Breast Cancer Detection and Characterization in the Era of AI

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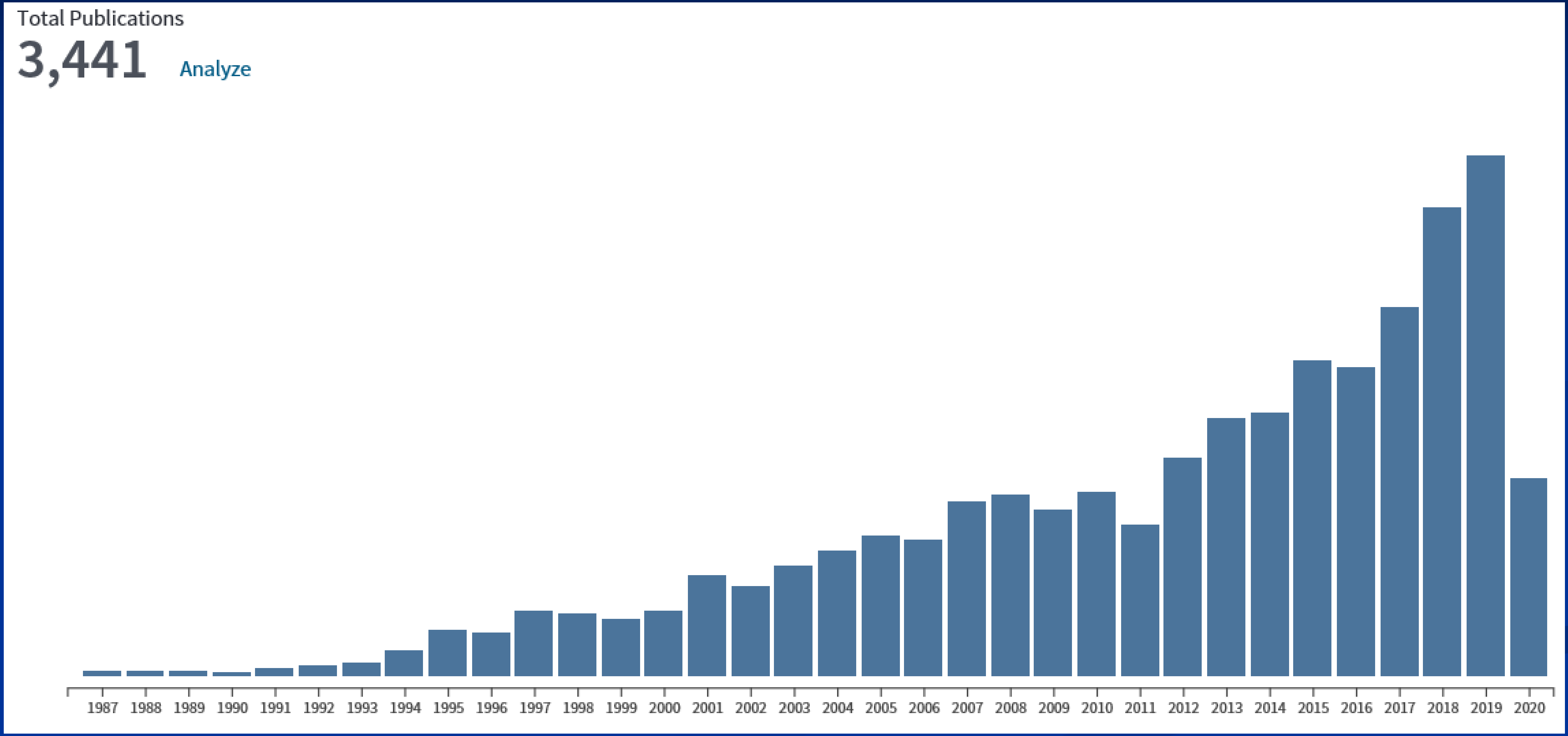
Outline

- Applications of Deep Learning to breast cancer detection and characterization
- Transfer Learning
- Dependence of Deep Learning performance on dataset quality and size

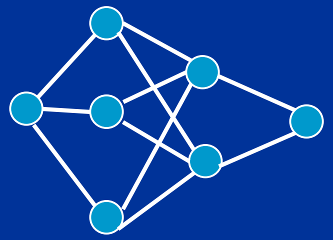
Number of publications for breast imaging and AI



Web of Science Core Collection

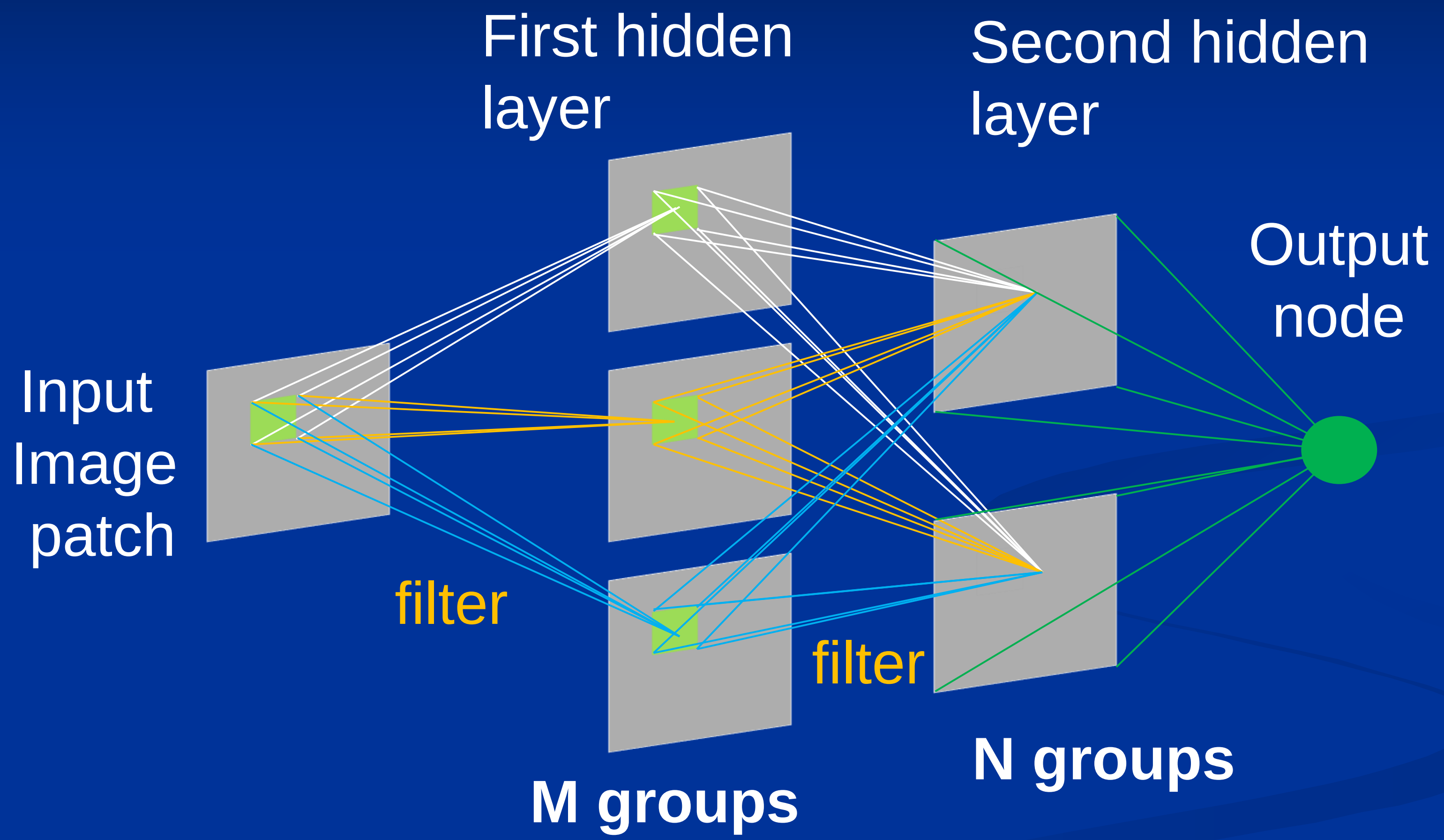
Neural network (NN)

Input
node

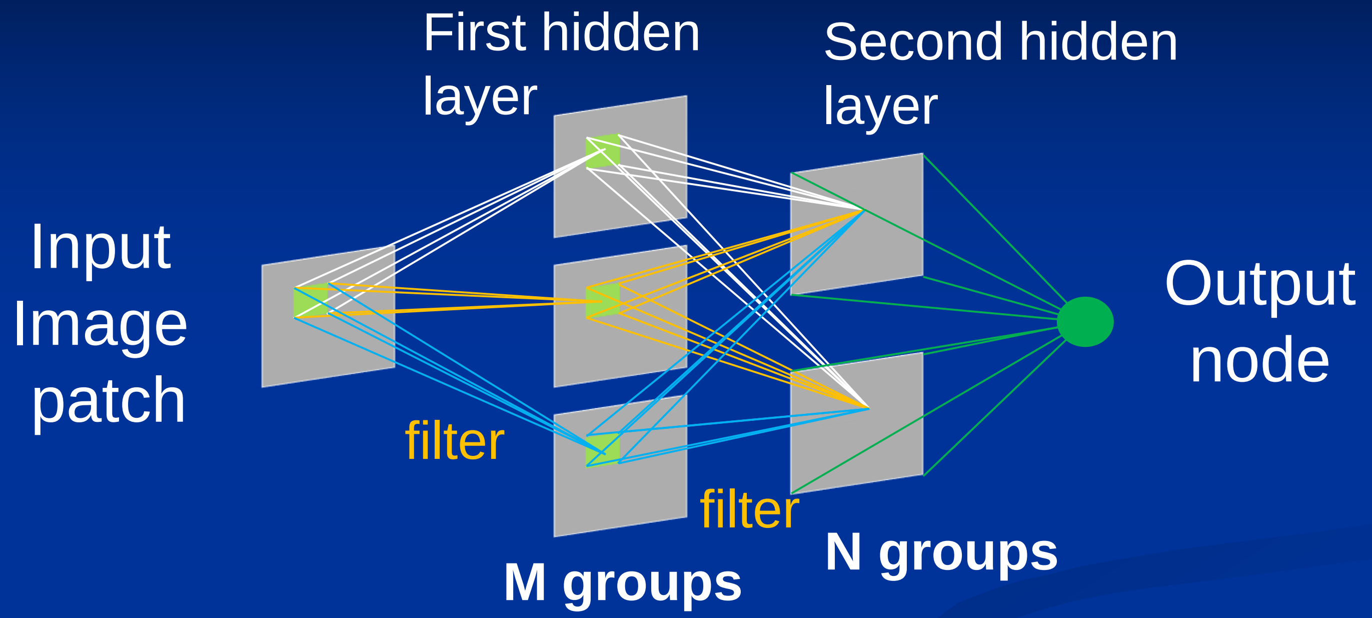


Output
node

Convolution neural network (CNN)



CNN in breast CAD applications



Chan H-P, Lo S-C B, Helvie MA, Goodsitt MM, Cheng S and Adler D D Recognition of mammographic microcalcifications with artificial neural network, *RSNA Program Book 189(P) 318.* **1993.**

Chan H-P, Lo S-C B, Sahiner B, Lam KL, Helvie MA, Computer-aided detection of mammographic microcalcifications: Pattern recognition with an artificial neural network, Medical Physics, **1995.**

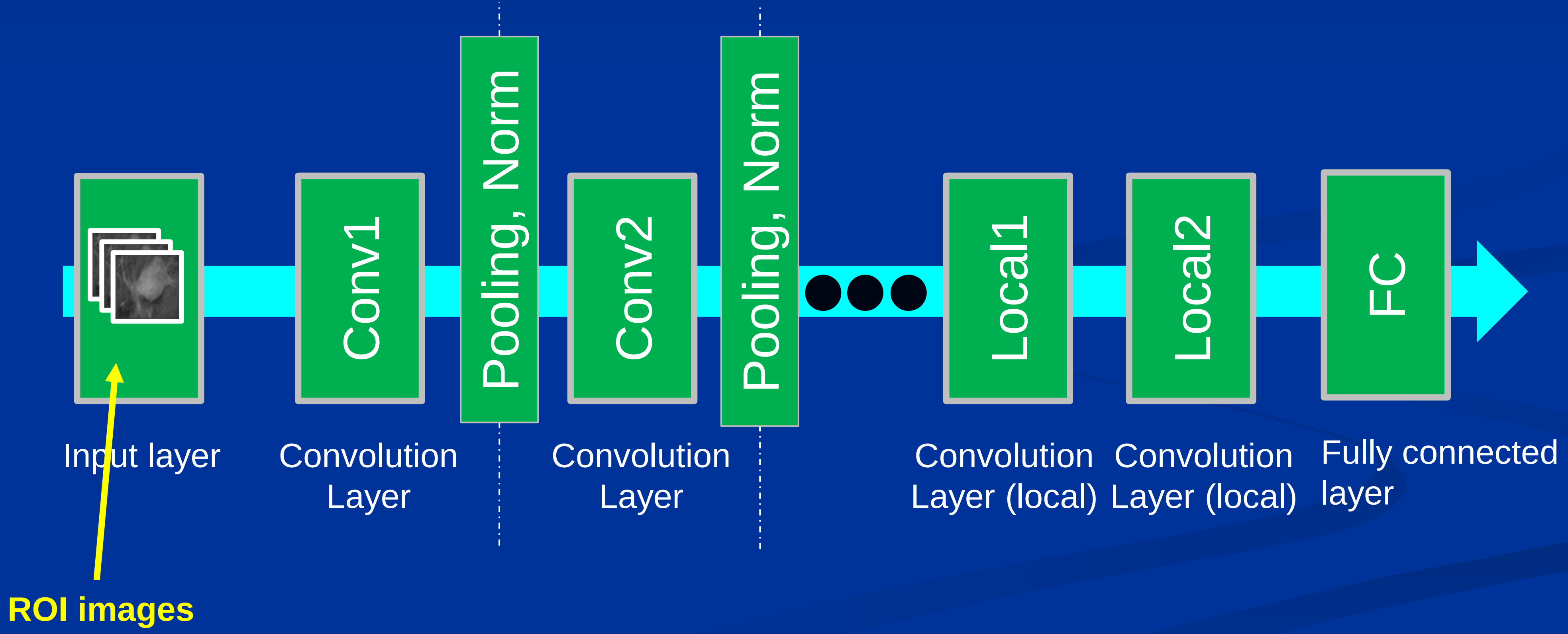
*Lo S-C B, Chan H-P, Lin J-S, Li H, Freedman MT and Mun SK***,** Artificial convolution neural network for medical image pattern recognition, *Neural Networks,* **1995.**

Sahiner B, Chan H-P, Petrick N, Wei D, Helvie MA, Adler DD and Goodsitt MM, Classification of mass and normal breast tissue: A convolution neural network classifier with spatial domain and texture images, *IEEE Trans.on Medical Imaging* **1996.**

Samala RK, Chan H-P, Lu Y, Hadjiiski L, Wei J, Helvie MA, Digital breast tomosynthesis: computer-aided detection of clustered microcalcifications on planar projection images, *Phys. Med. Biol.* **2014**.

Deep Learning

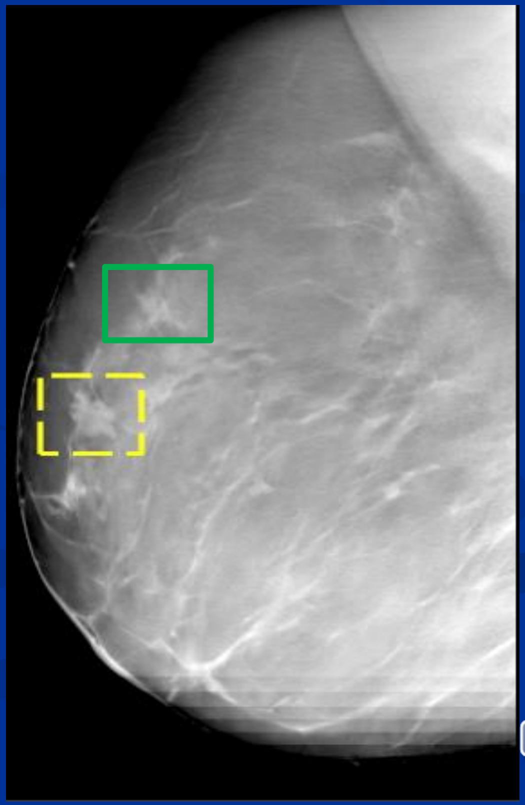
- **Deep-Learning Convolutional Neural Network (DL-CNN)**



Krizhevsky et al, Adv. Neu. Info. Proc. Sys. 2012.

