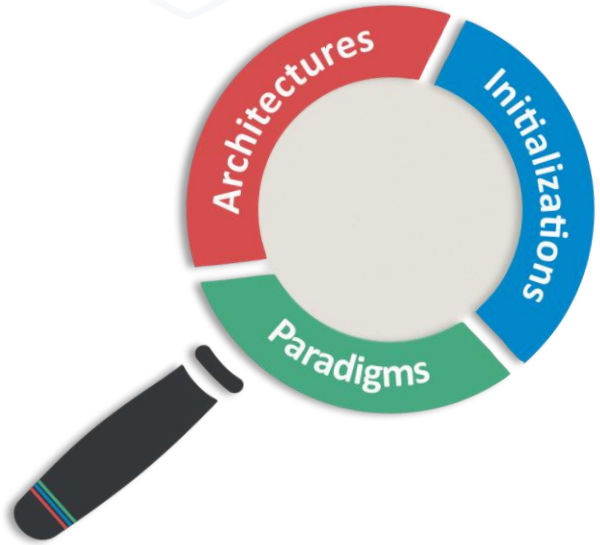
Seeking an Optimal Approach for Computer-aided Pulmonary Embolism Detection

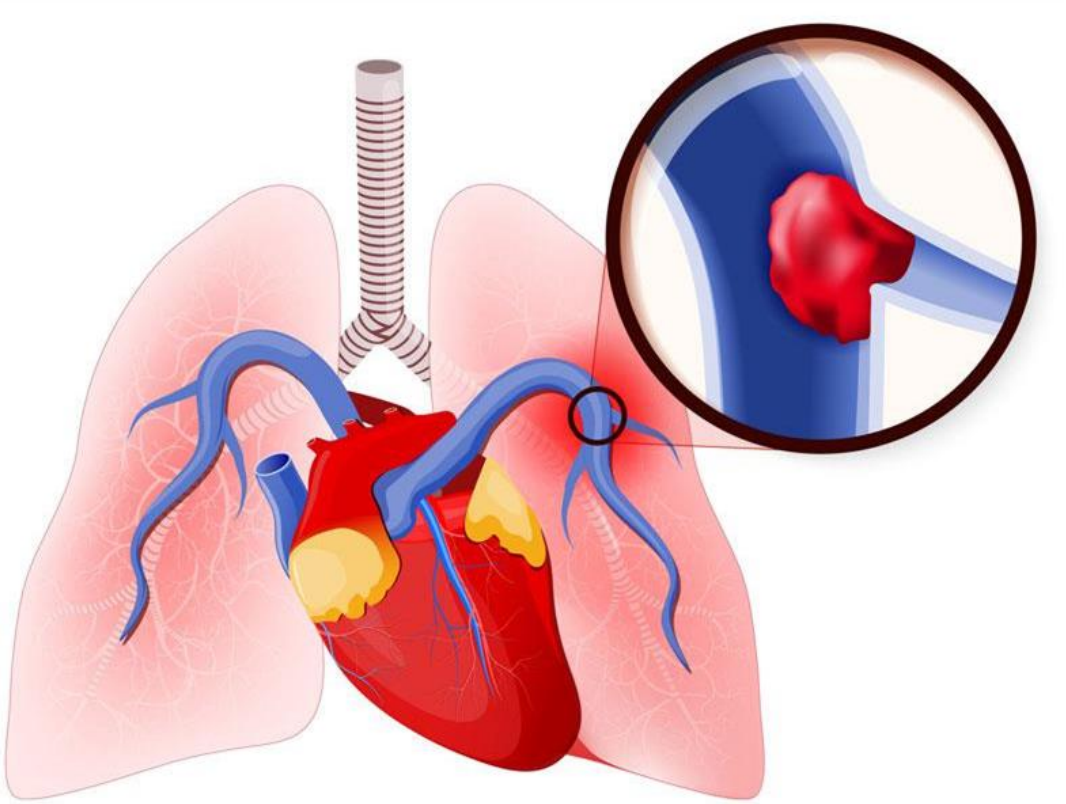


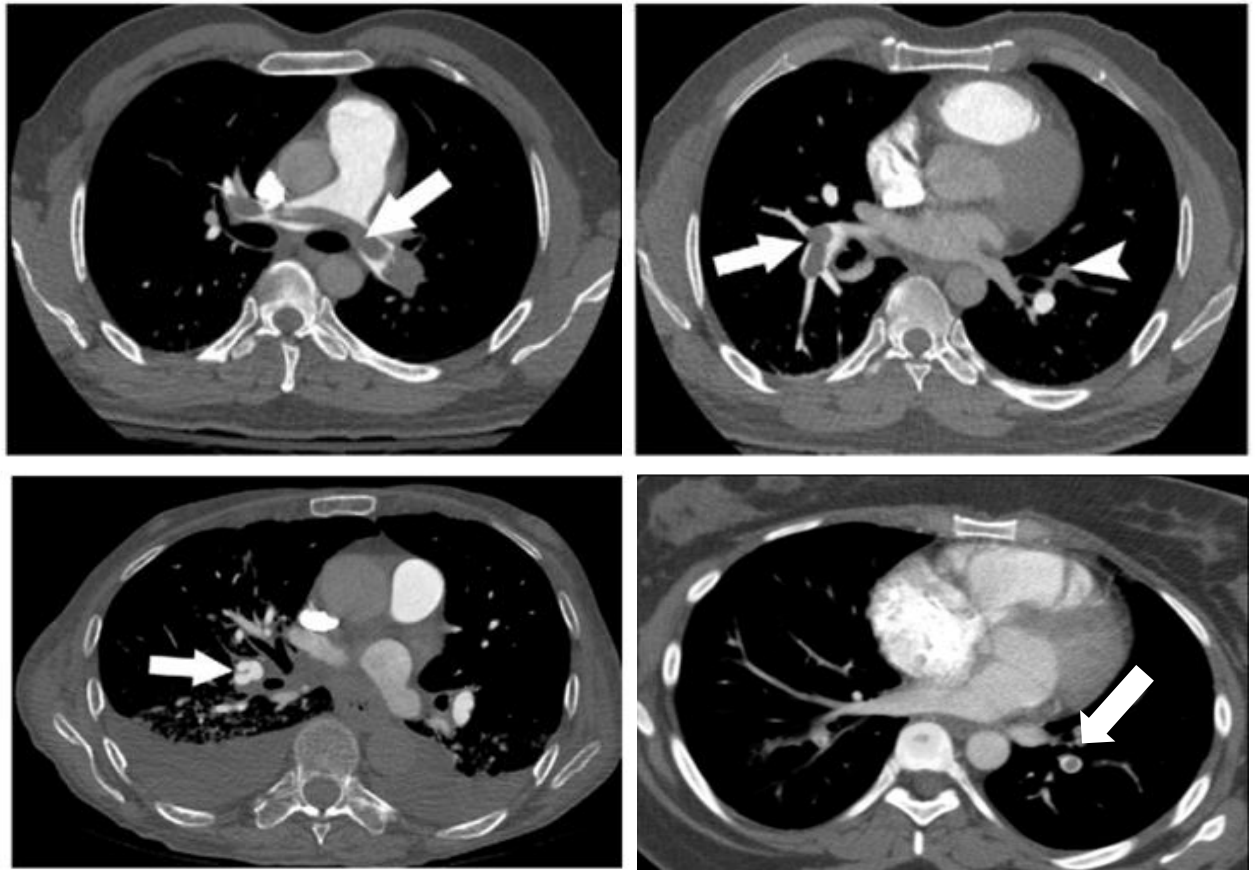
Nahid Ul Islam[1], Shiv Gehlot[1], Zongwei Zhou[1],

Michael B Gotway[2], and Jianming Liang[1]

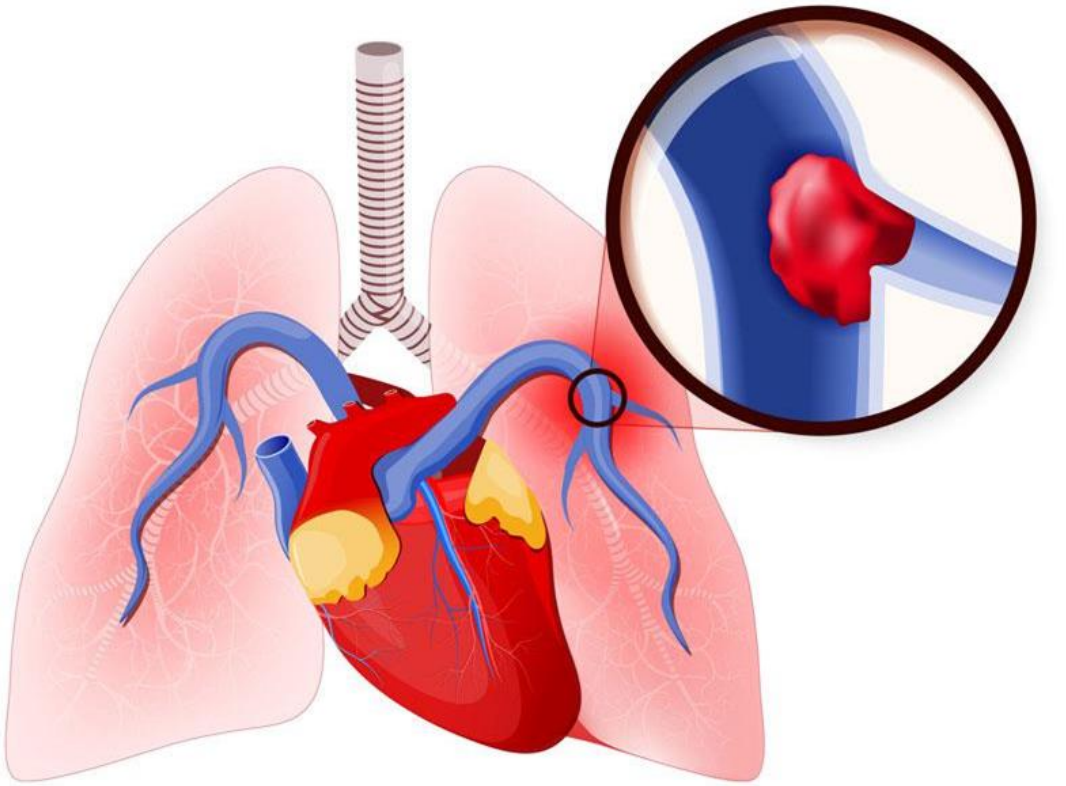
[1]Arizona State University [2]Mayo Clinic

