masking approach
  - A filter on non-fgt portions for mlo