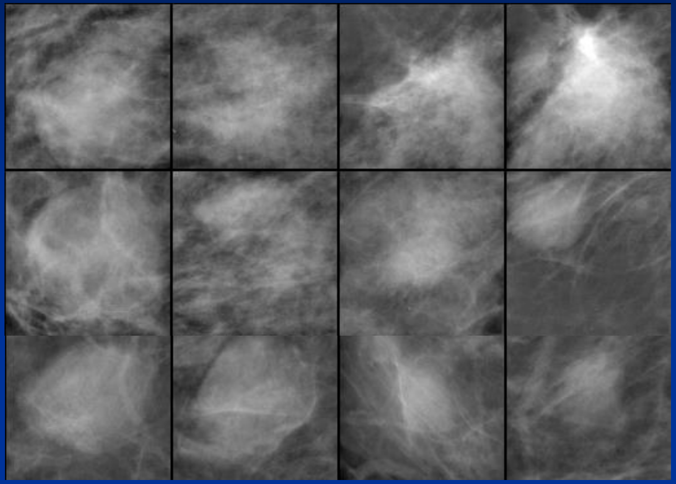
Deep Learning

- Task – to distinguish masses from normal tissue
- Large number of convolution kernels and weights
- Trained with ROIs



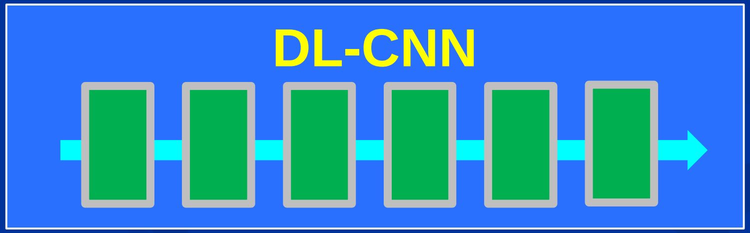
Deep Learning

Examples of training ROIs



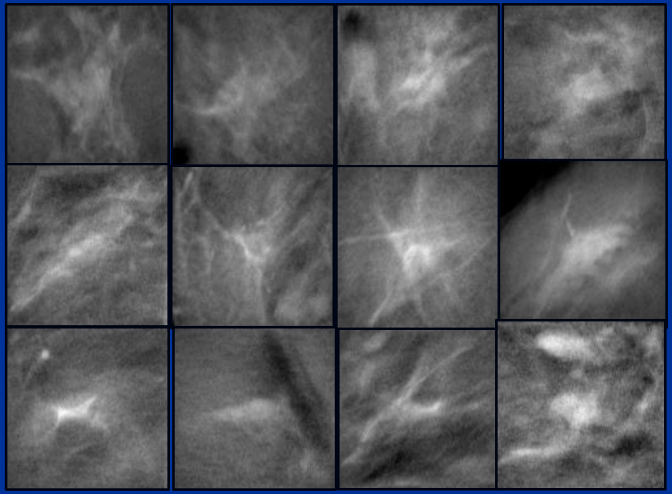
Mass

Training



1 - Mass

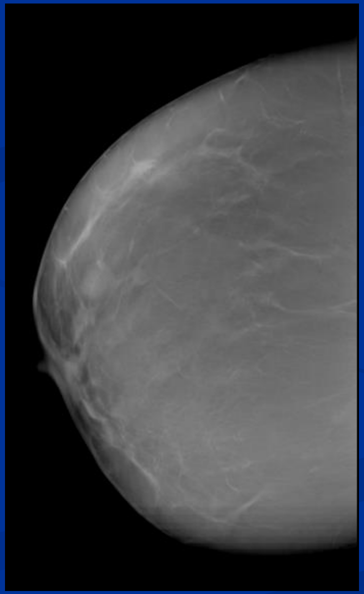
0 - Normal



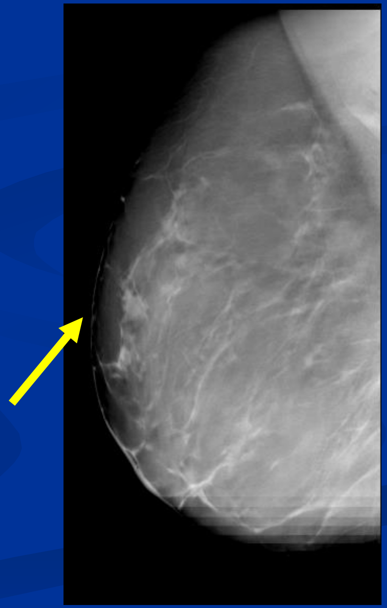
Normal

Deep Learning

- Task – to distinguish **abnormal from normal mammographic images**
- Large number of convolution kernels and weights
- Trained with entire images



Normal

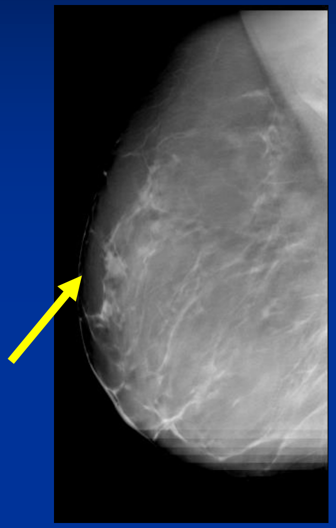


Abnormal
(Mass)

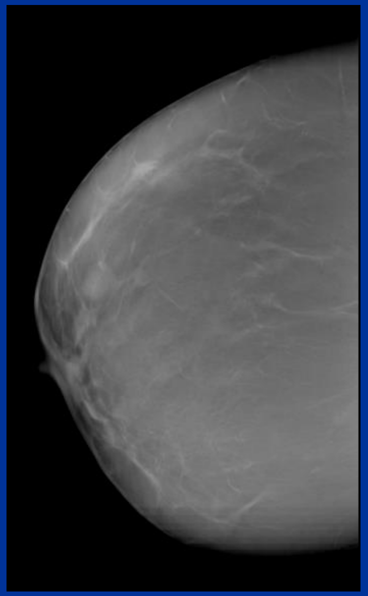
Deep Learning

Examples of training entire images

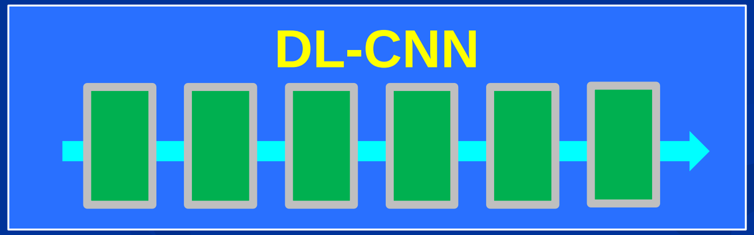
Abnormal (Mass)