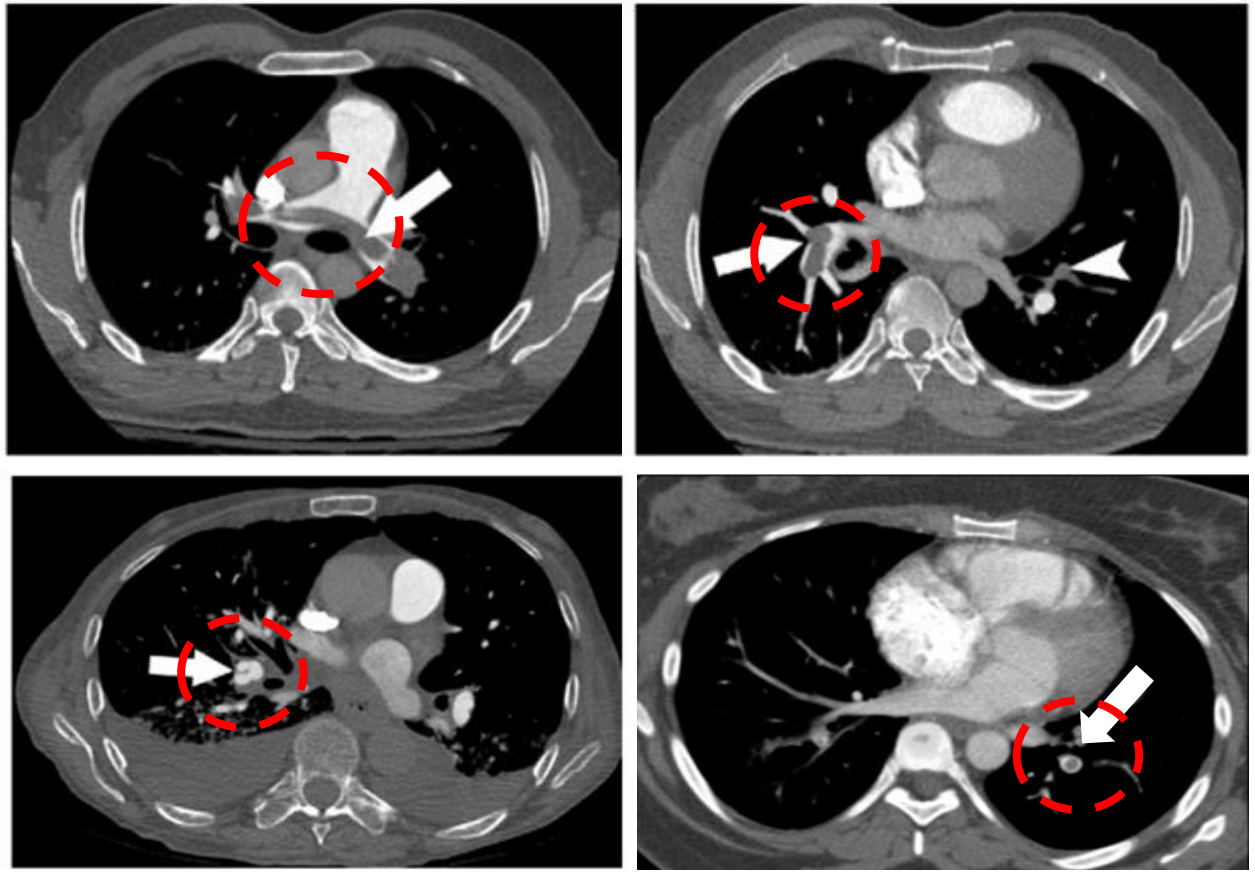
Pulmonary Embolism



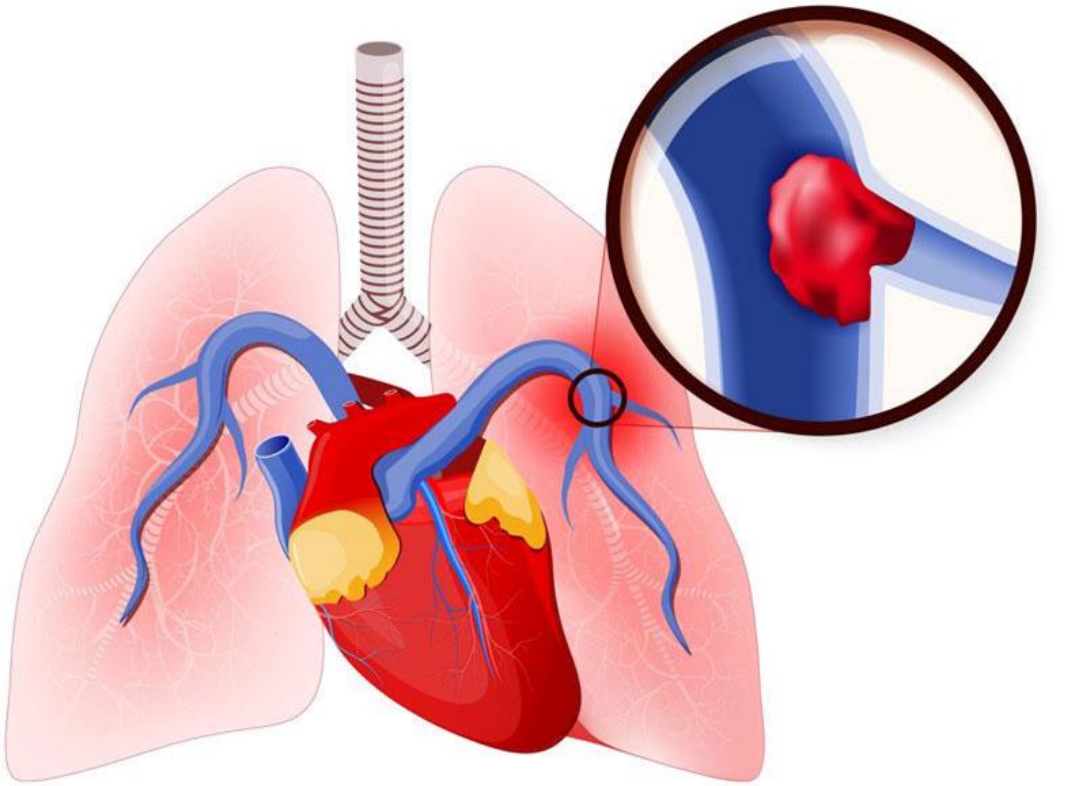


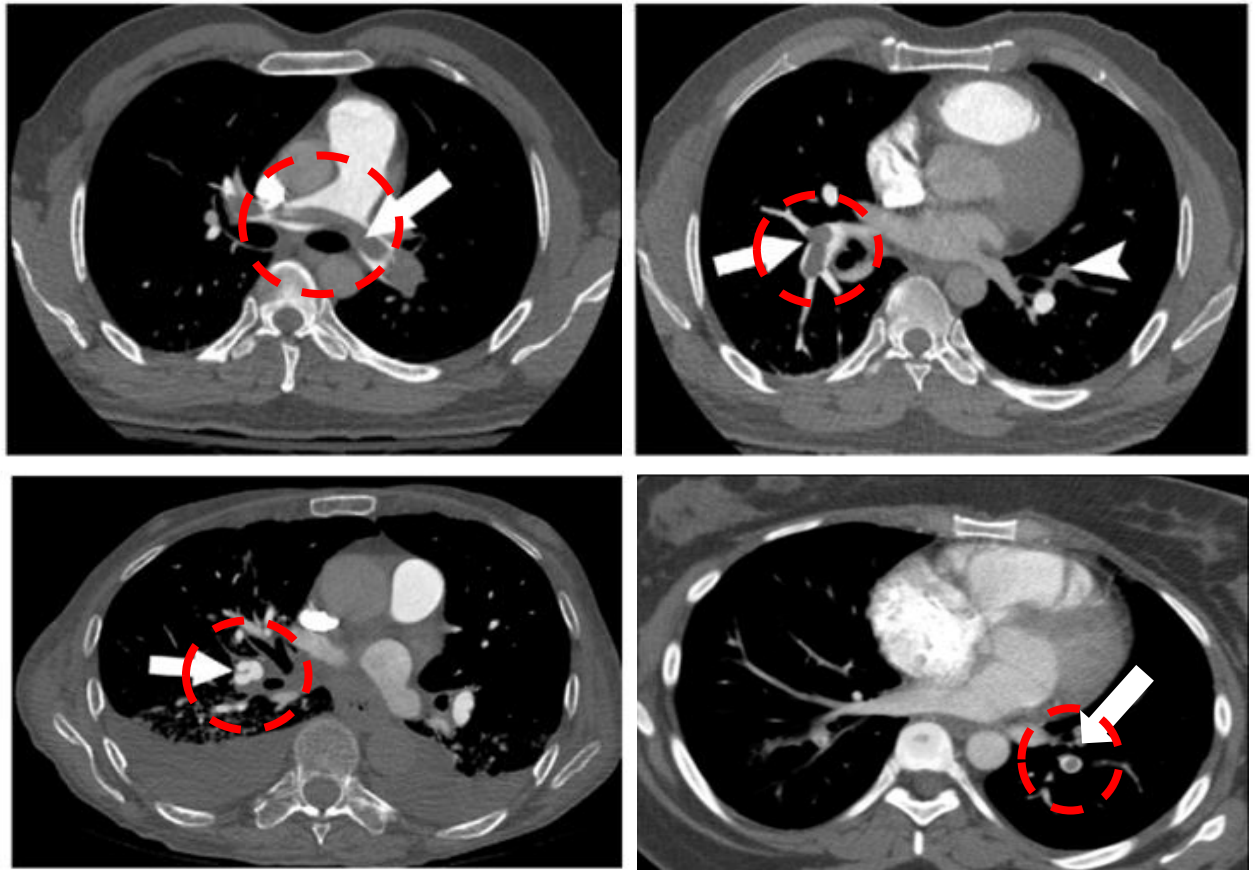
Pulmonary Embolism





Pulmonary Embolism





RSNA Pulmonary Embolism Dataset

Colak, E., Kitamura, F. C., Hobbs, S. B., Wu, C. C., Lungren, M. P., Prevedello, L. M., Kalpathy-Cramer, J., Ball, R. L., Shih, G., Stein, A., Halabi, S. S., Altinmakas, E., Law, M., Kumar, P., Manzalawi, K. A., Nelson Rubio, D. C., Sechrist, J. W., Germaine, P., Lopez, E. C., Amerio, T., … RSNA-STR Annotators and Dataset Curation Contributors (2021). The RSNA Pulmonary Embolism CT Dataset. *Radiology. Artificial intelligence*, *3*(2), e200254. https://doi.org/10.1148/ryai.2021200254

RSNA Pulmonary Embolism Dataset

Exams: 7,279 (with 1,790,624 slices)

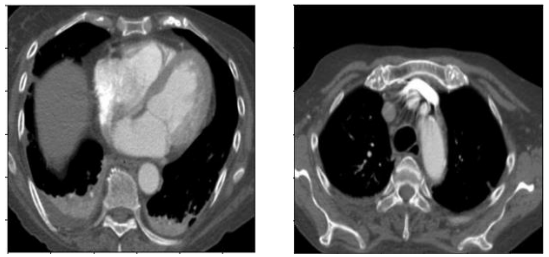
Colak, E., Kitamura, F. C., Hobbs, S. B., Wu, C. C., Lungren, M. P., Prevedello, L. M., Kalpathy-Cramer, J., Ball, R. L., Shih, G., Stein, A., Halabi, S. S., Altinmakas, E., Law, M., Kumar, P., Manzalawi, K. A., Nelson Rubio, D. C., Sechrist, J. W., Germaine, P., Lopez, E. C., Amerio, T., ... RSNA-STR Annotators and Dataset Curation Contributors (2021). The RSNA Pulmonary Embolism CT Dataset. *Radiology. Artificial intelligence*, *3*(2), e200254. https://doi.org/10.1148/ryai.2021200254

RSNA Pulmonary Embolism Dataset

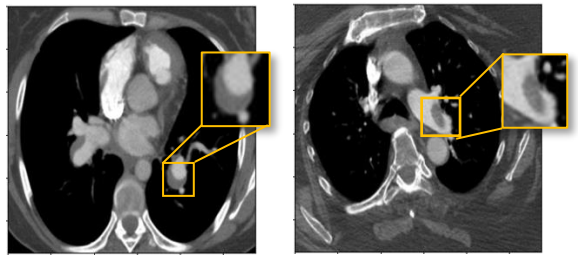
Exams: 7,279 (with 1,790,624 slices)

Ground Truth

1. PE present or not



PE absent



PE present

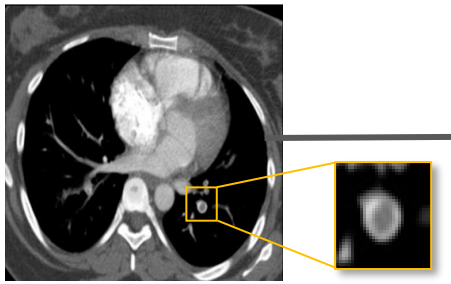
Ground Truth

1. Negative Exam for PE
2. Indeterminate
3. Chronic PE
4. Acute & Chronic PE
5. Central PE
6. Left PE