Normal



Training

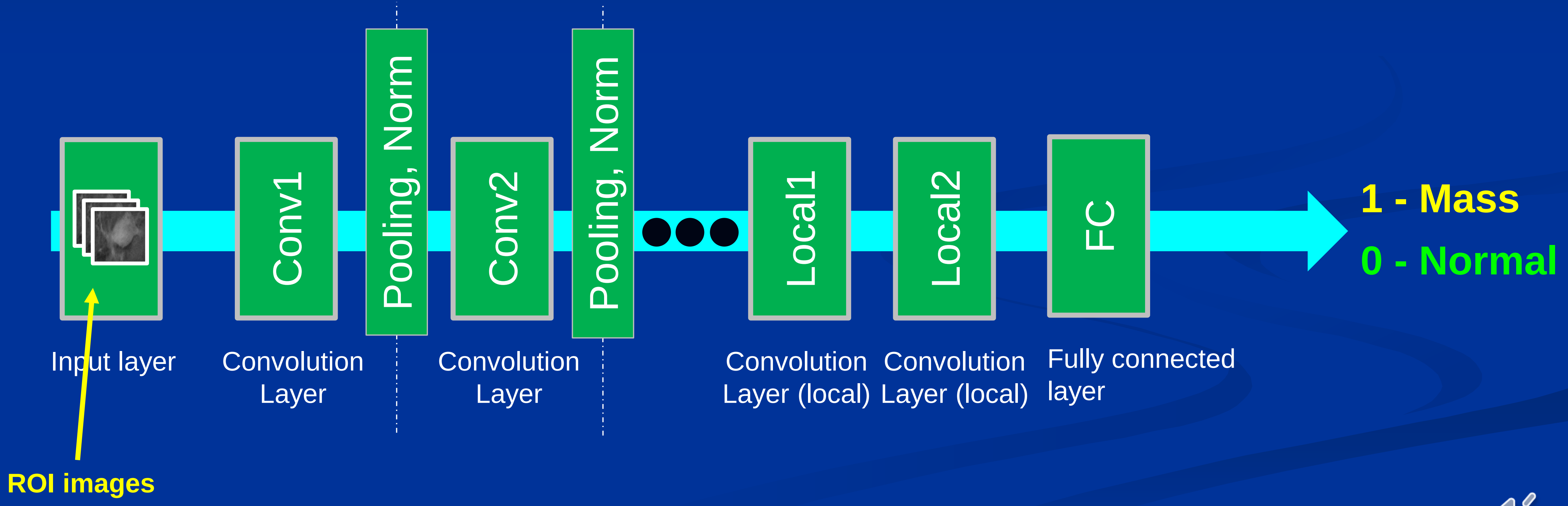


1 - Abnormal

0 - Normal

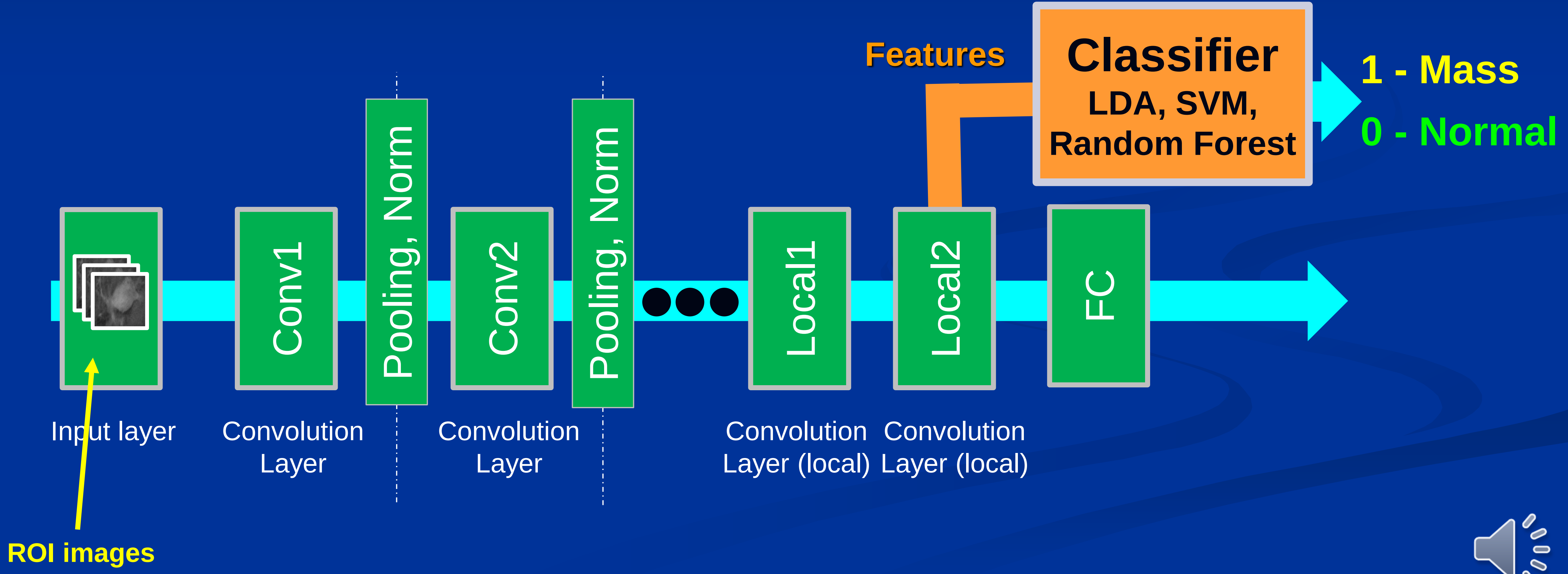
Deep Learning

- **DL-CNN: Classifier**



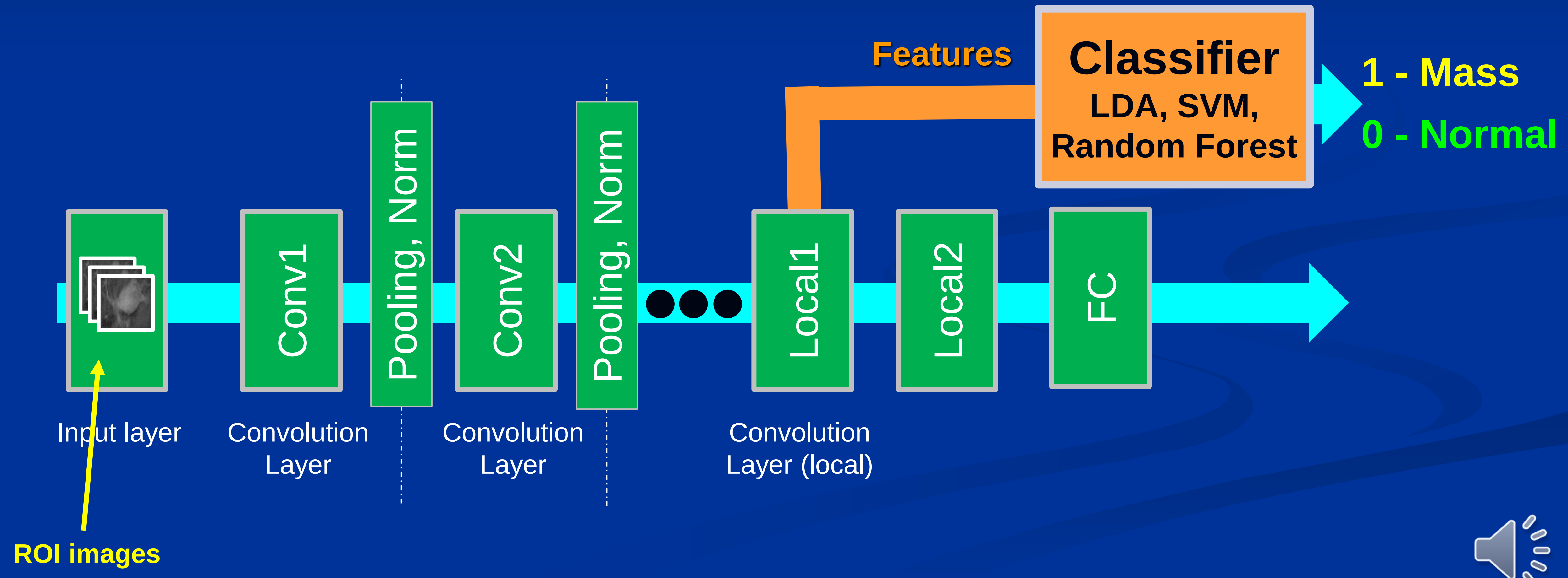
Deep Learning

- DL-CNN: Feature extractor



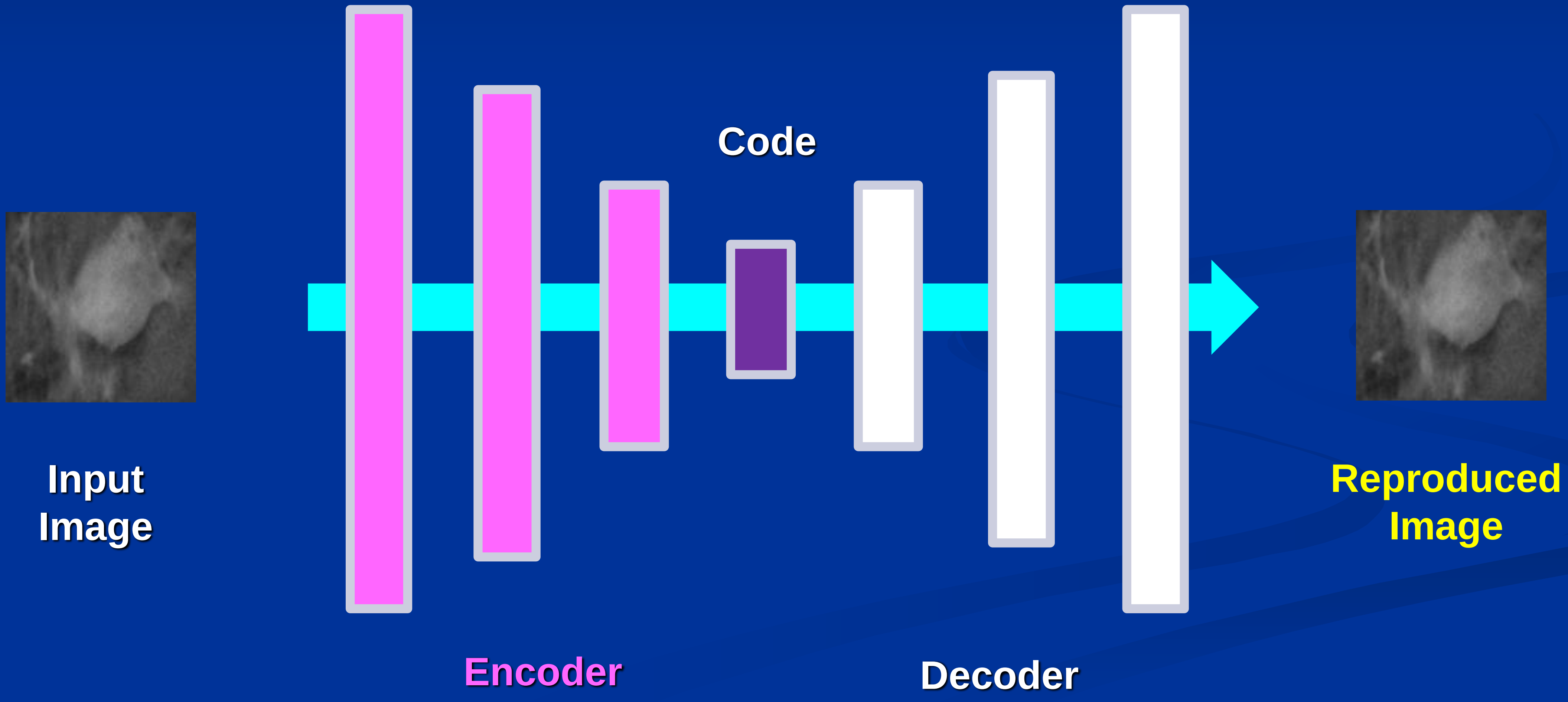
Deep Learning

- DL-CNN: Feature extractor

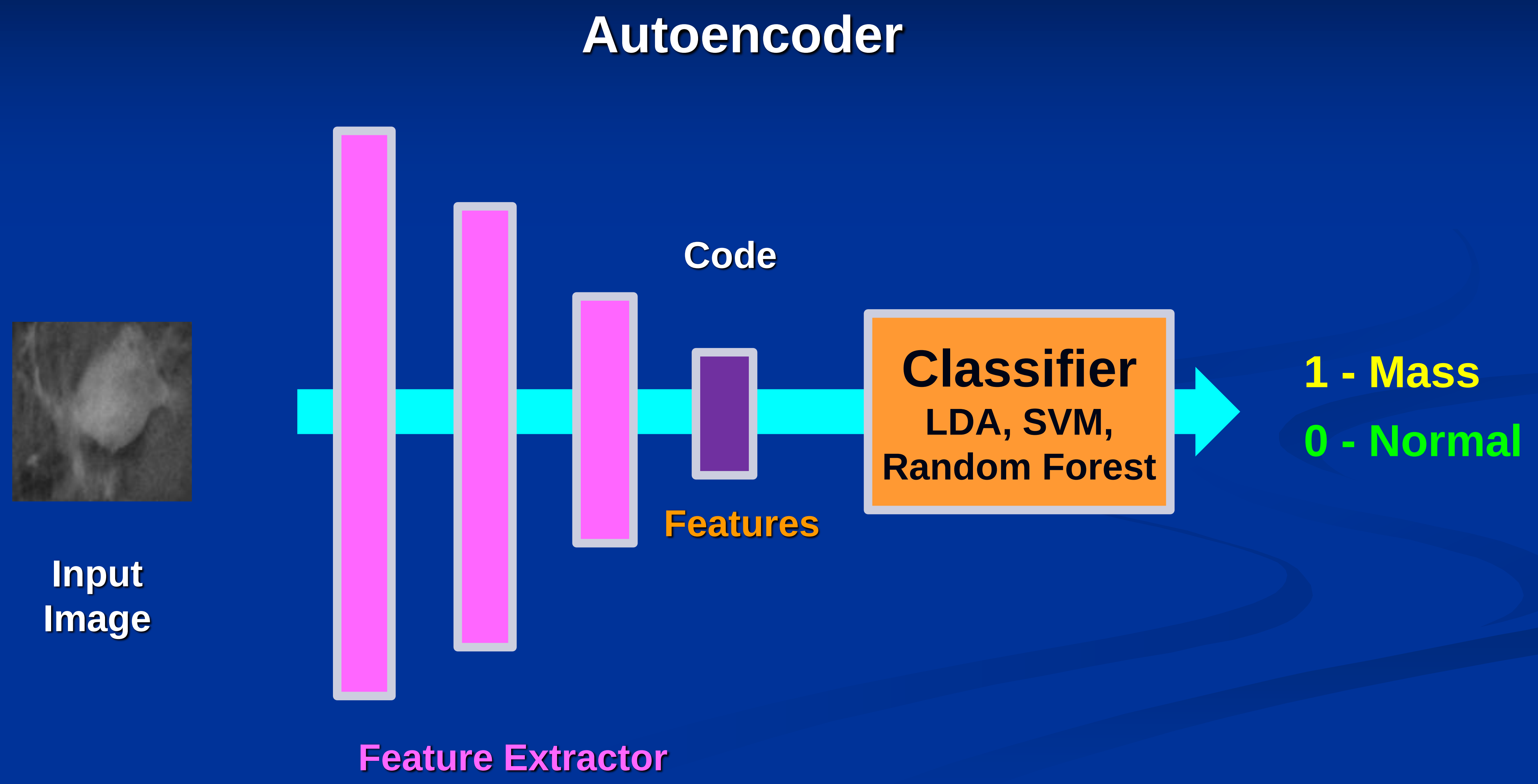


Deep Learning

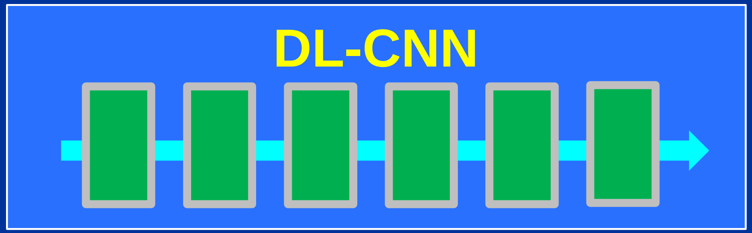
Autoencoder



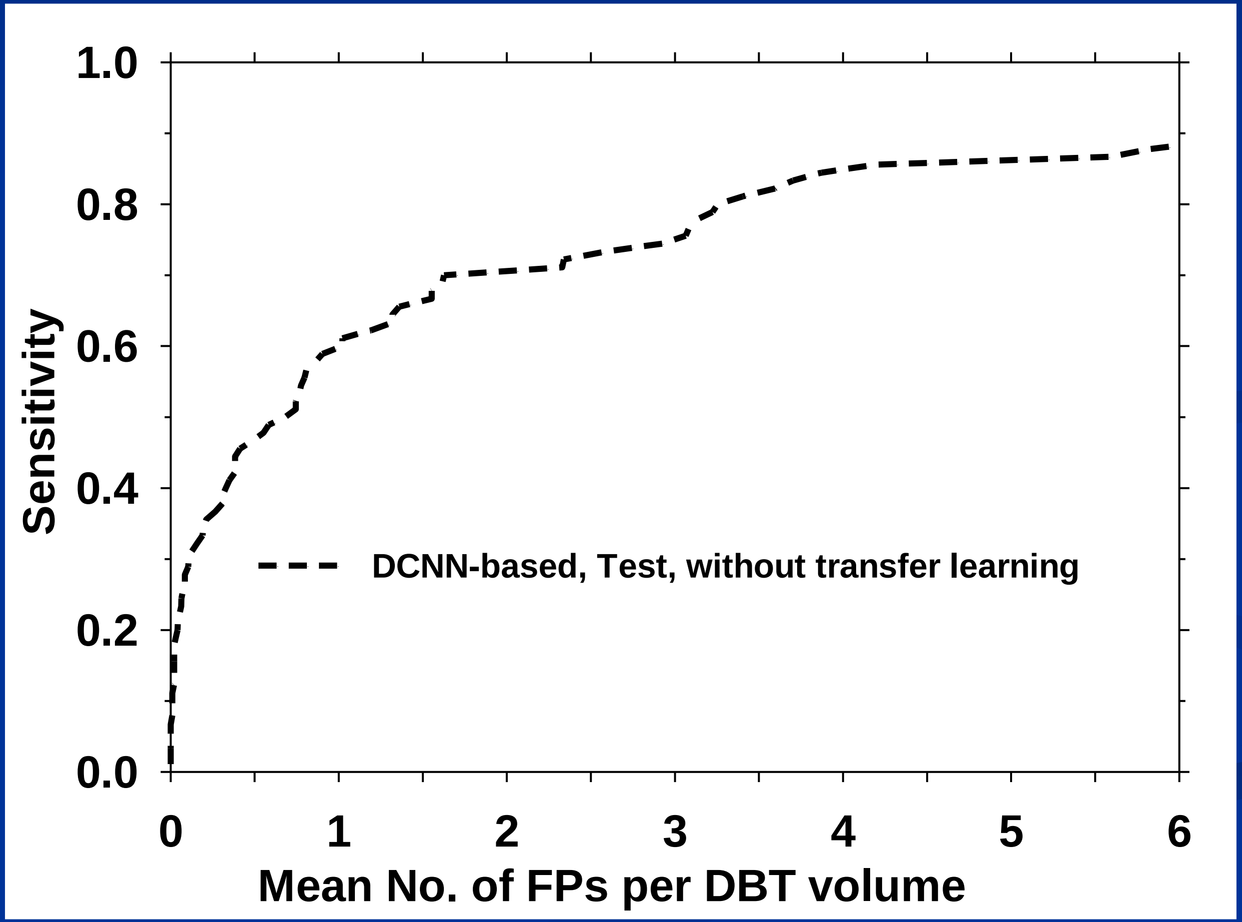
Deep Learning



Deep Learning



FROC analysis

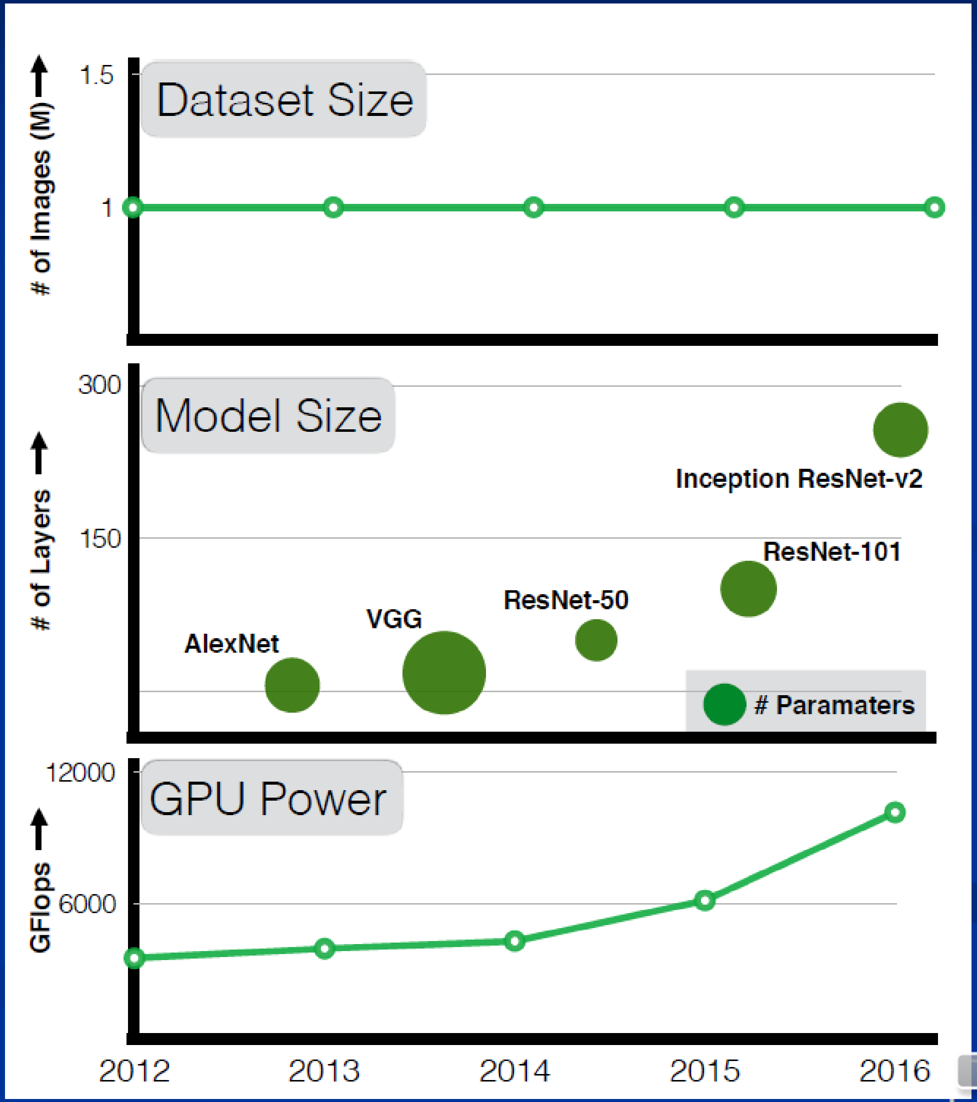


Dependence of DL-CNN performance on data size

Revisiting Unreasonable Effectiveness of Data in Deep Learning Era

Chen Sun[1], Abhinav Shrivastava[1,2], Saurabh Singh[1], and Abhinav Gupta[1,2]

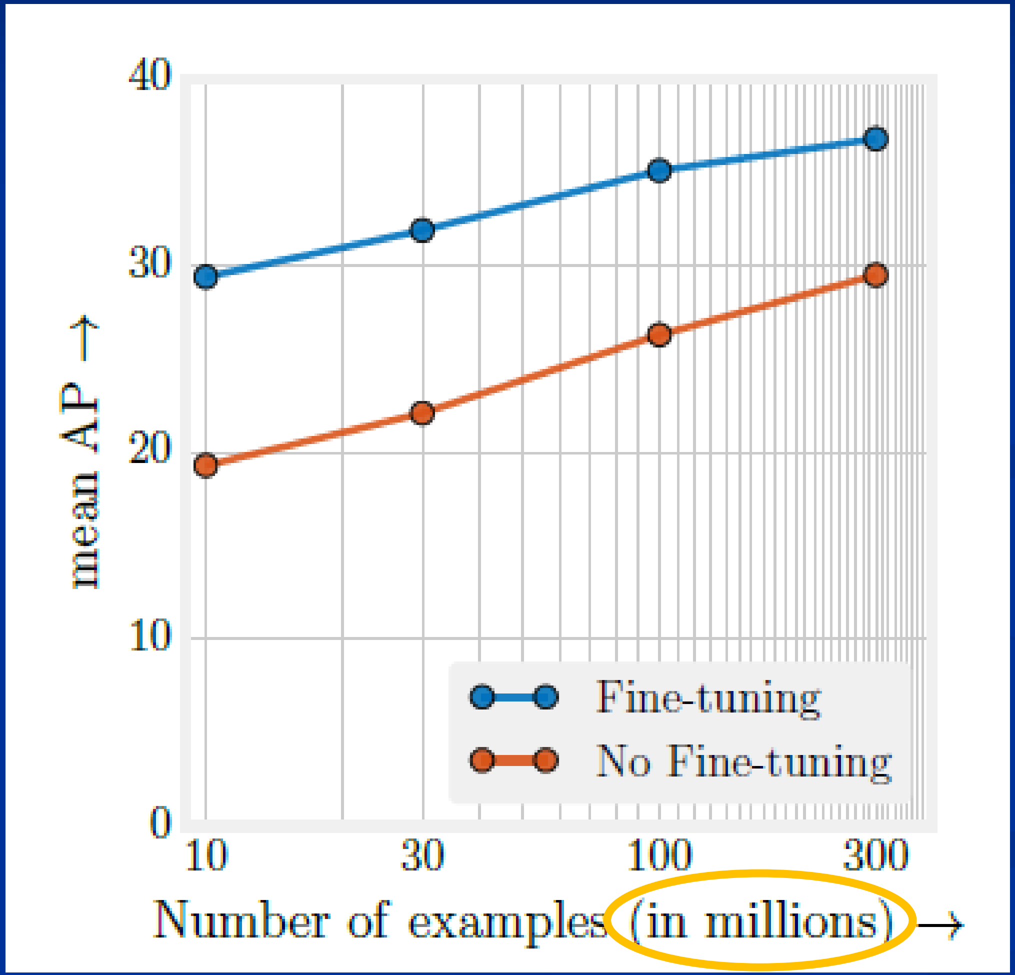
[1]Google Research
[2]Carnegie Mellon University



Sun C, et al. arXiv, 2017.

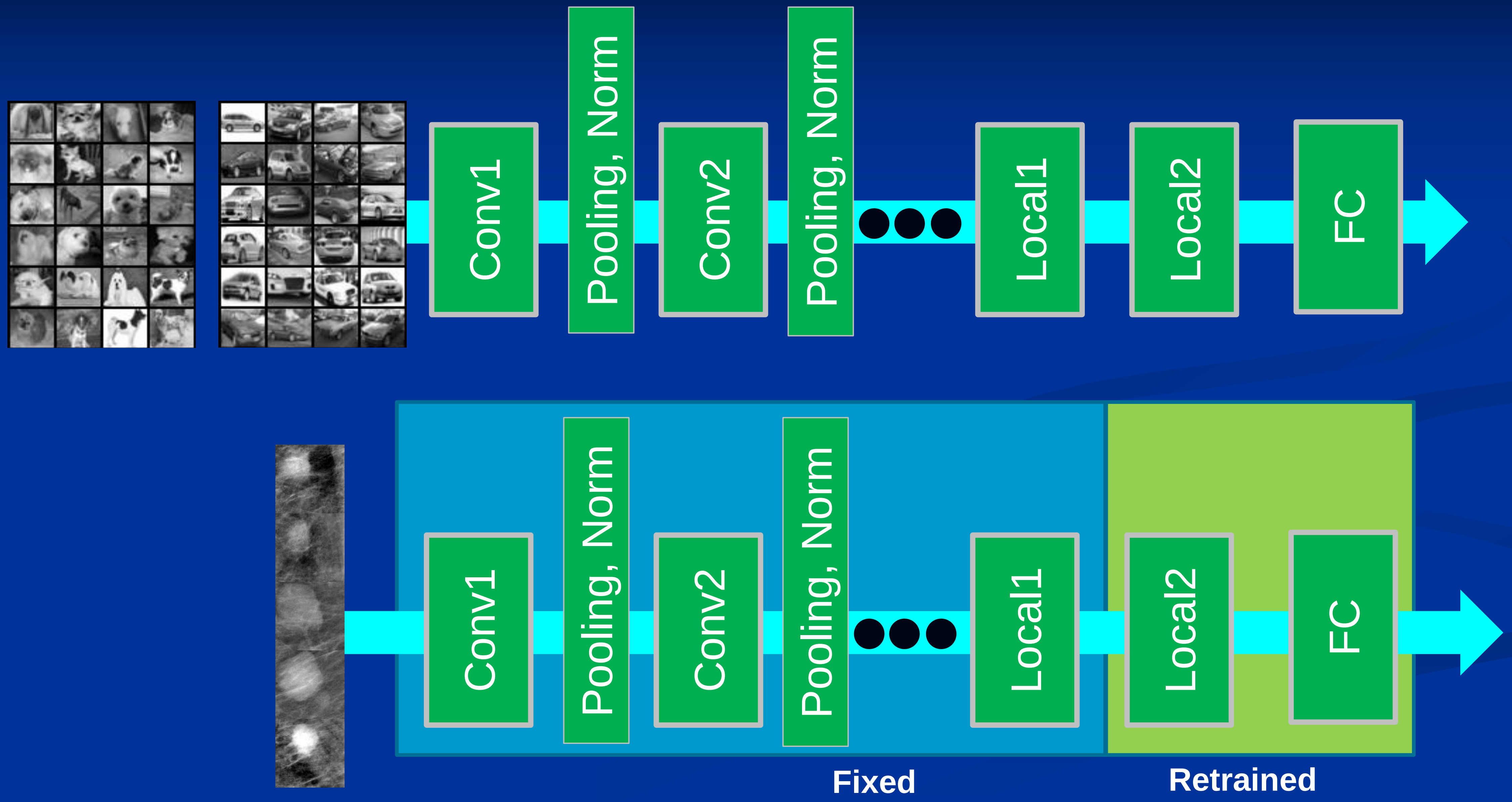
Dependence of DL-CNN performance on data size

natural scenes images

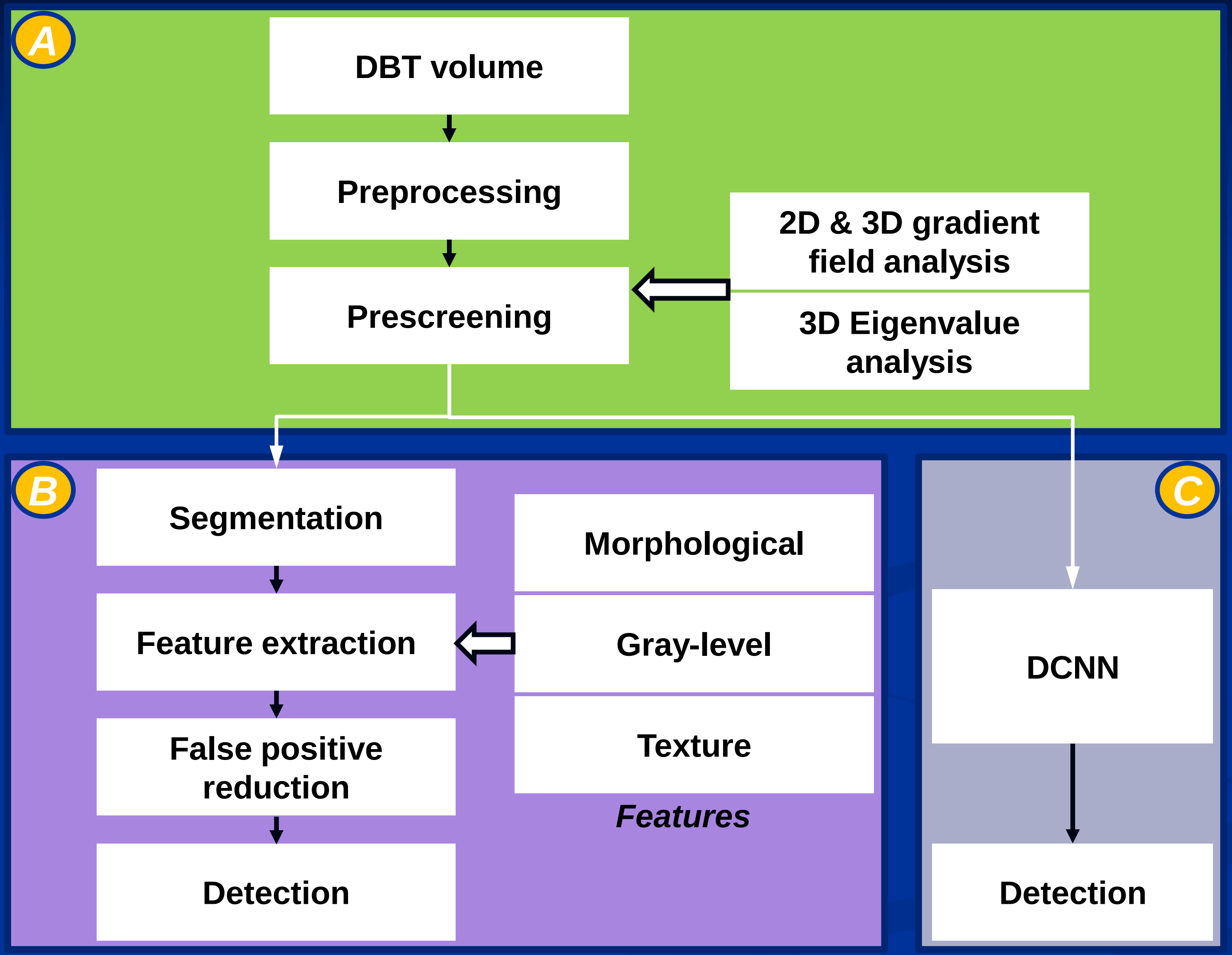


Sun C, et al. arXiv, 2017.

Transfer Learning

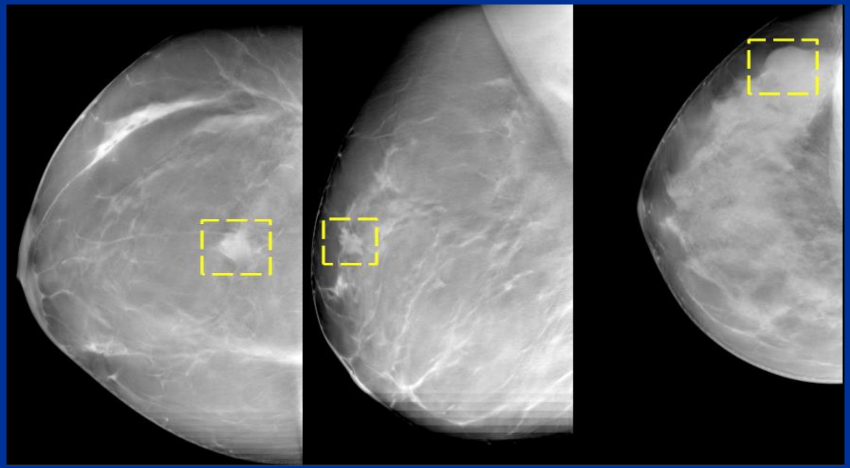


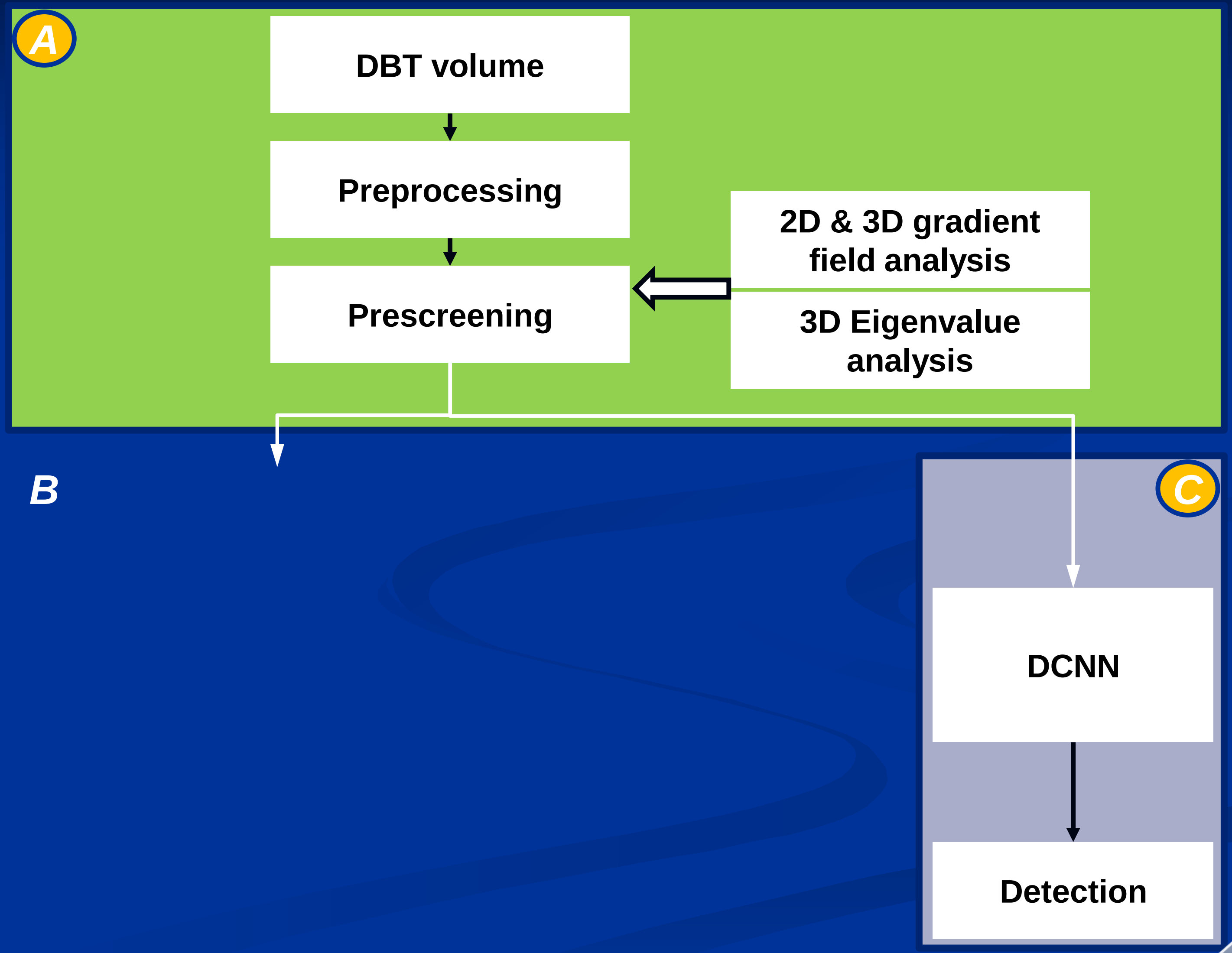
Mass Detection in Digital Breast Tomosynthesis



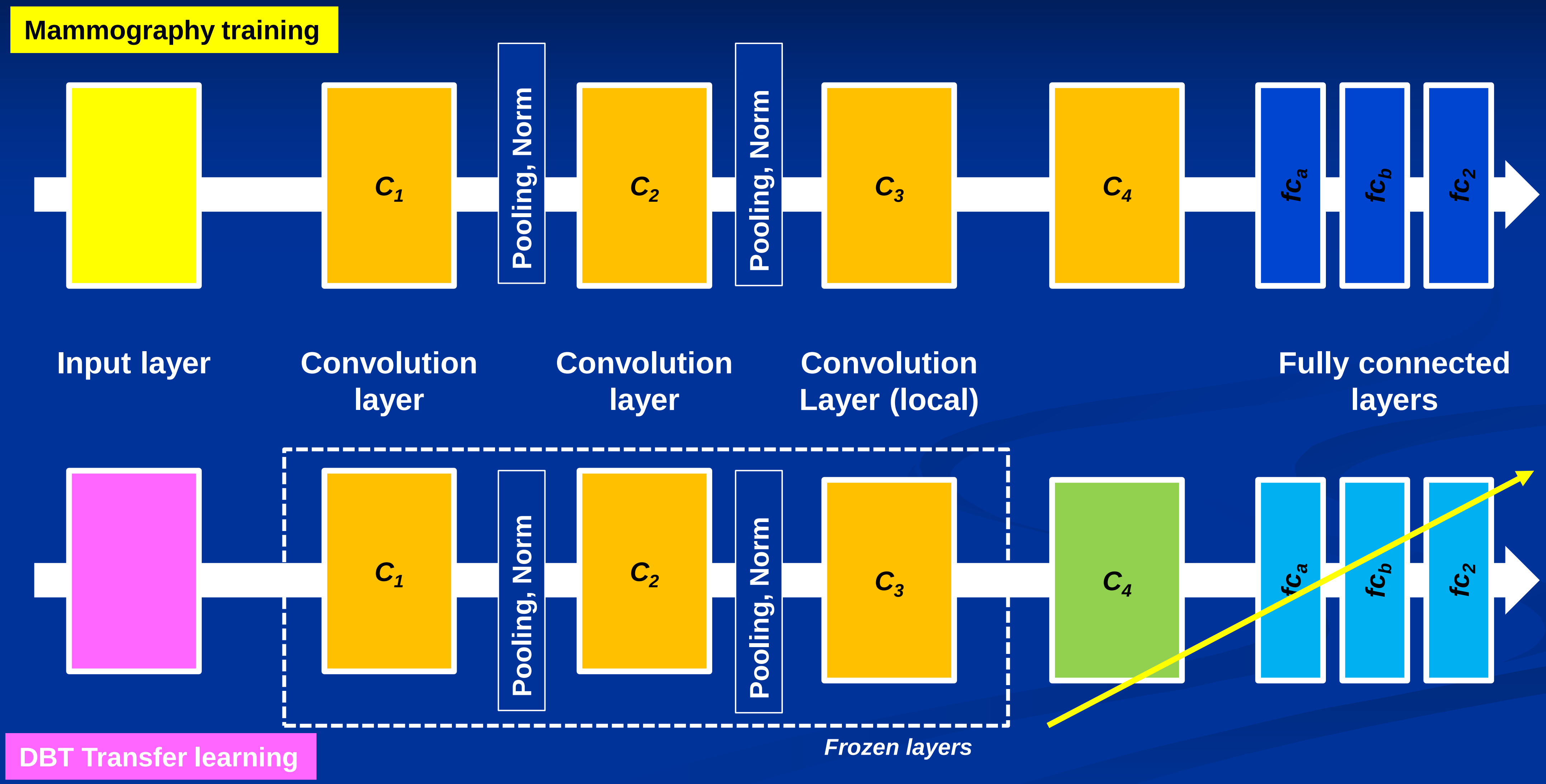
Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Wei J, Cha K. Mass Detection in Digital Breast Tomosynthesis: Deep Convolutional Neural Network with Transfer Learning from Mammography, Medical Physics, 2016.