7. Right PE
8. RV LV Ratio > 1
9. RV LV Ratio < 1

Colak, E., Kitamura, F. C., Hobbs, S. B., Wu, C. C., Lungren, M. P., Prevedello, L. M., Kalpathy-Cramer, J., Ball, R. L., Shih, G., Stein, A., Halabi, S. S., Altinmakas, E., Law, M., Kumar, P., Manzalawi, K. A., Nelson Rubio, D. C., Sechrist, J. W., Germaine, P., Lopez, E. C., Amerio, T., … RSNA-STR Annotators and Dataset Curation Contributors (2021). The RSNA Pulmonary Embolism CT Dataset. *Radiology. Artificial intelligence*, *3*(2), e200254. https://doi.org/10.1148/ryai.2021200254

RSNA Pulmonary Embolism Dataset

Exams: 7,279 (with 1,790,624 slices)



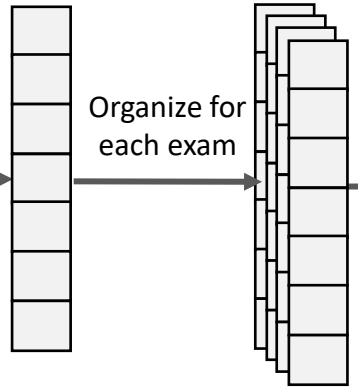
Input image

1

Slice-level Classification

Ground Truth

1. PE present or not



Feature vector

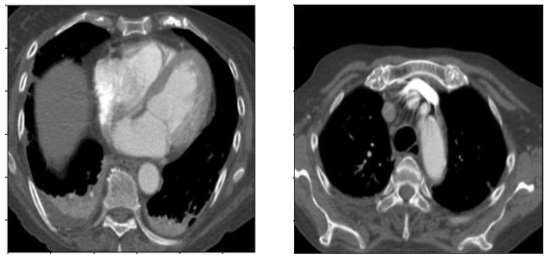
Organize for each exam

2

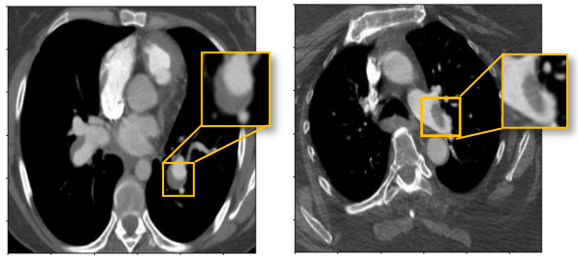
Exam-level Classification

Ground Truth

1. Negative Exam for PE
2. Indeterminate
3. Chronic PE
4. Acute & Chronic PE
5. Central PE
6. Left PE
7. Right PE
8. RV LV Ratio > 1
9. RV LV Ratio < 1



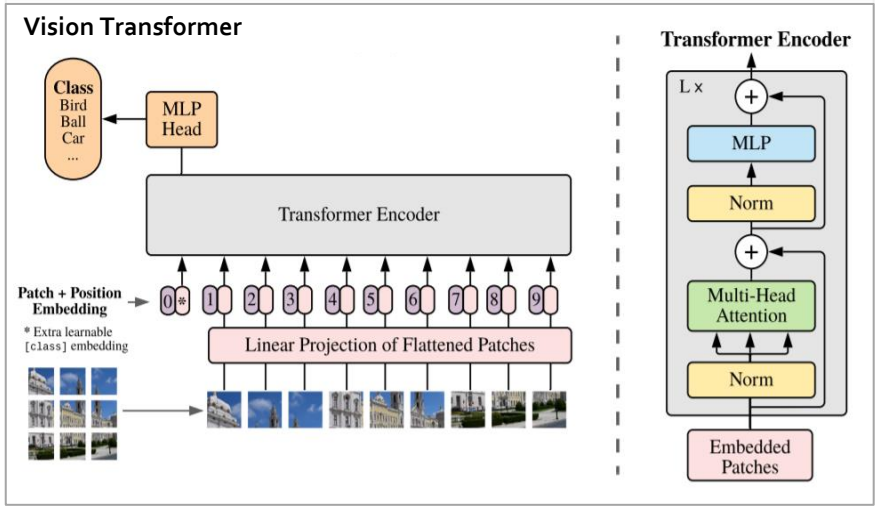
PE absent



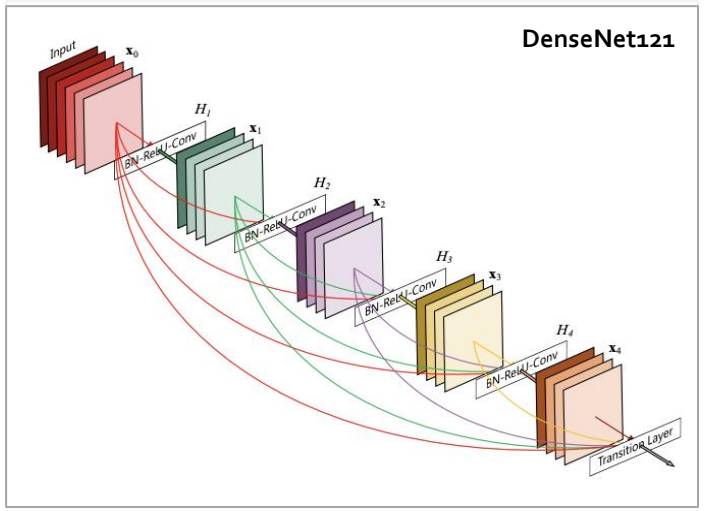
PE present

Colak, E., Kitamura, F. C., Hobbs, S. B., Wu, C. C., Lungren, M. P., Prevedello, L. M., Kalpathy-Cramer, J., Ball, R. L., Shih, G., Stein, A., Halabi, S. S., Altinmakas, E., Law, M., Kumar, P., Manzalawi, K. A., Nelson Rubio, D. C., Sechrist, J. W., Germaine, P., Lopez, E. C., Amerio, T., … RSNA-STR Annotators and Dataset Curation Contributors (2021). The RSNA Pulmonary Embolism CT Dataset. *Radiology. Artificial intelligence*, *3*(2), e200254. https://doi.org/10.1148/ryai.2021200254