Mass Detection in Digital Breast Tomosynthesis

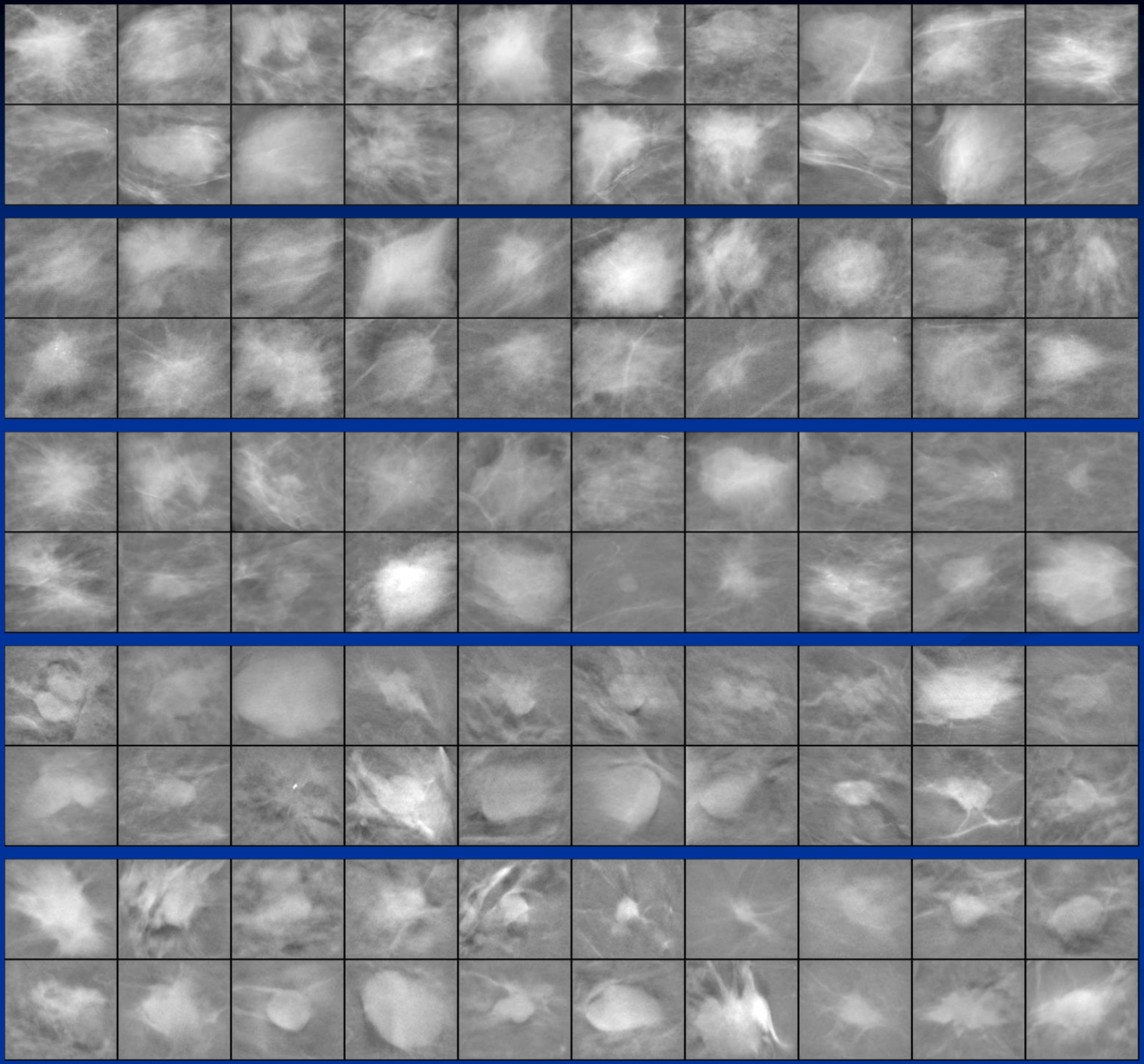




Transfer Learning DL-CNN



ROIs of 128 x 128 pixels



SFM-UM set

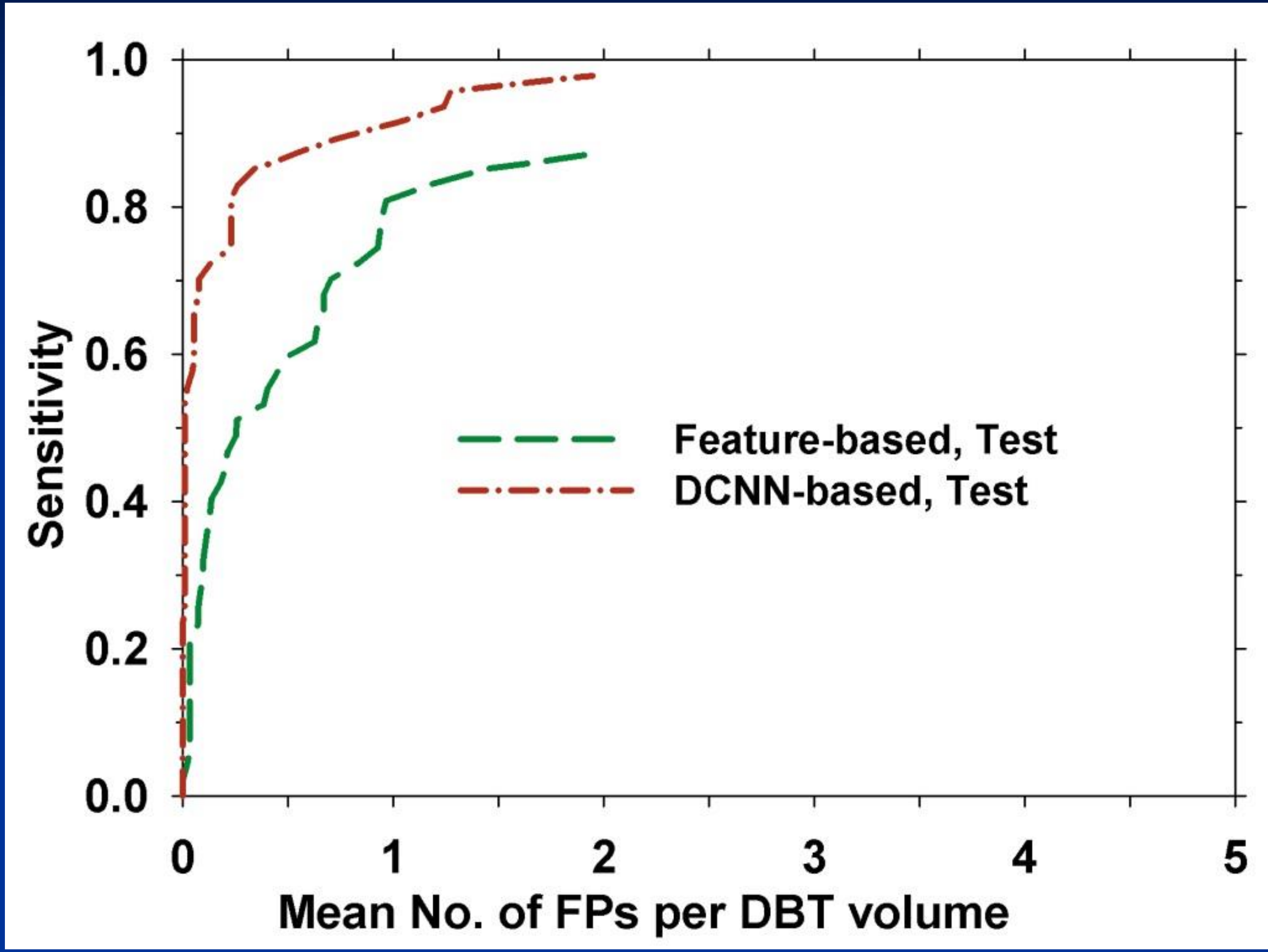
SFM-USF set

DM set

DBT-MGH set

DBT-UM set

Transfer Learning DL-CNN

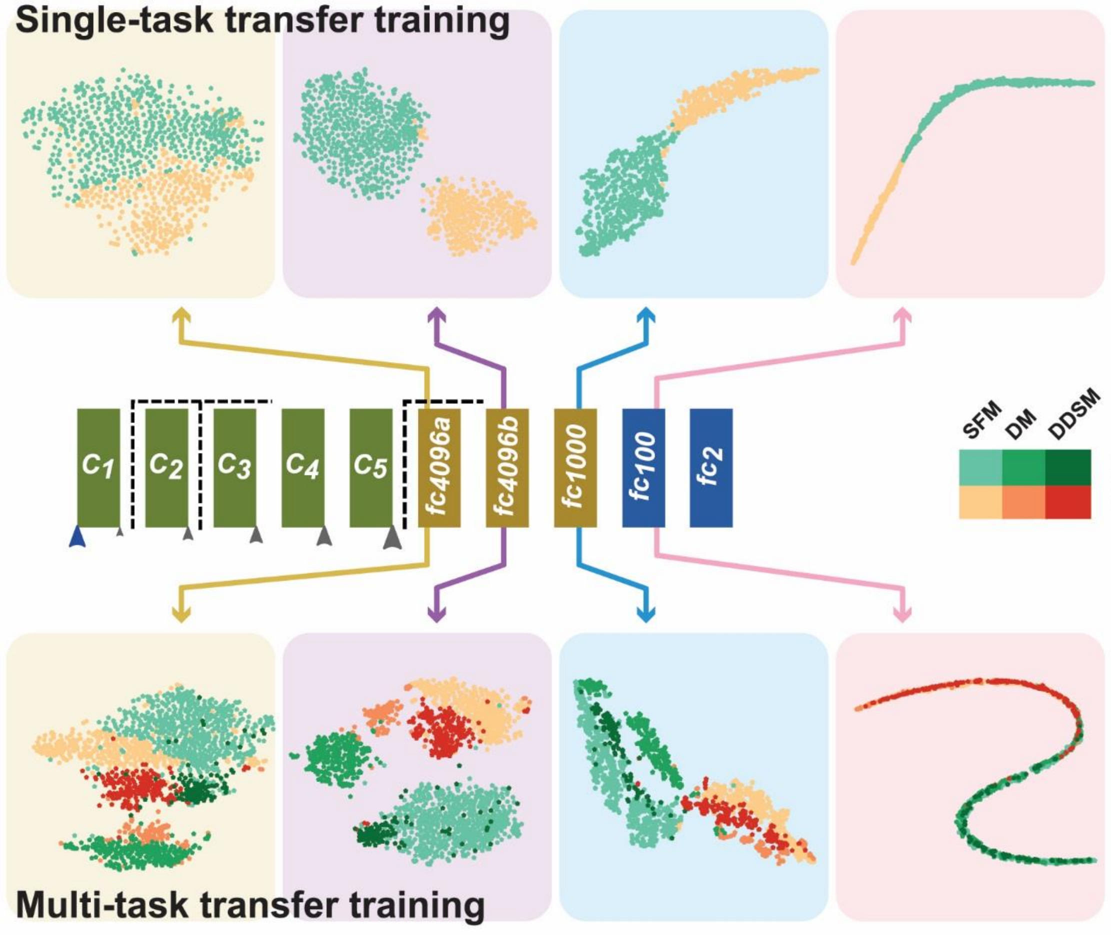


	Conventional CAD	DL-CNN Trained on mammograms	DL-CNN Transfer learning
Sensitivity	0.70	0.83	0.91
False Positive/ DBT Volume	1	1	1

$(p < 0.05)$

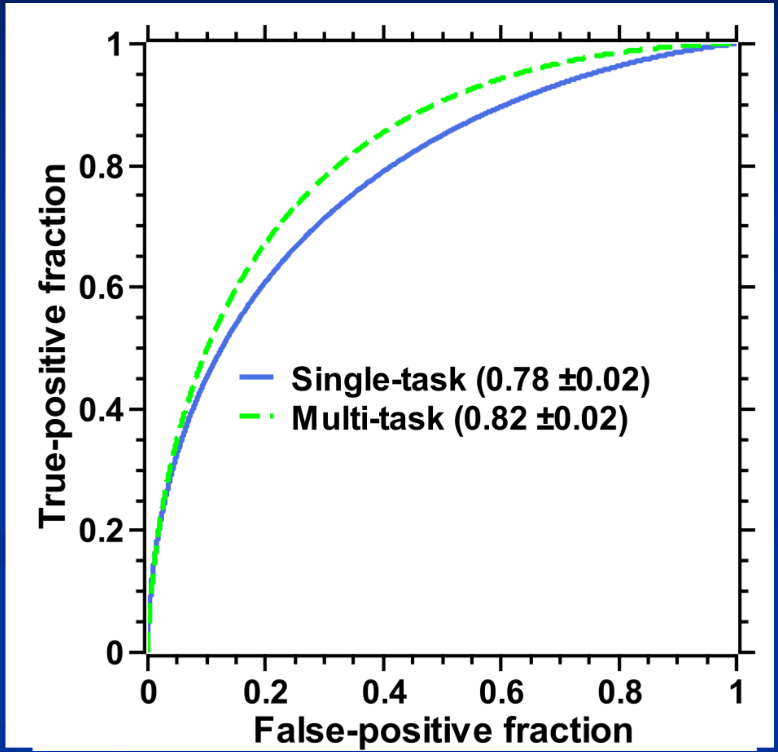
DL-CNN Classification of Breast Masses

2454 Unique Lesions



SFM

SFM + DM

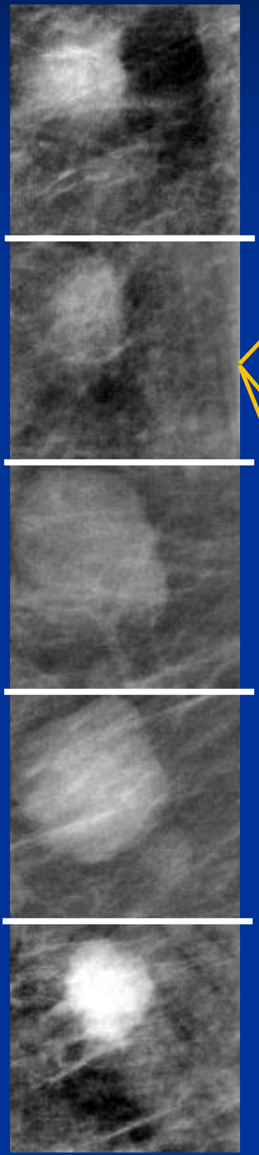


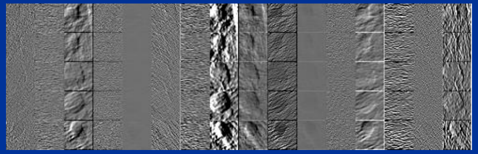
Independent test set

Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Cha K, Richter C. Physics in Medicine and Biology 2017.
Samala RK, Chan H-P, Hadjiiski L, Cha K, Helvie MA, Richter C. RSNA meeting, 2017.

Convolution activation layer output

Input mammography ROIs





C_1 activation layer (frozen) ImageNet Pre-trained

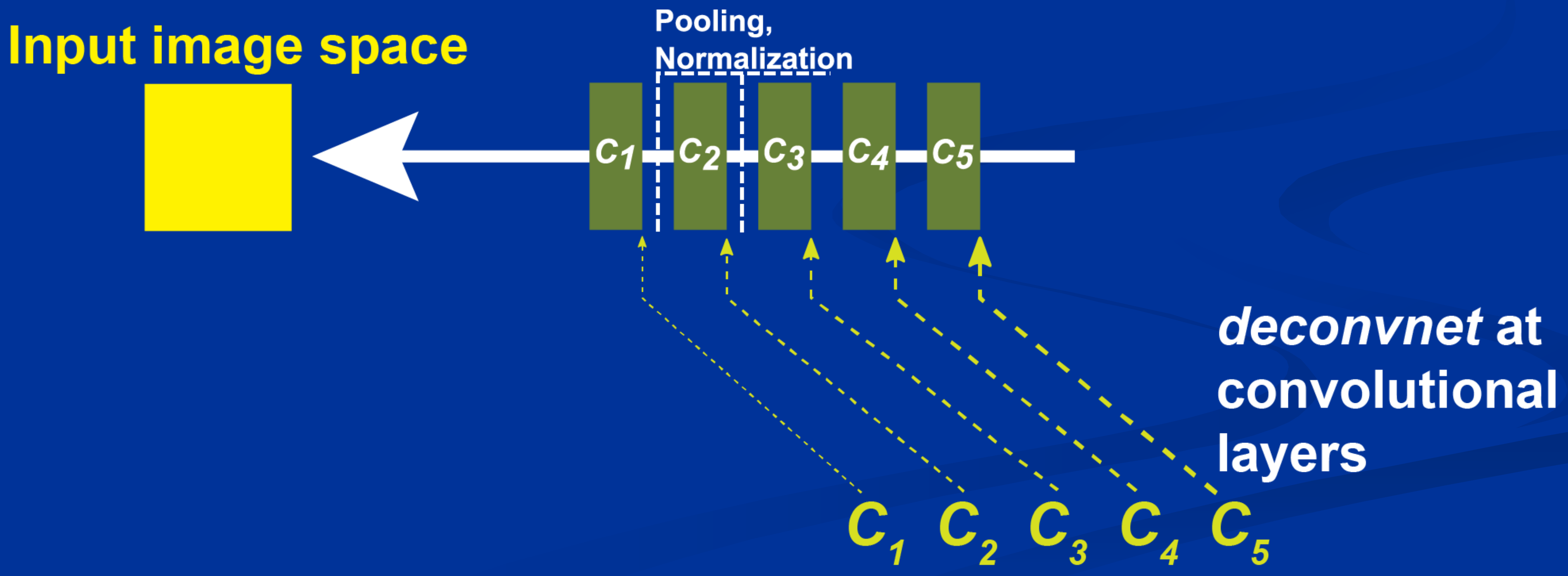
C_2 activation layer (frozen) ImageNet Pre-trained

C_2 activation layer (mammography fine-tuned)

Deep visualization

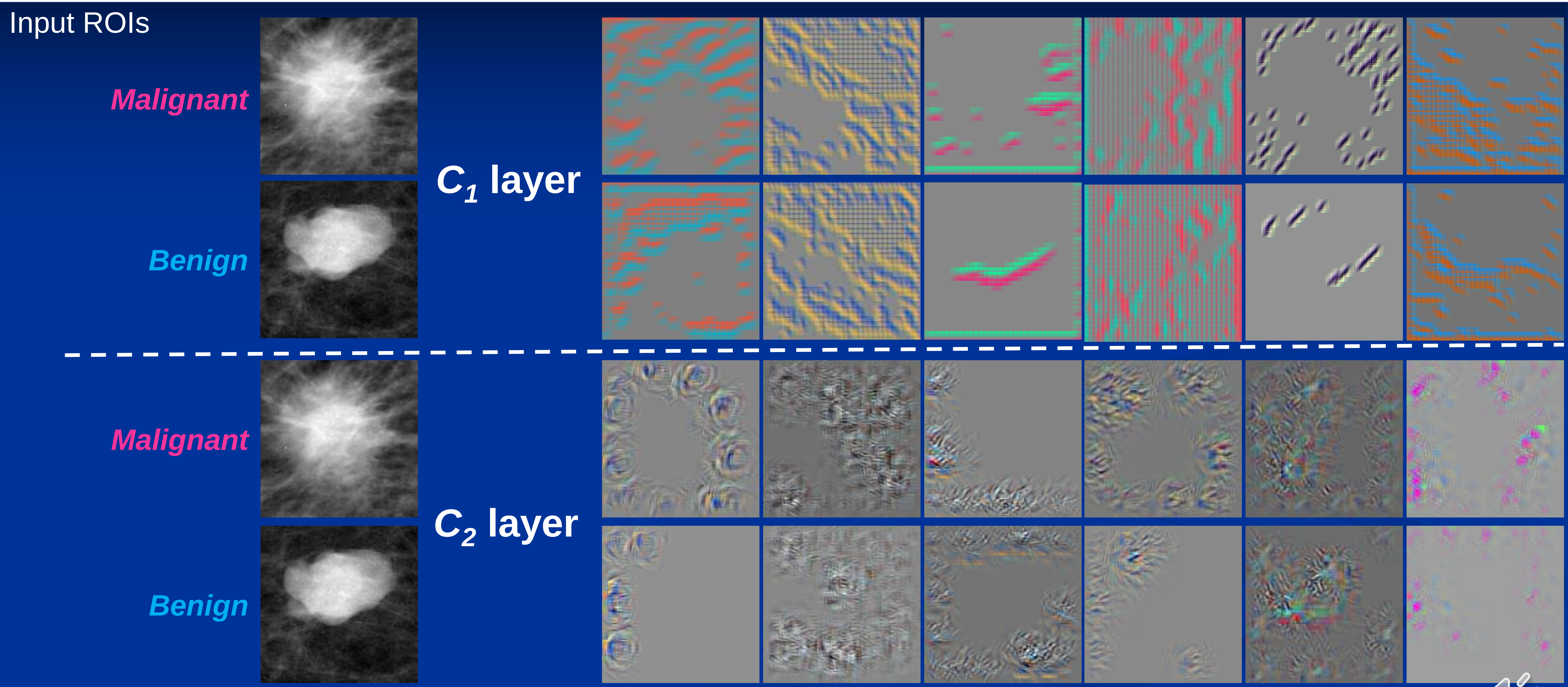
Multi-layered deconvolution network (*deconvnet*)

- Visualization technique to project feature activations back to the input image space



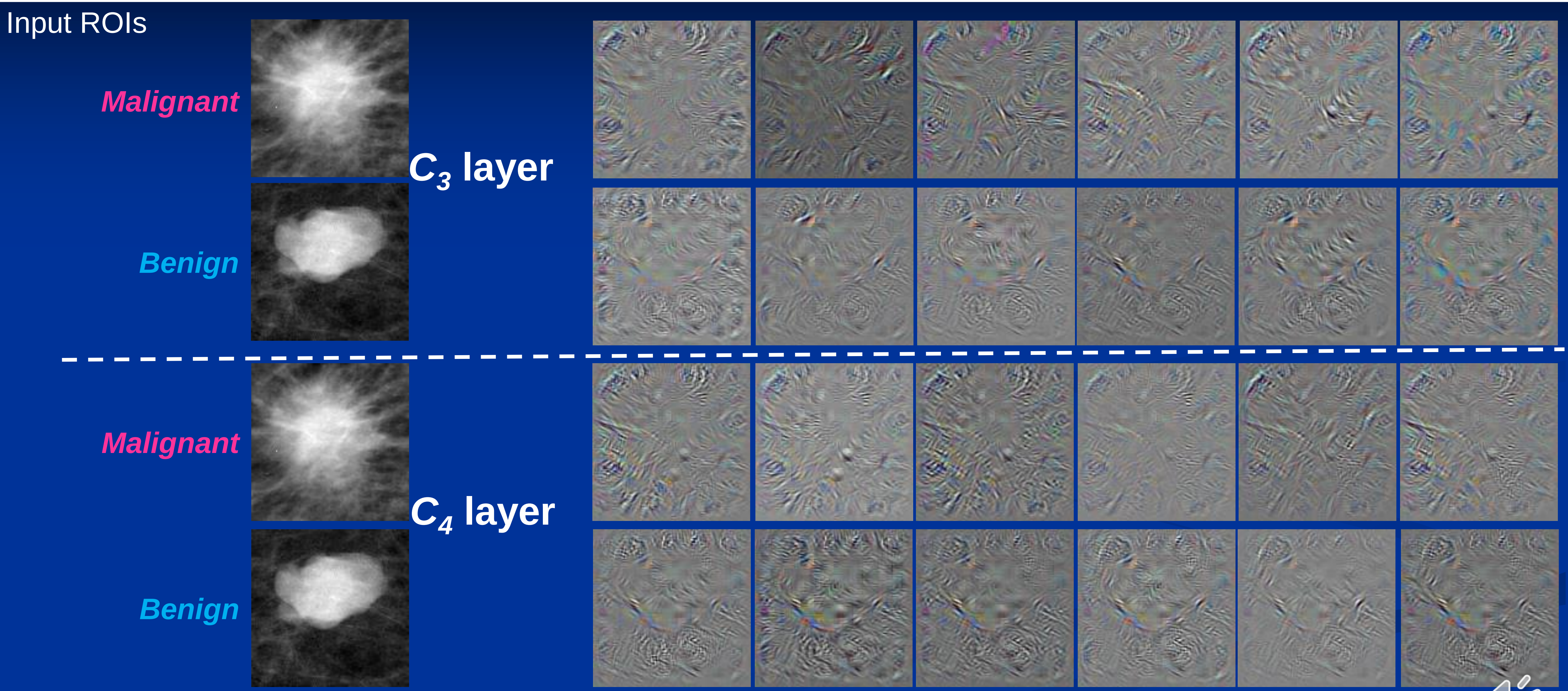
Zeiler and Fergus, ECCV. 2014.

Deep visualization



Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Cha K, Richter C. Phys. Med. Biol. 2017.

Deep visualization



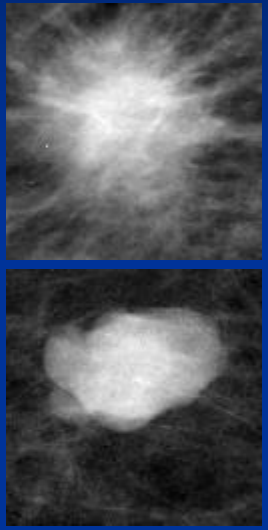
Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Cha K, Richter C. Phys. Med. Biol. 2017.

Deep visualization

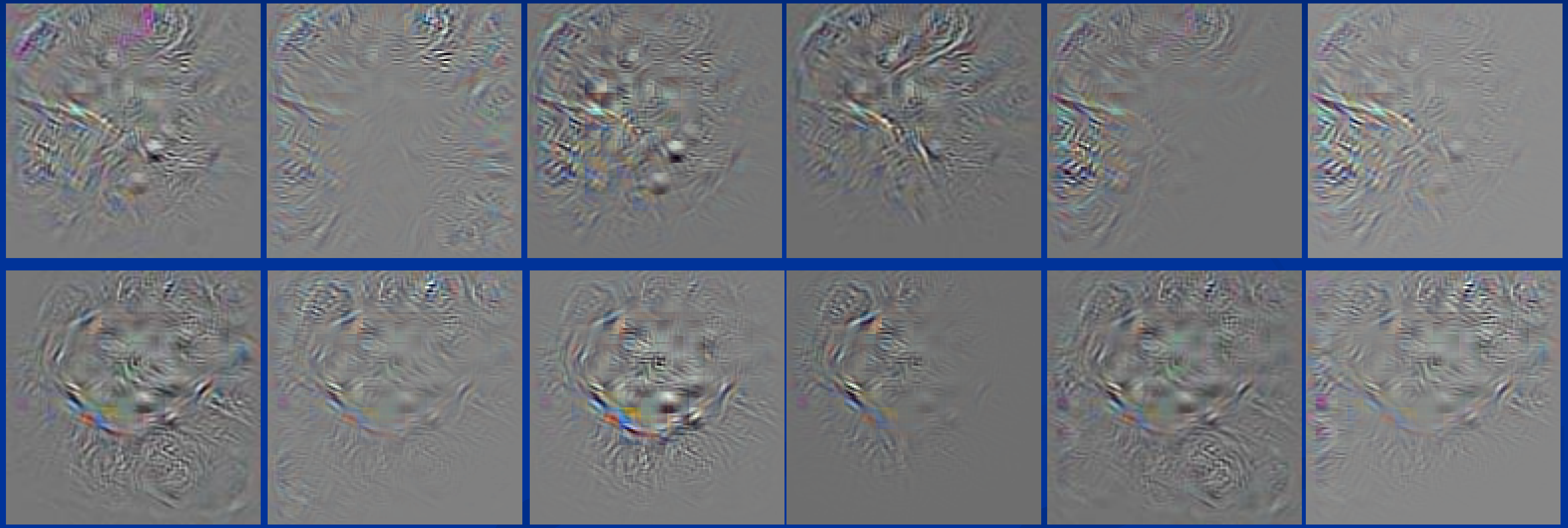
Input ROIs

Malignant

Benign



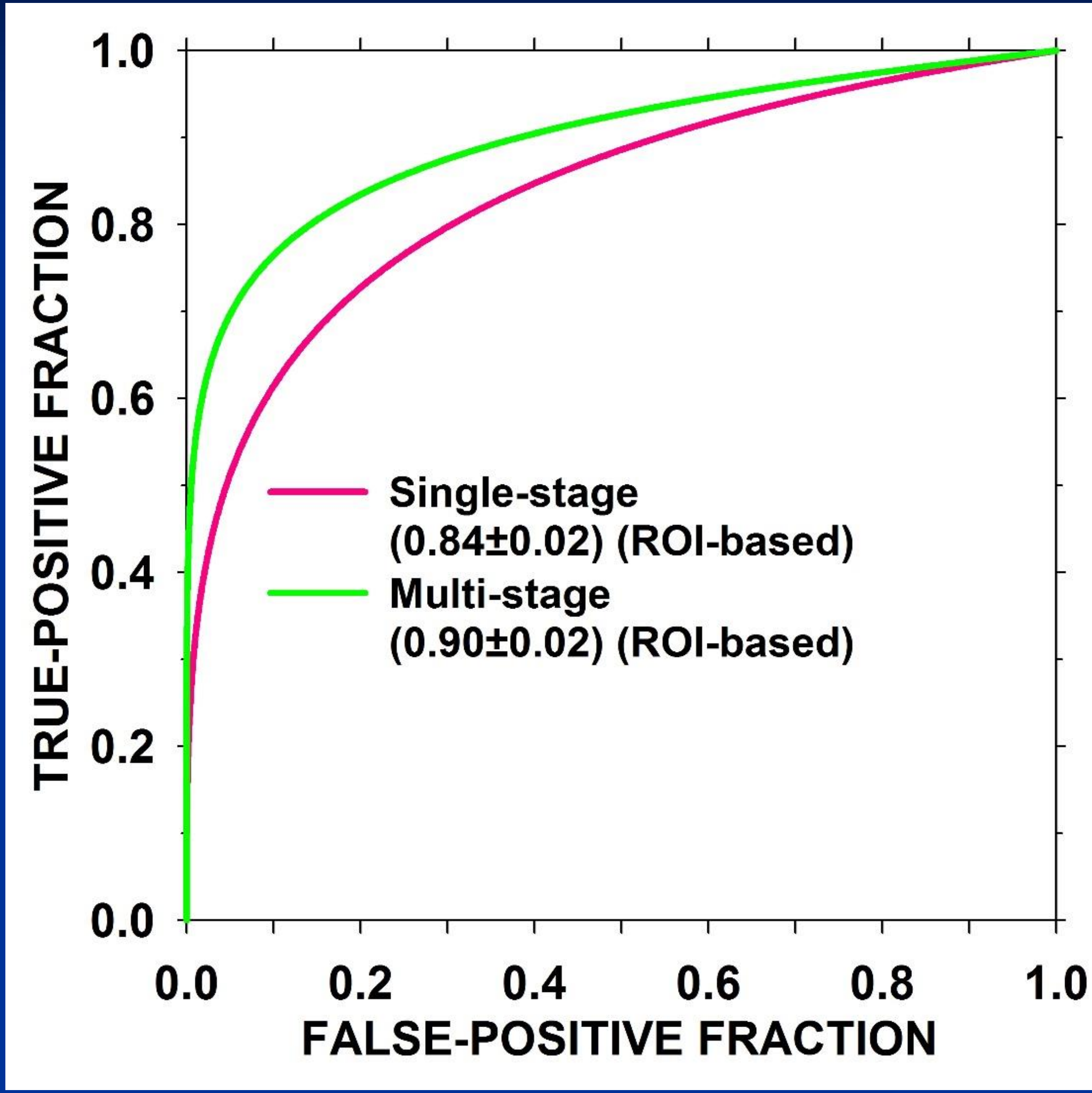
C_5 layer



Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Cha K, Richter C. Phys. Med. Biol. 2017.