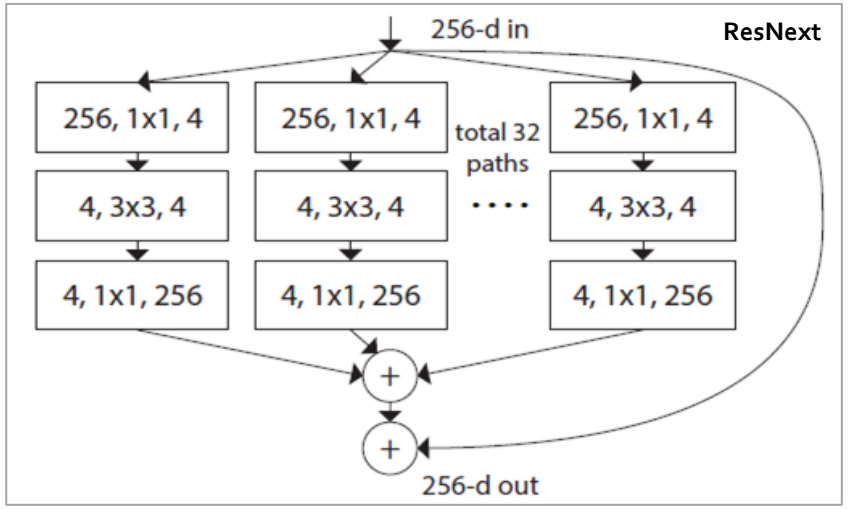
Vision Transformer



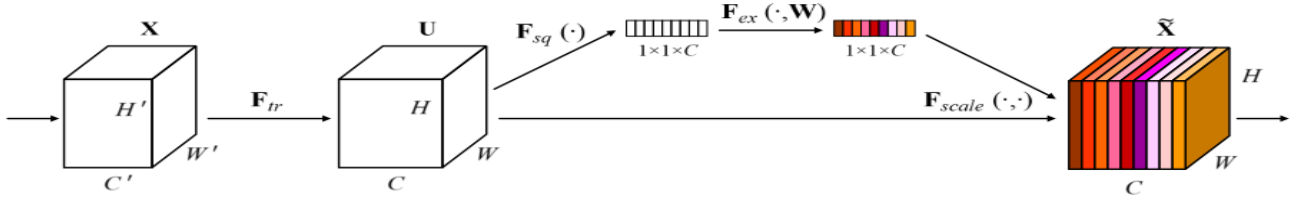
DenseNet121



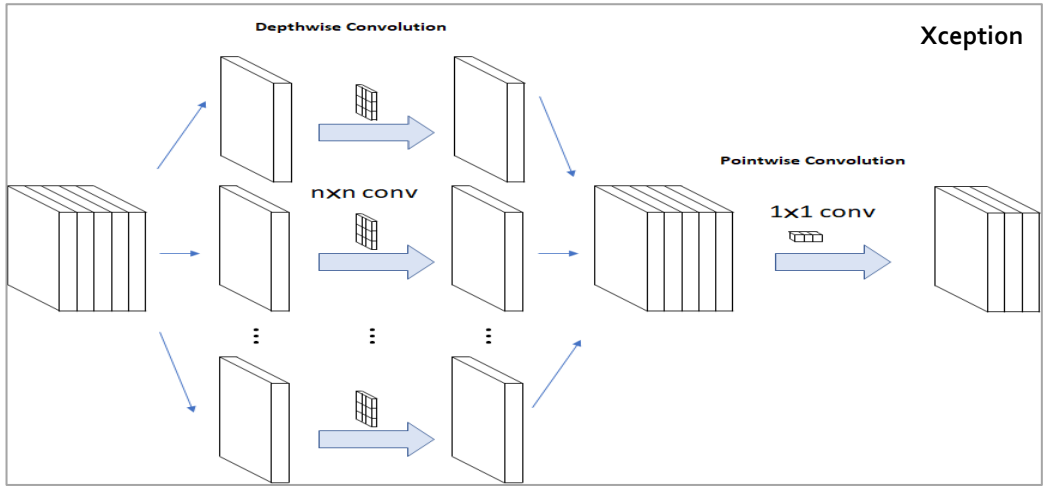
ResNext



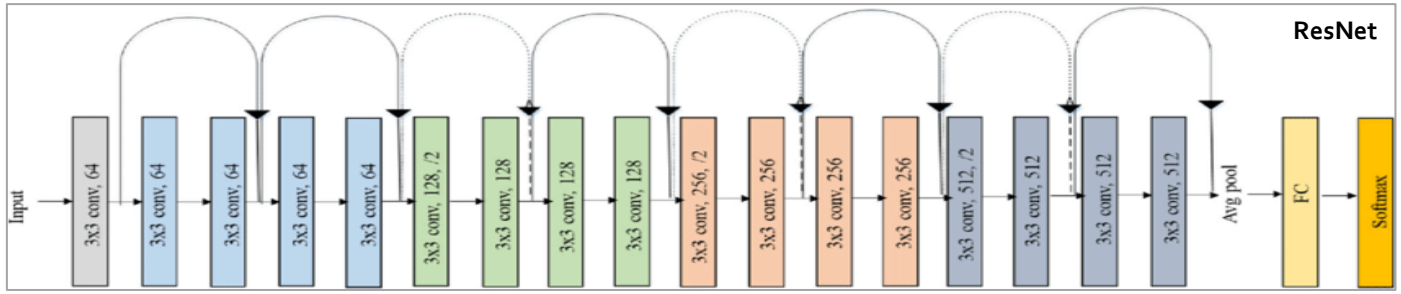
Squeeze & Excitation Block



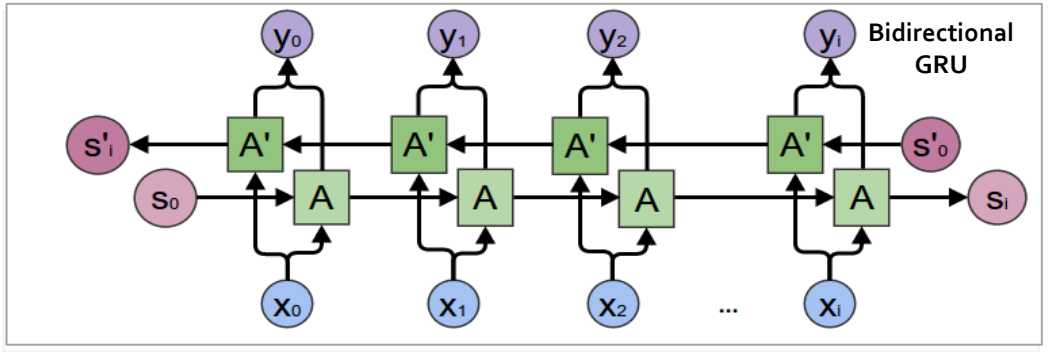
Xception

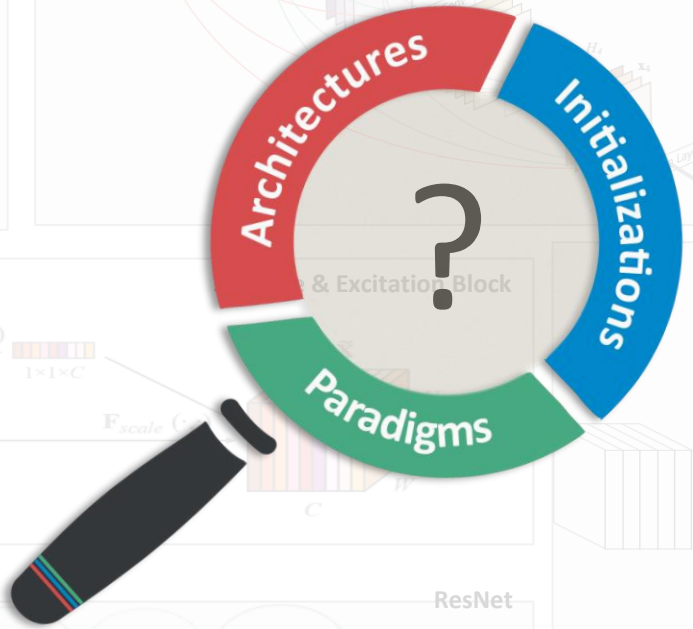


ResNet



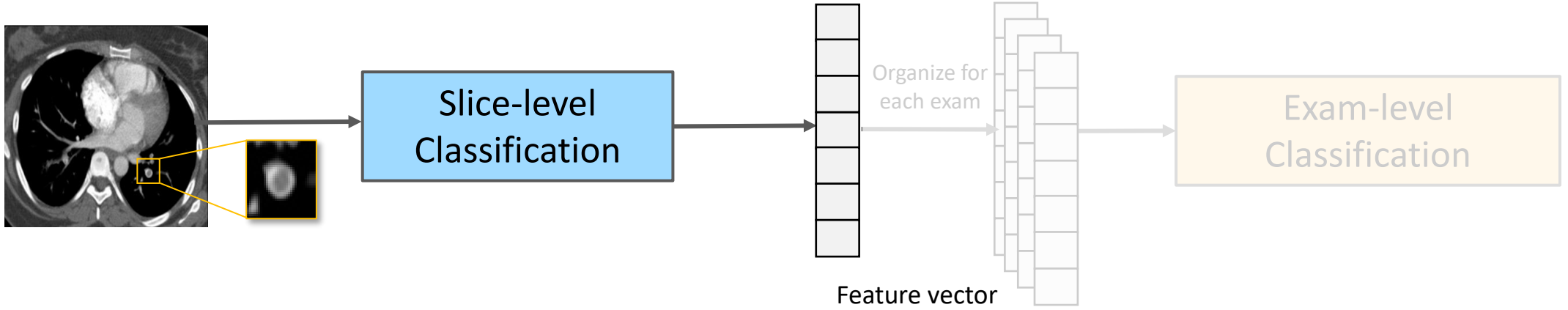
Bidirectional GRU



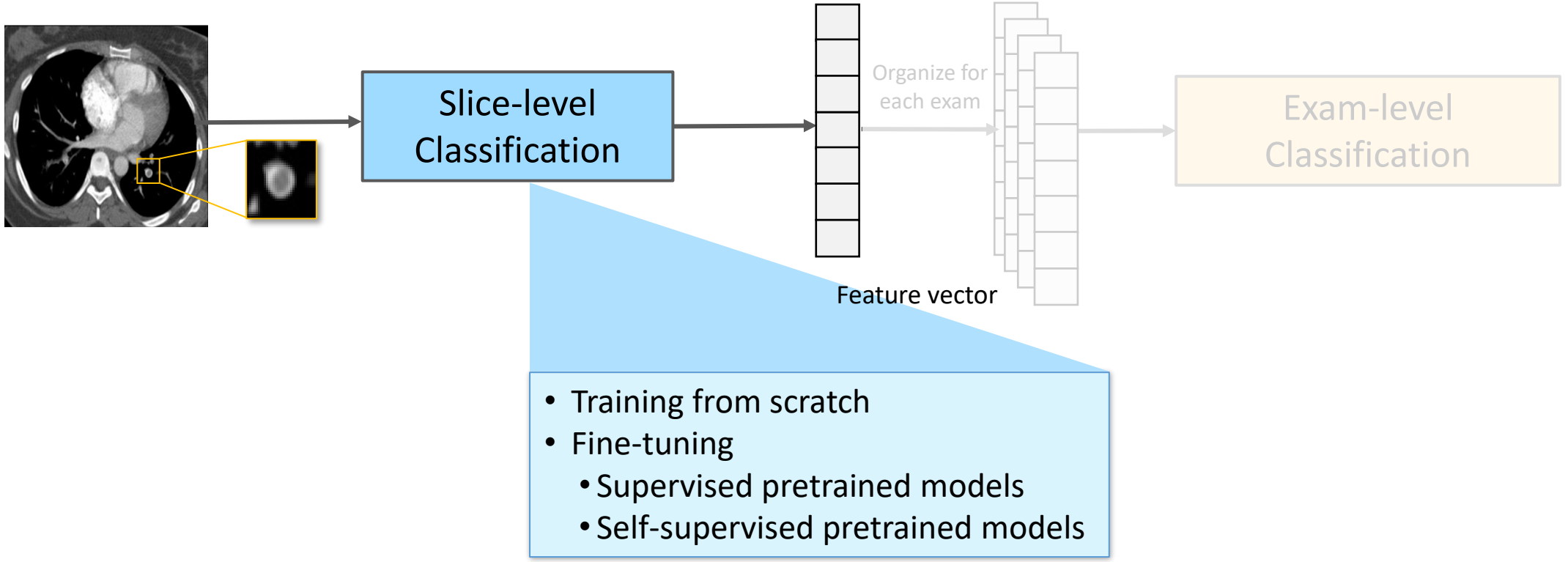


for computer-aided pulmonary embolism detection

First Stage

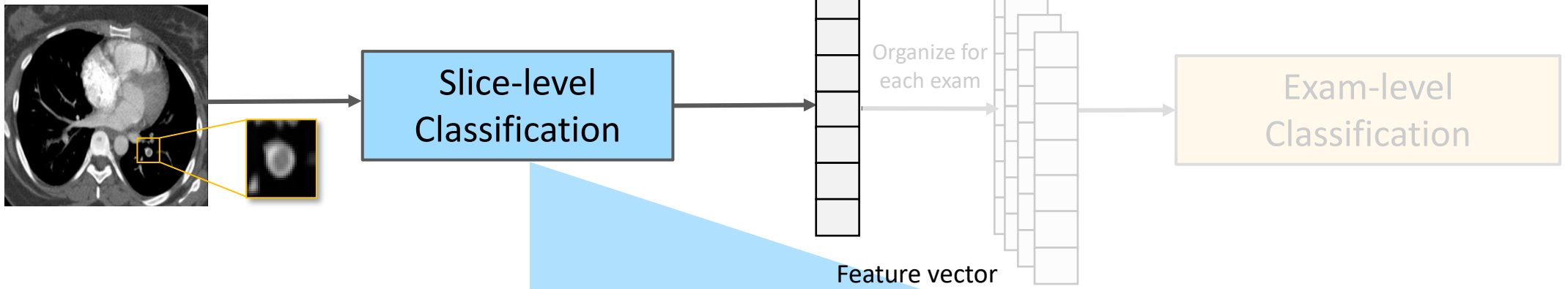

Slice-level Classification
Organize for each exam
Feature vector
Exam-level Classification

First Stage



https://www.kaggle.com/c/rsna-str-pulmonary-embolism-detection/discussion/194145

First Stage



Convolutional Neural Networks

1. ResNet18
2. ResNet50
3. ResNext50
4. SeResNet50
5. SeResNext50
6. DRN-A-50
7. Xception
8. SeXception
9. DenseNet121
10. SeNet154