DL-CNN Classification of Breast Masses - DBT

1585
Unique
ROIs



Transfer Learning:

Single-stage:

ImageNet - DBT

Multi-stage:

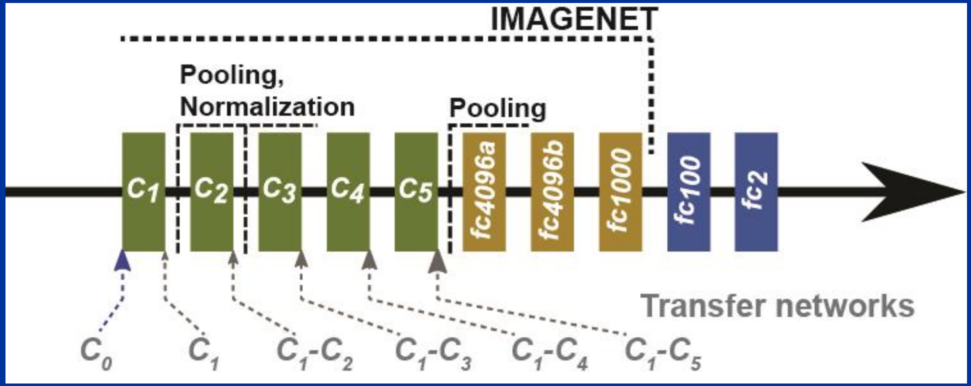
ImageNet - Mammo - DBT

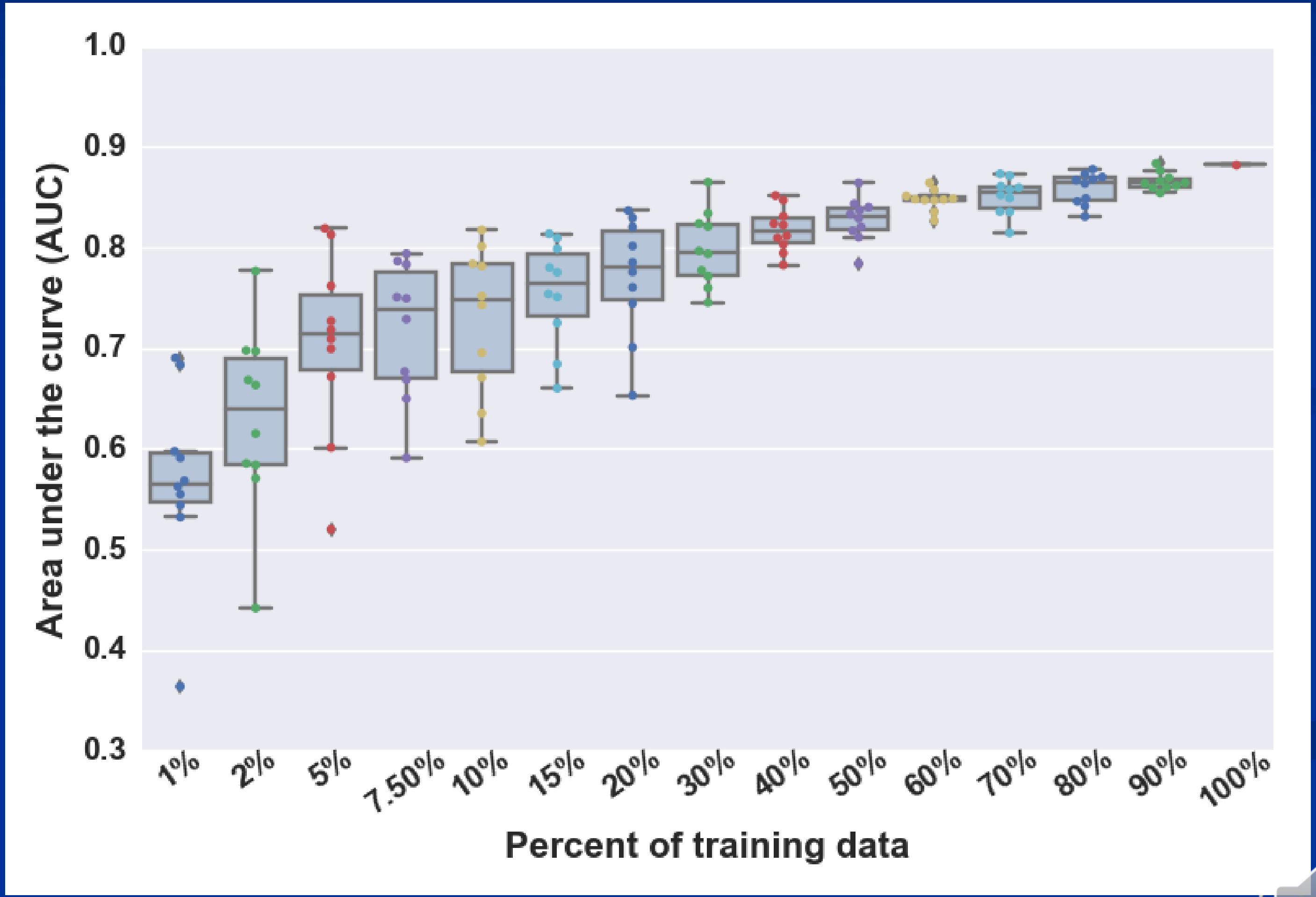
Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C, Cha K, IEEE TMI 2019.

Dependence of DL-CNN performance on data size

Dependence of DL-CNN performance of breast masses on mammography data (100% - 2282 views)

C_1 frozen

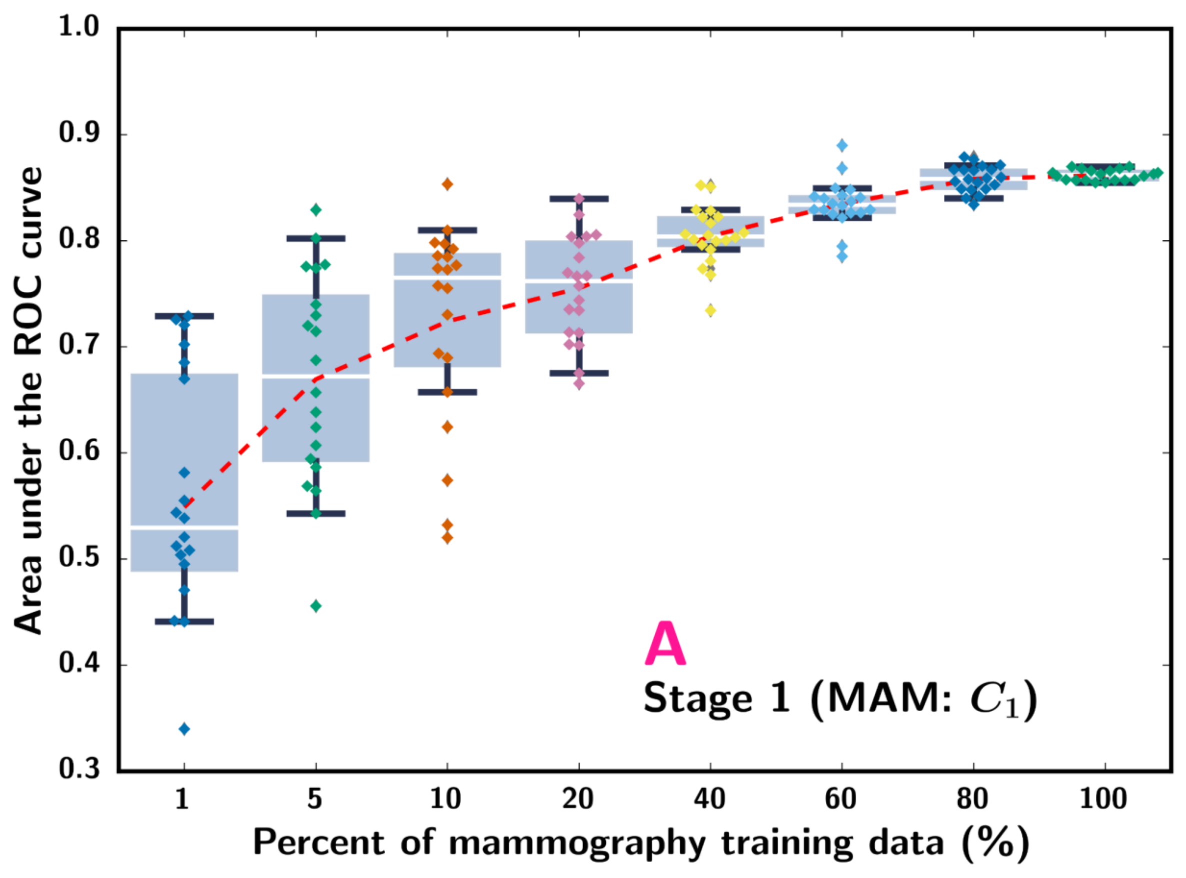


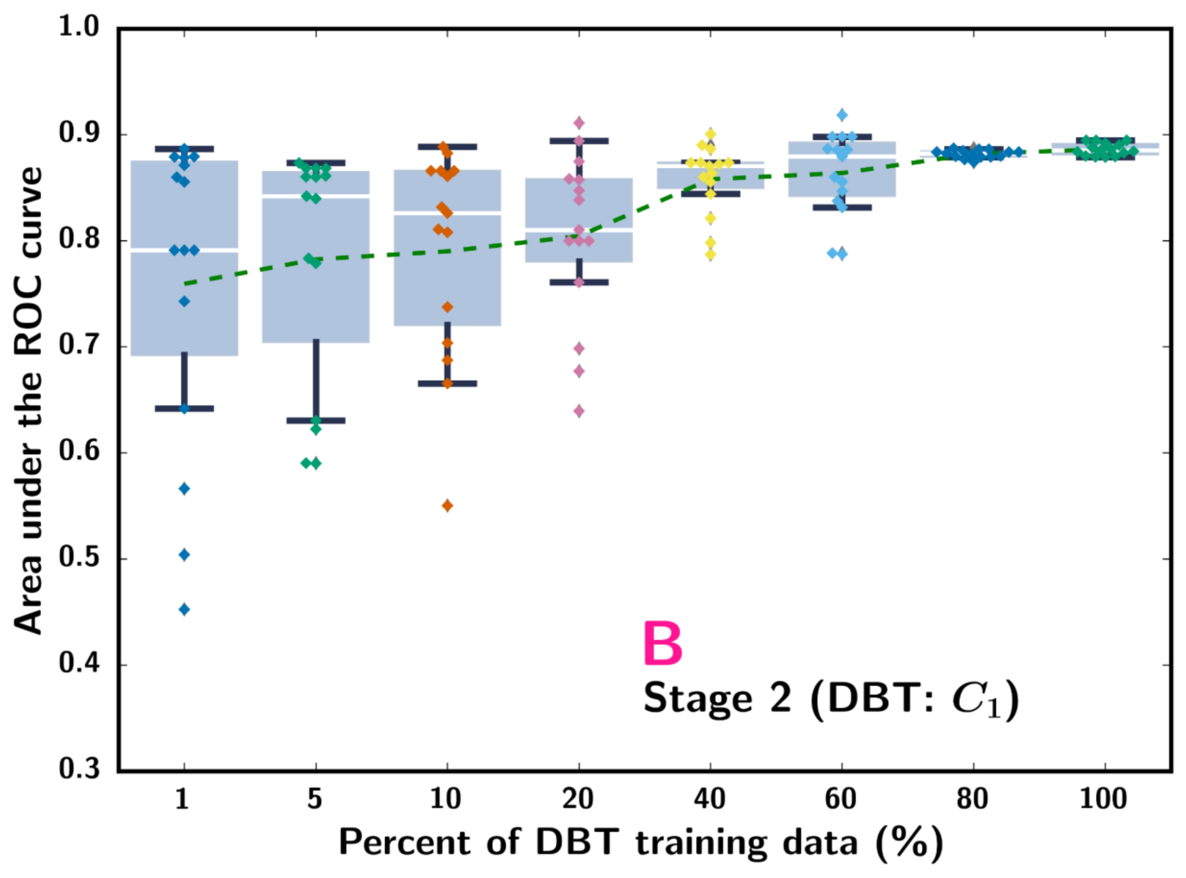


Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C, Cha K, IEEE TMI 2019.

Dependence of DL-CNN performance on data size

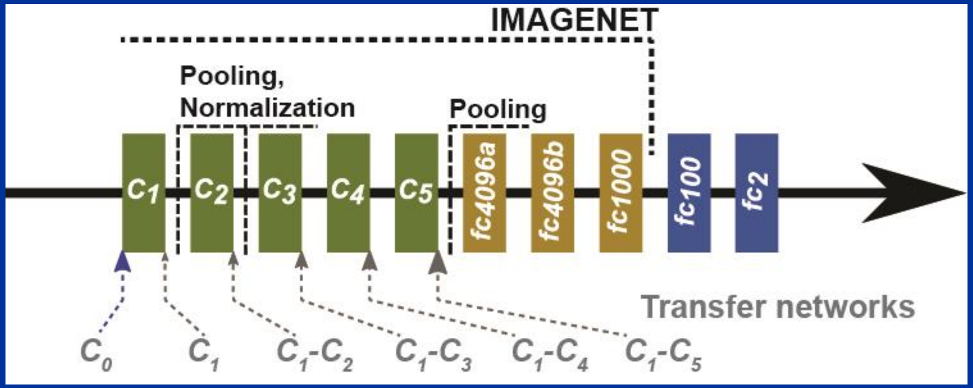
Dependence of DL-CNN performance of breast masses on mammography and DBT data

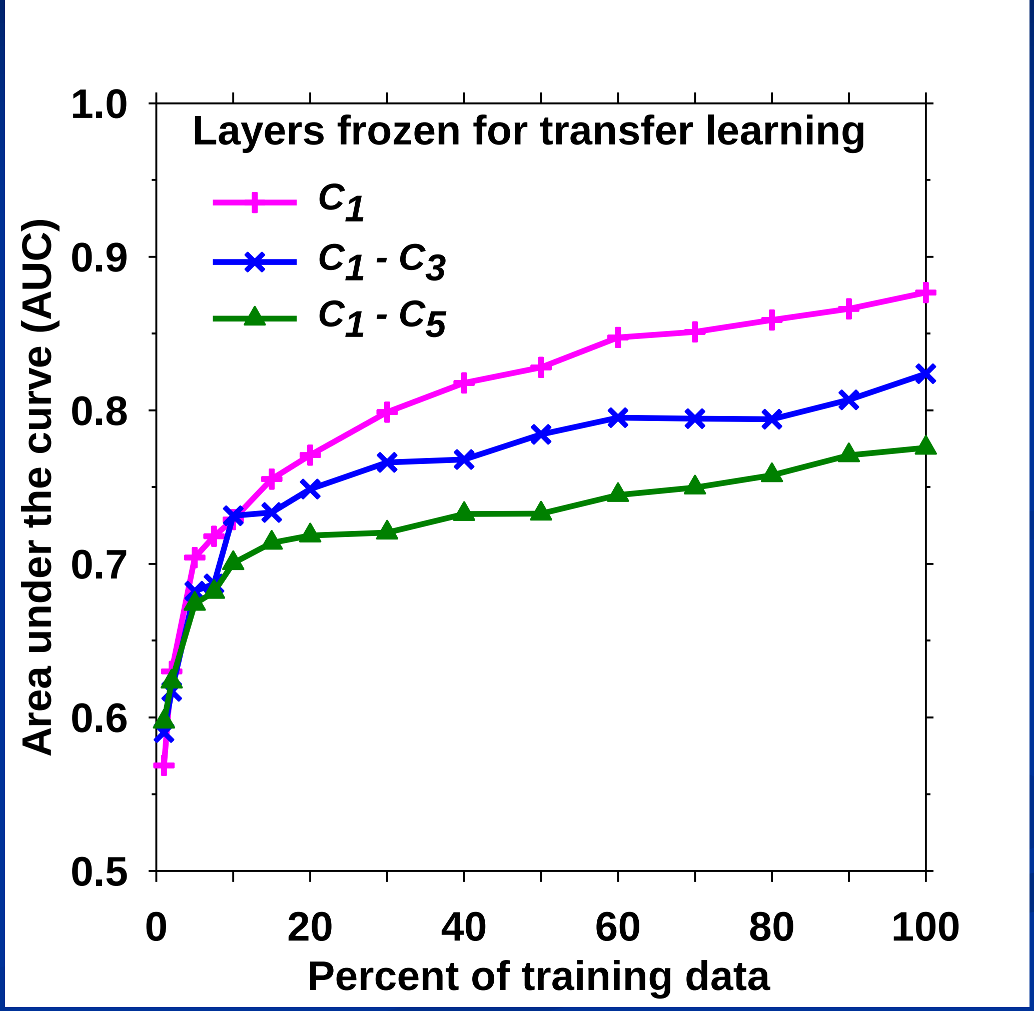




Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C, Cha K, IEEE TMI 2019.