Vision Transformers

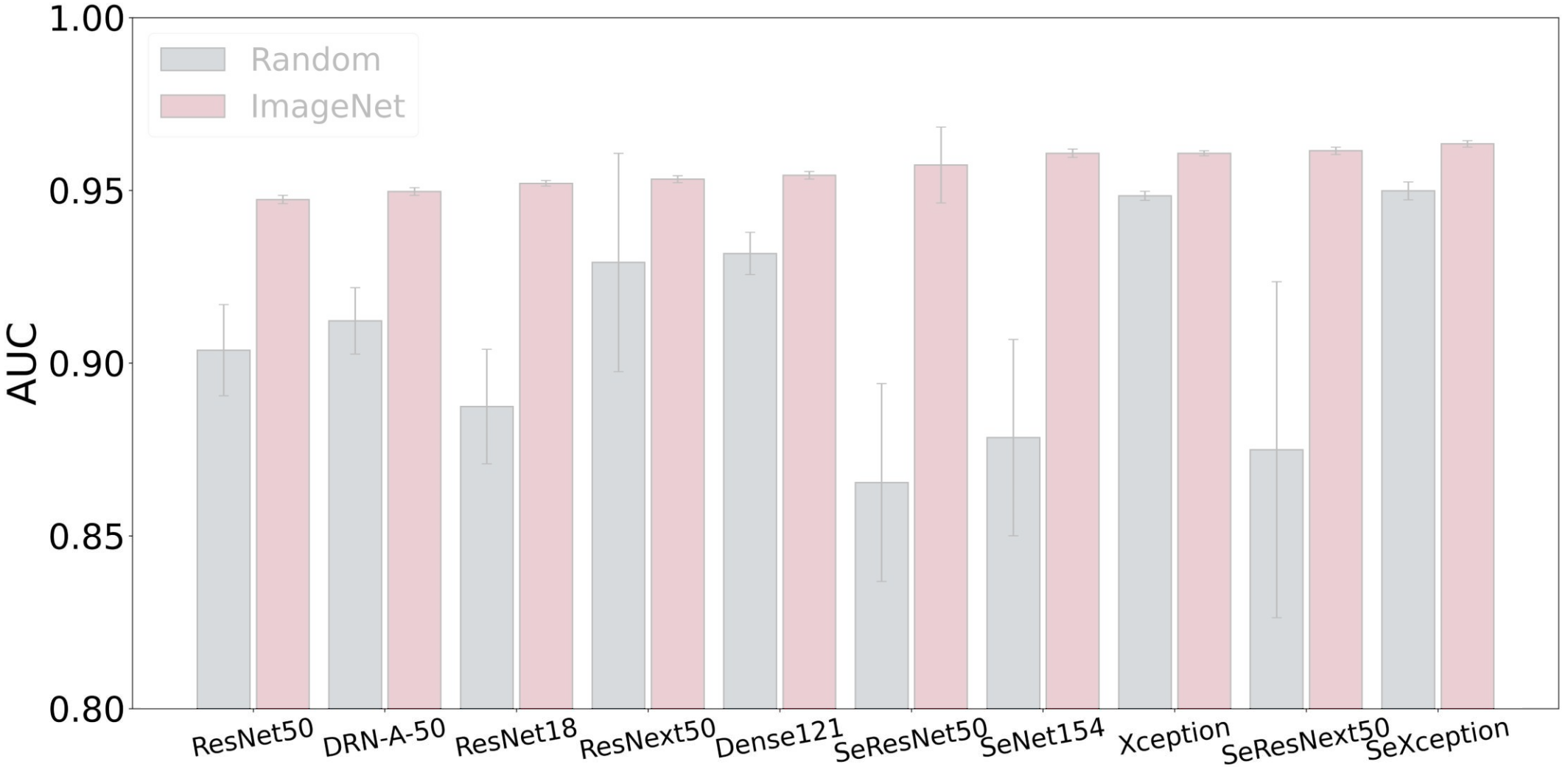
1. ViT-B_16
2. ViT-B_32

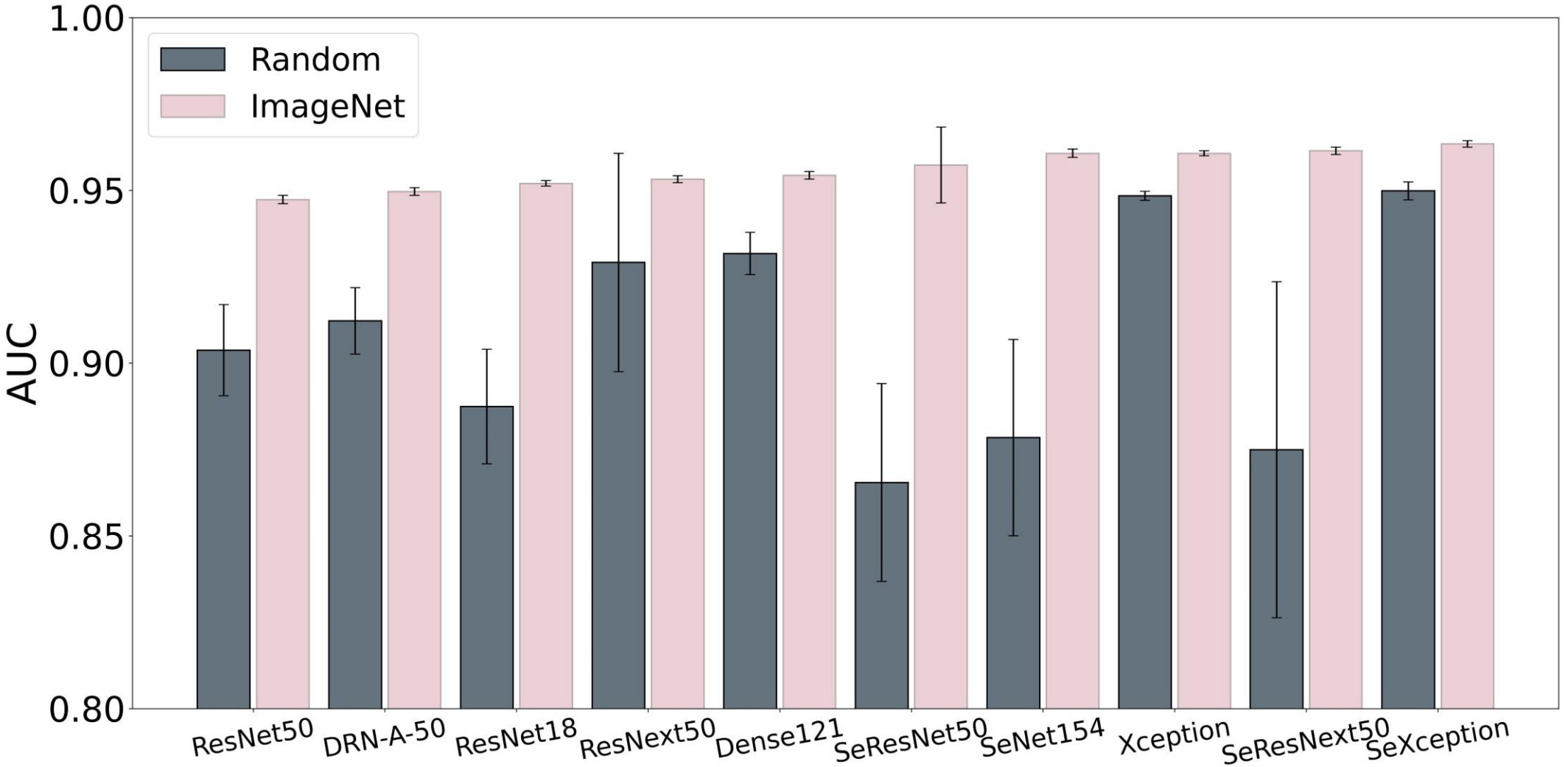
- Training from scratch
- Fine-tuning
  - Supervised pretrained models
  - Self-supervised pretrained models

Self-supervised Methods

1. InsDis
2. InfoMin
3. MoCo-v1
4. BYOL
5. MoCo-v2
6. DeepCluster-v2
7. PCL-v1
8. SwAV
9. PCL-v2
10. SimCLR-v1
11. PIRL
12. SimCLR-v2
13. SeLa-v2
14. Barlow Twins

https://www.kaggle.com/c/rsna-str-pulmonary-embolism-detection/discussion/194145


1.00
0.95
0.90
0.85
0.80
AUC
Random
ImageNet
ResNet50
DRN-A-50
ResNet18
ResNext50
Dense121
SeResNet50
SeNet154
Xception
SeResNext50
SeXception