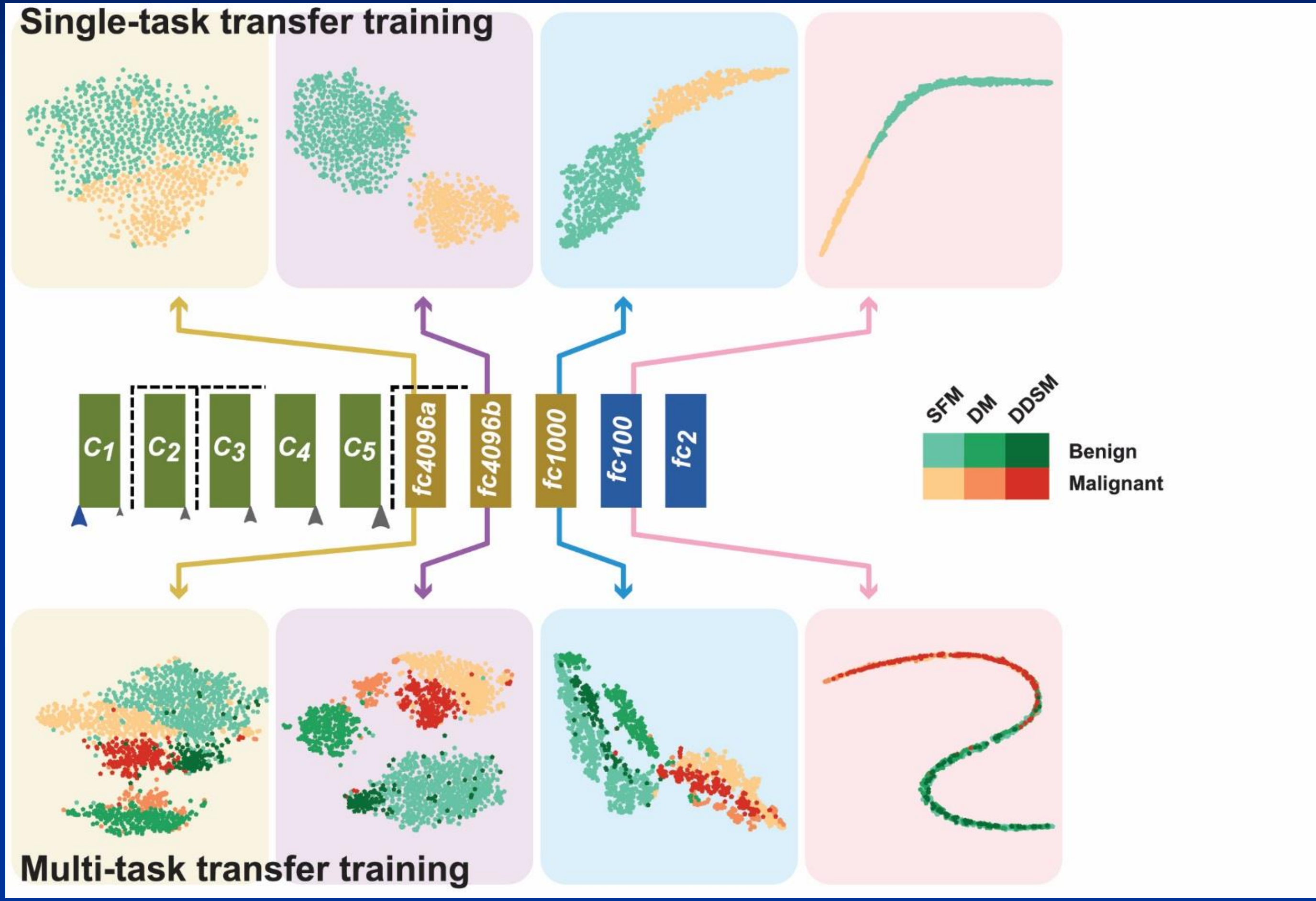
Transfer Learning

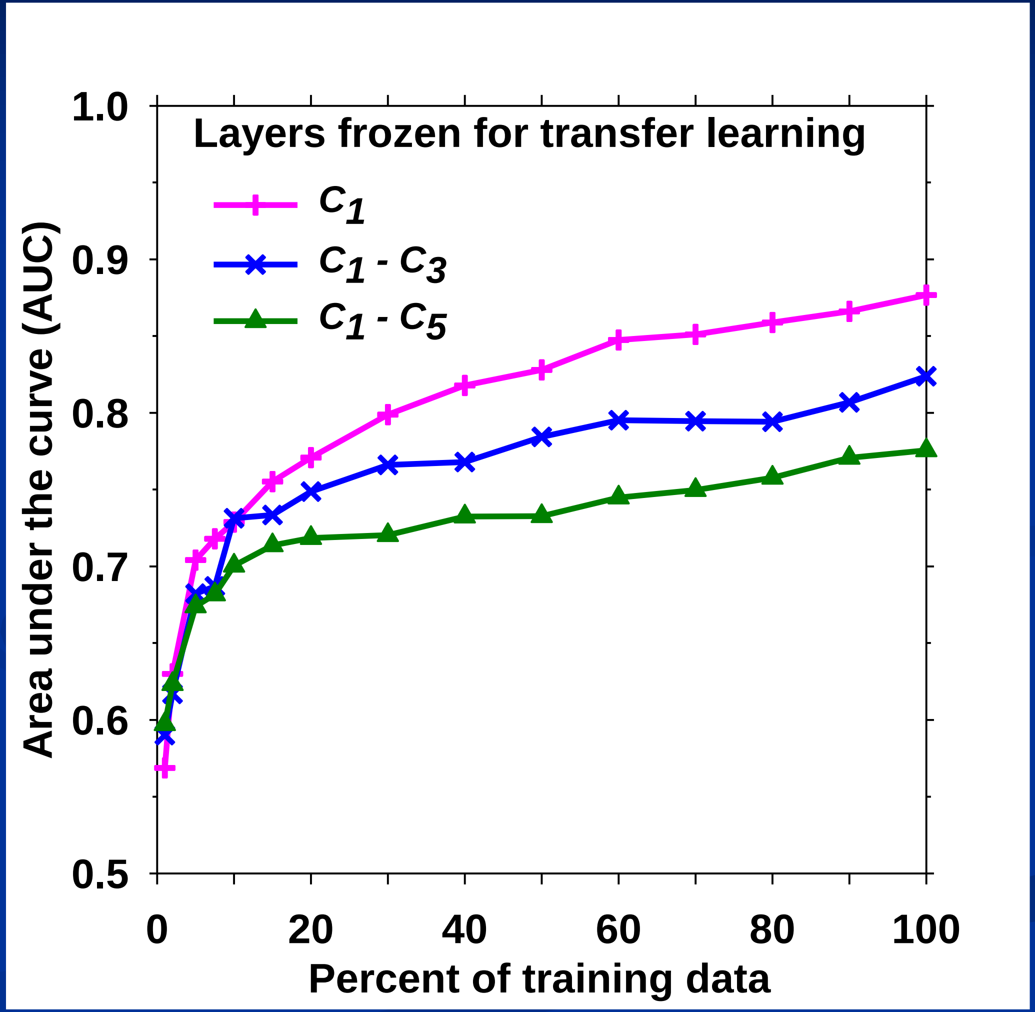




Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C, Cha K, IEEE TMI 2019.

Transfer Learning



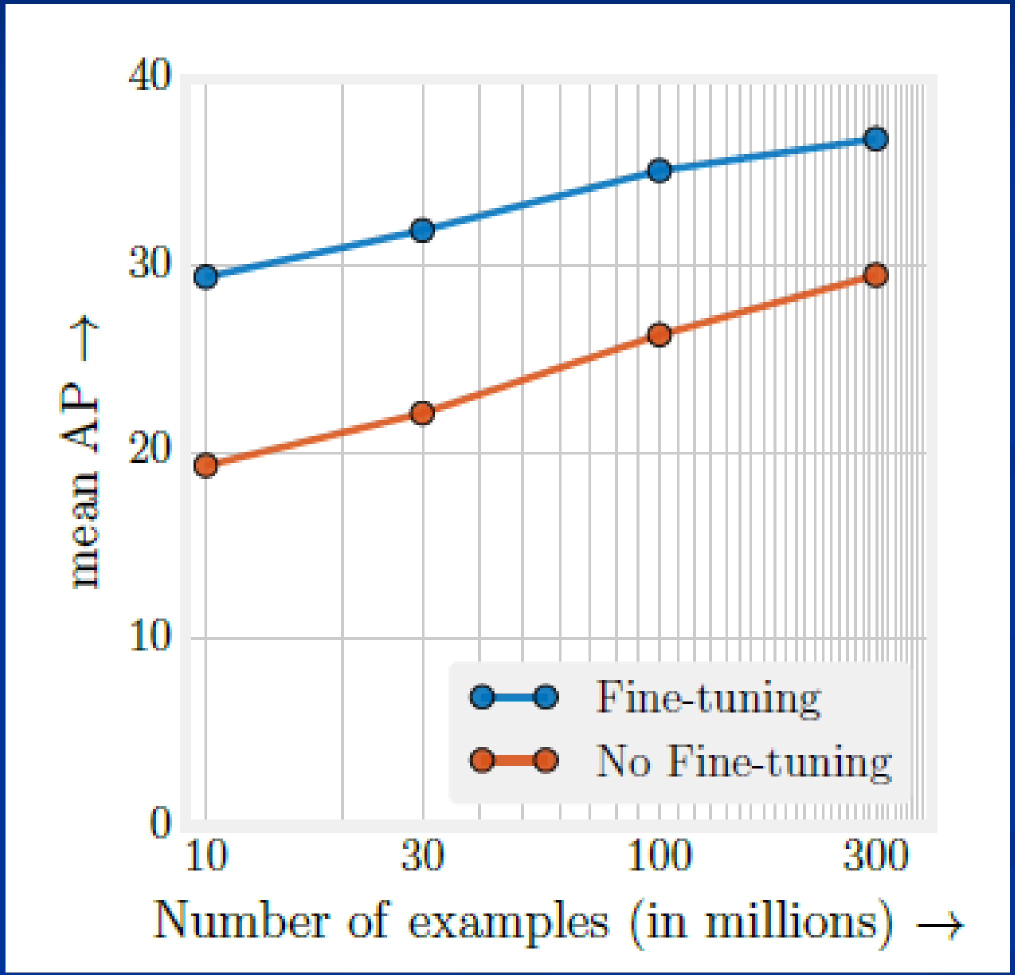


Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Cha K, Richter C. Phys. Med. Biol. 2017.

Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C, Cha K, IEEE TMI 2019.

Quality of Labels

natural scenes images

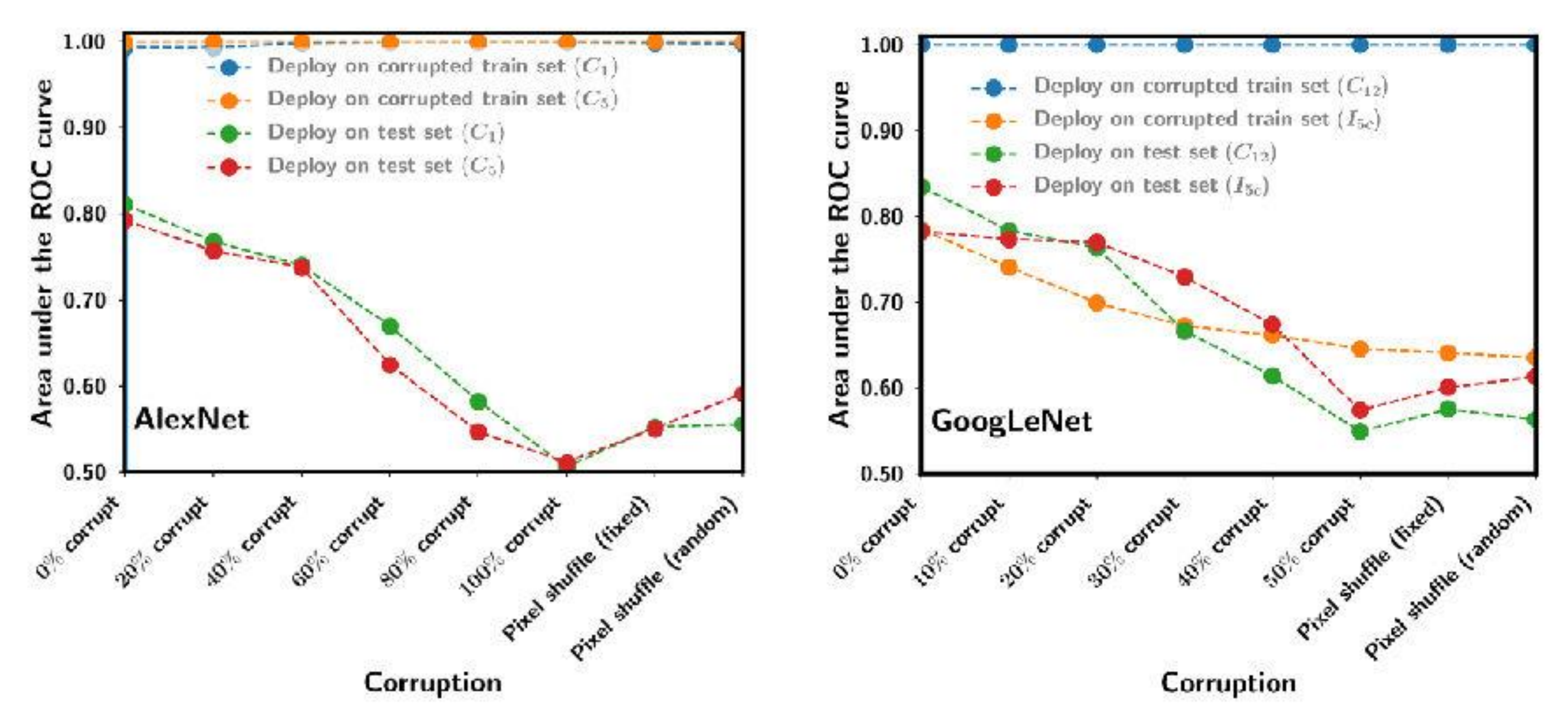


Sun C, et al. arXiv, 2017.

Quality of Labels

Classifying malignant and benign masses on mammograms

AlexNet *GoogLeNet*

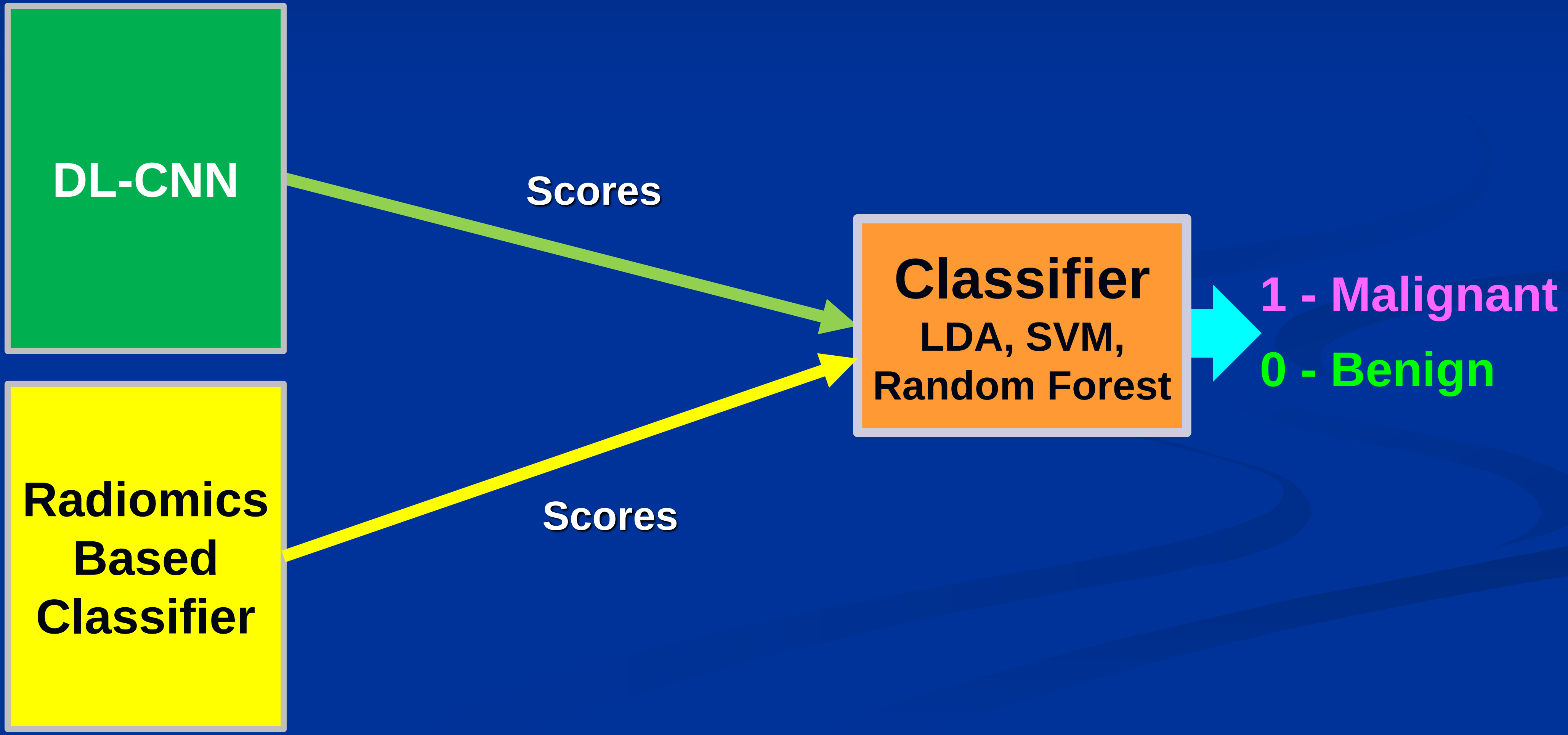


Samala RK, Chan H-P, Hadjiiski L, Helvie MA, Richter C. Phys. Med. Biol. 2020.

Deep Learning Fusion Classifiers

Classifying malignant and benign masses on mammograms

- DL-CNN, Radiomics: Scores Fusion



Deep Learning Fusion Classifiers

Classifying malignant and benign masses on mammograms

- DL-CNN, Radiomics: Feature Fusion

DL-CNN

Features

Radiomics Based Classifier

Features

Classifier
LDA, SVM, Random Forest

1 - Malignant

0 - Benign

AUC:
Radiomics = 0.79
DL-CNN = 0.81
Fusion = 0.86

Antropova N, et al. Medical Physics 2017.

Conclusions

- Deep Learning is promising approach for breast cancer detection and characterization

- Deep Learning extracted features may be useful for breast cancer detection and characterization

Conclusions

- Transfer Learning is important technique for applications with small datasets

- Transfer Learning still needs sufficient data for robust training

Acknowledgments

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Clinical Faculty

Mark Helvie, MD
Marilyn Roubidoux, MD
Chintana Paramagul, MD