1.00
0.95
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AUC
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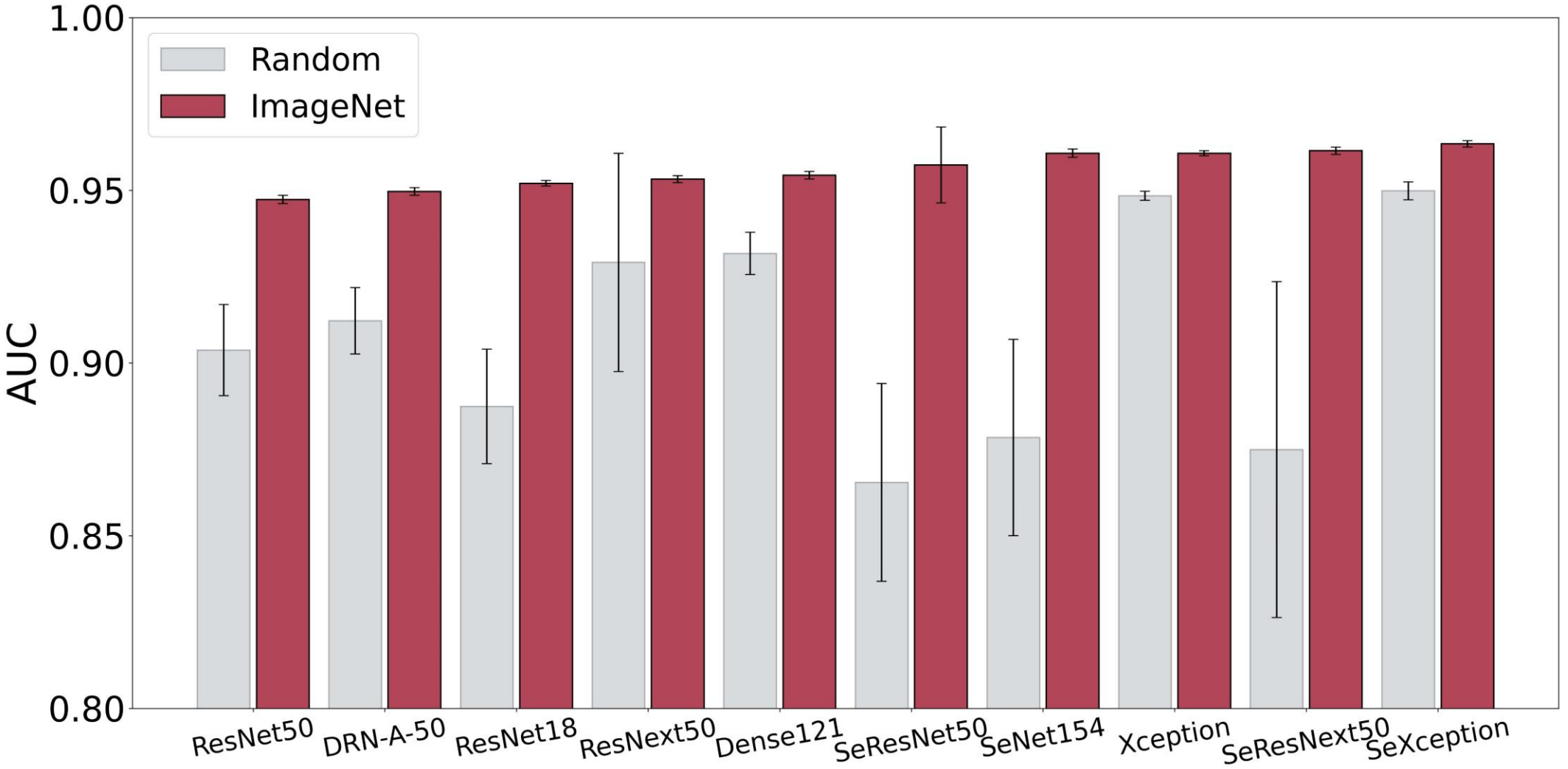
1.00
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AUC
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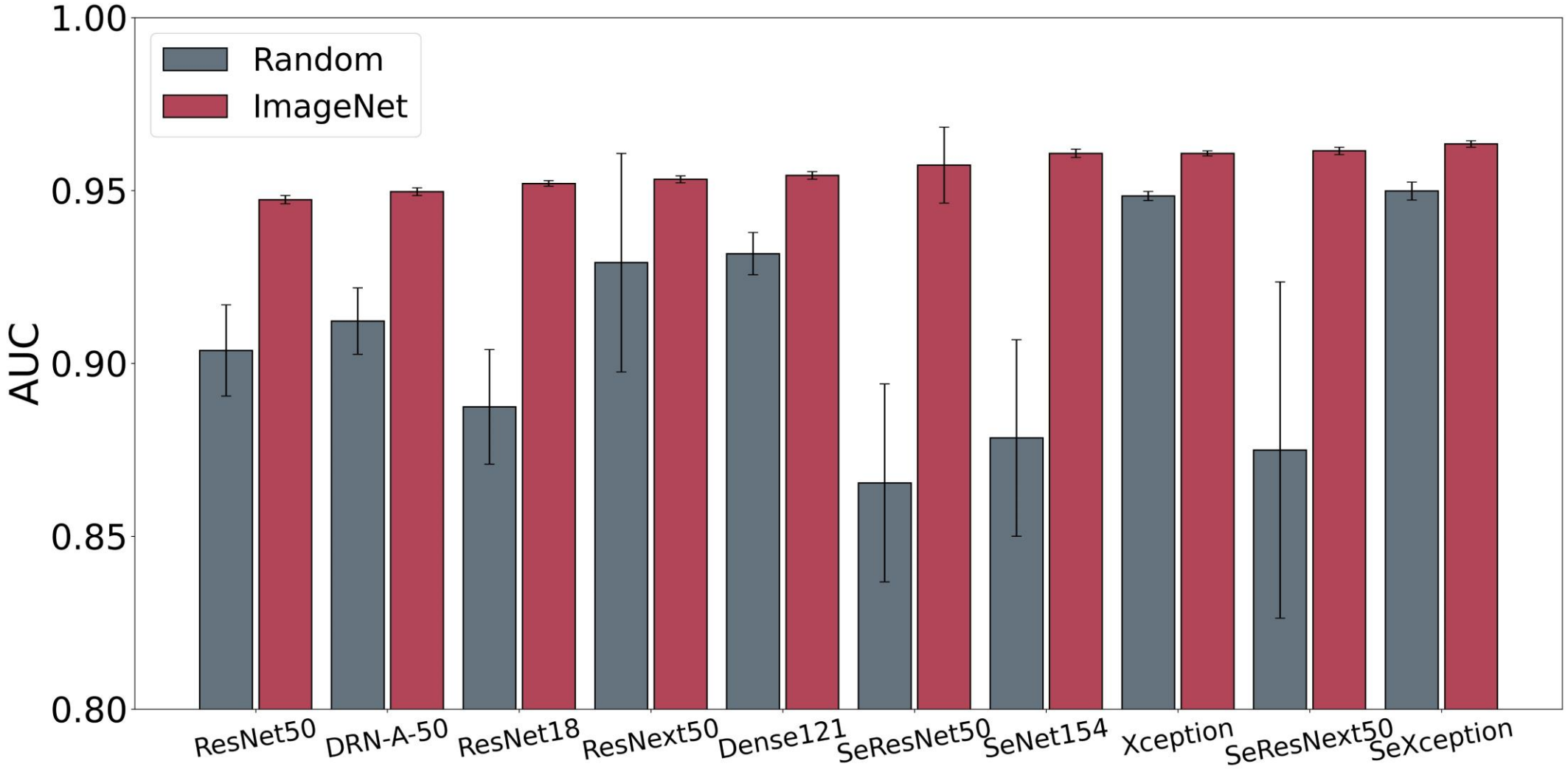
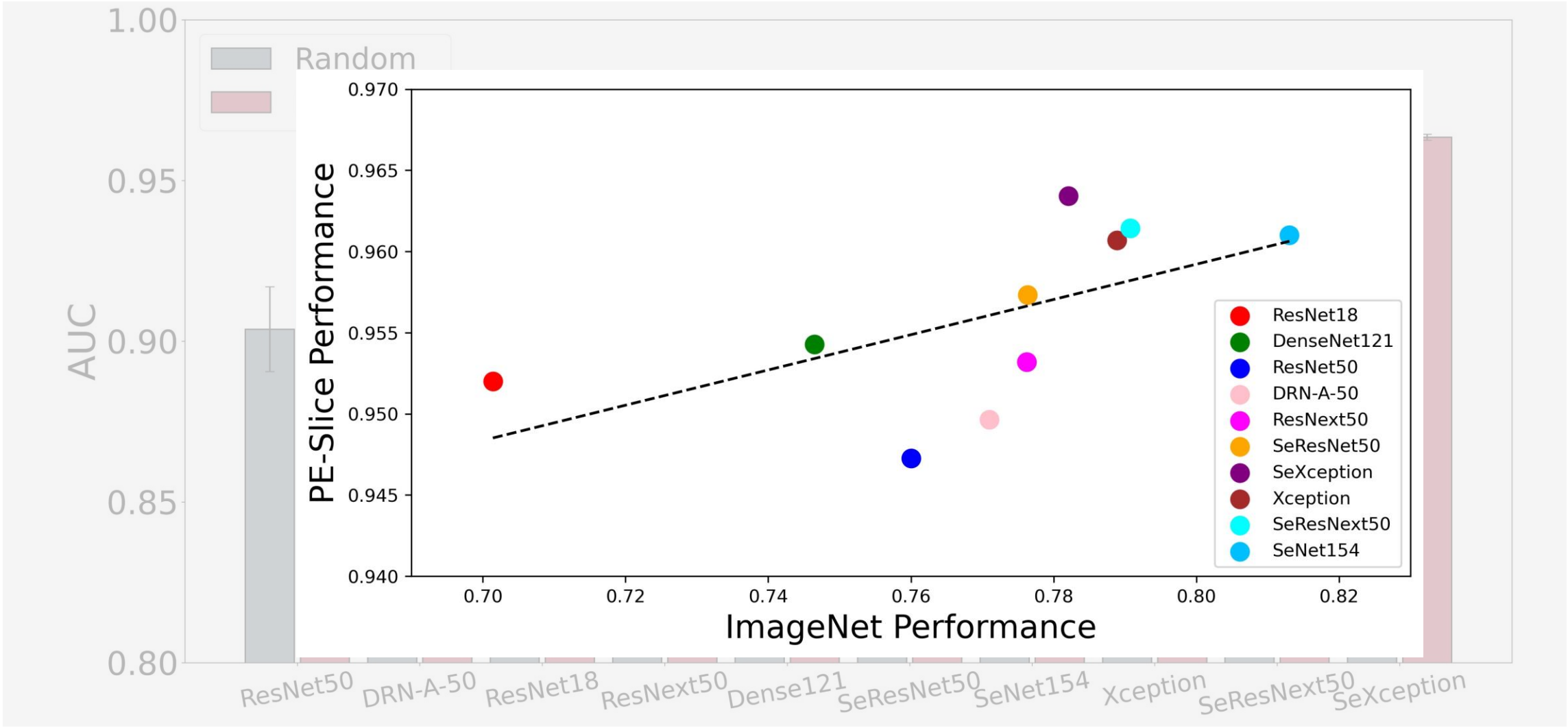
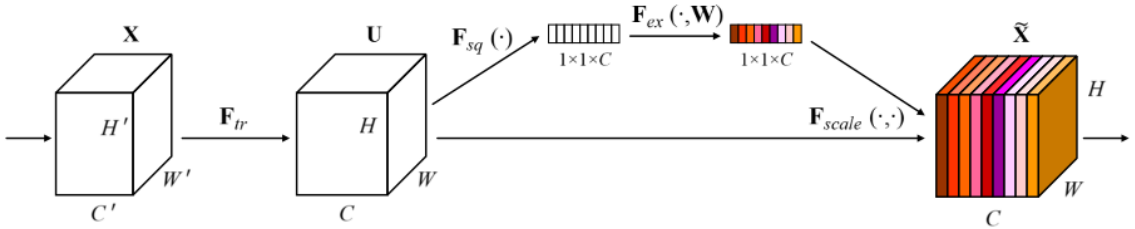
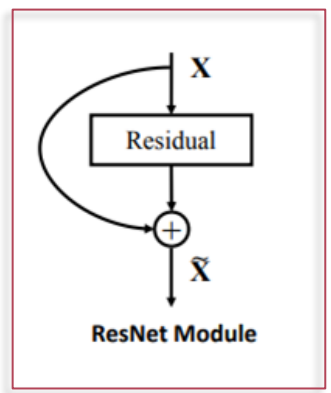
Transfer learning consistently improves performance across the 10 different CNN architectures

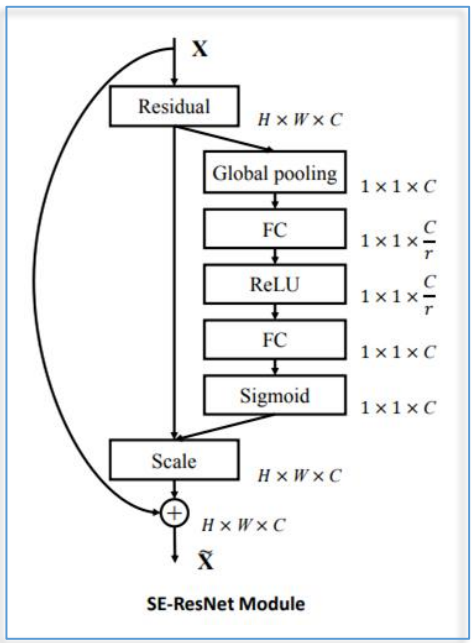


Transfer learning consistently improves performance across the 10 different CNN architectures

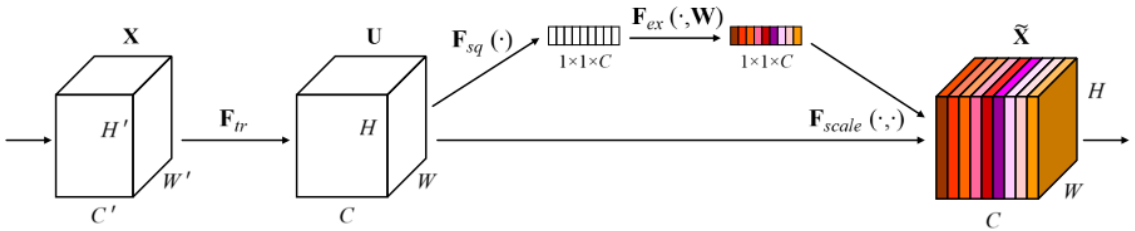


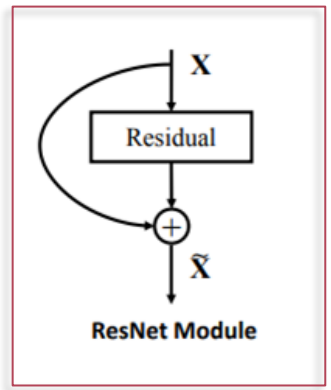


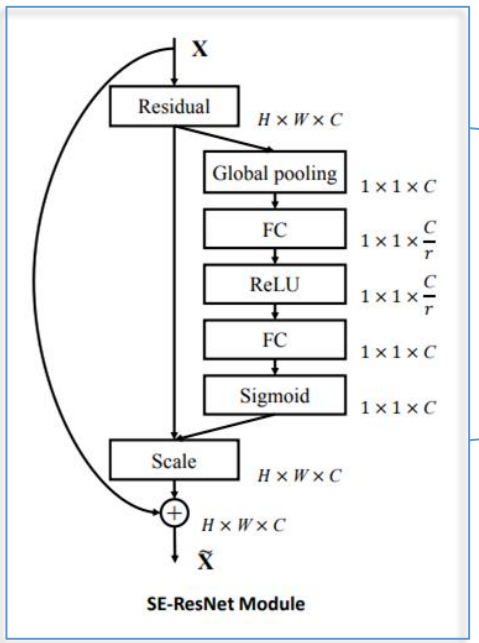




Hu, J., Shen, L., & Sun, G. (2018). Squeeze-and-excitation networks. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 7132-7141).

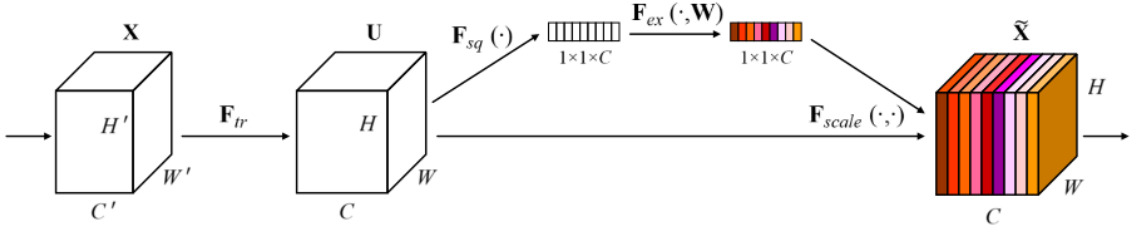


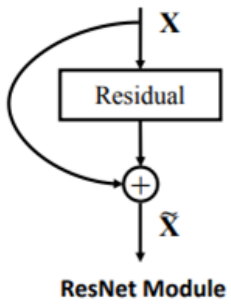




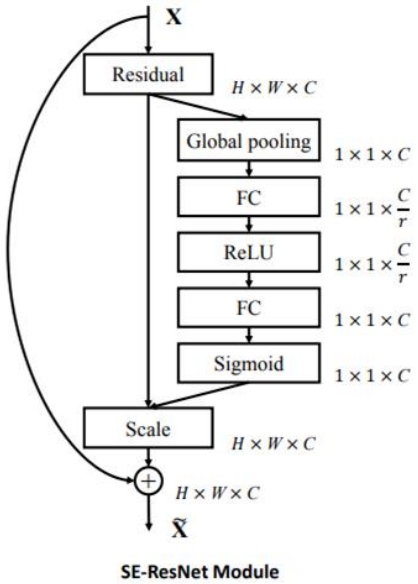

```
def se_block(in_block, ch, ratio=16):
    x = GlobalAveragePooling2D()(in_block)
    x = Dense(ch//ratio, activation='relu')(x)
    x = Dense(ch, activation='sigmoid')(x)
    return multiply()([in_block, x])
```

Hu, J., Shen, L., & Sun, G. (2018). Squeeze-and-excitation networks. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 7132-7141).

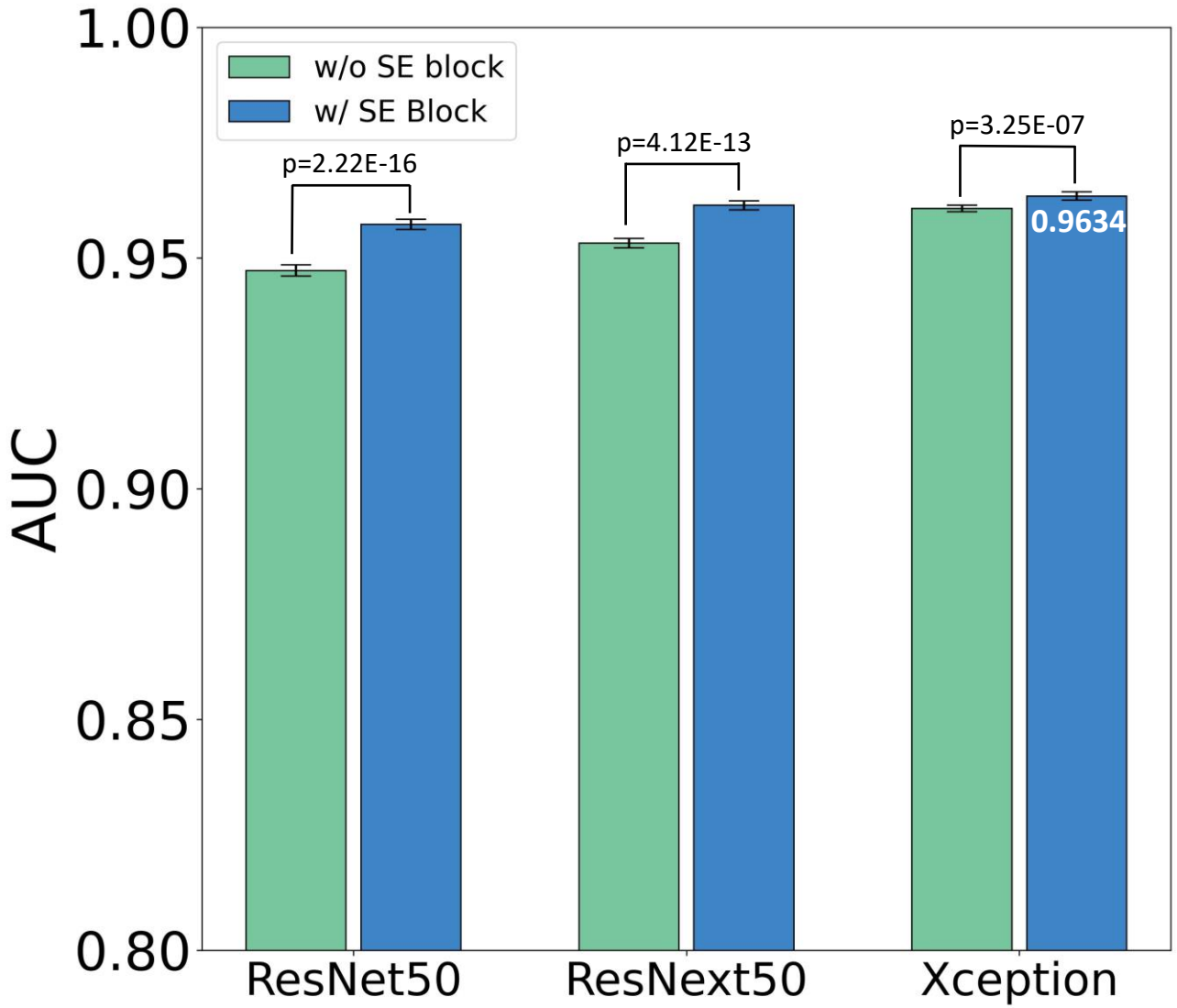




ResNet Module



SE-ResNet Module



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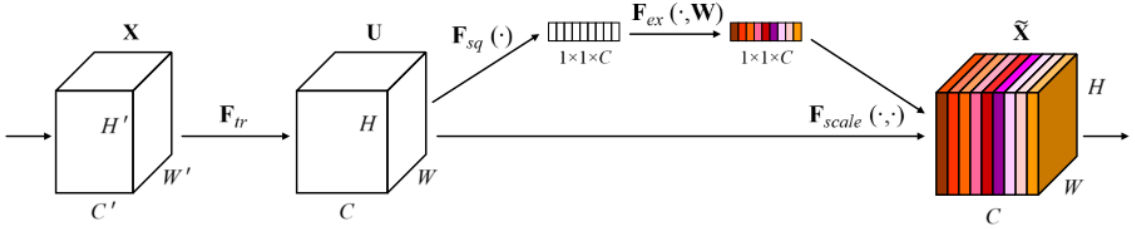
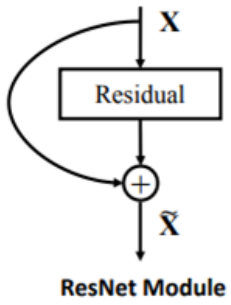
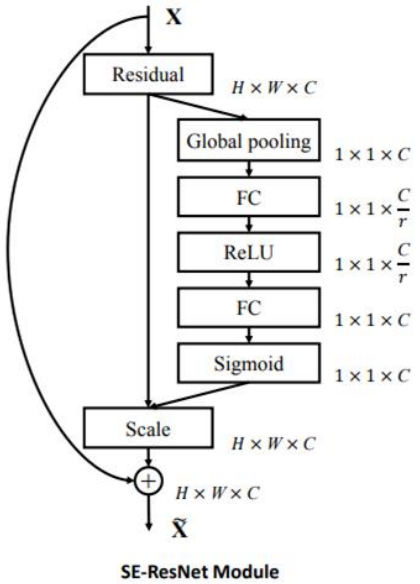
Squeeze and excitation (SE) blocks enhance CNN performance

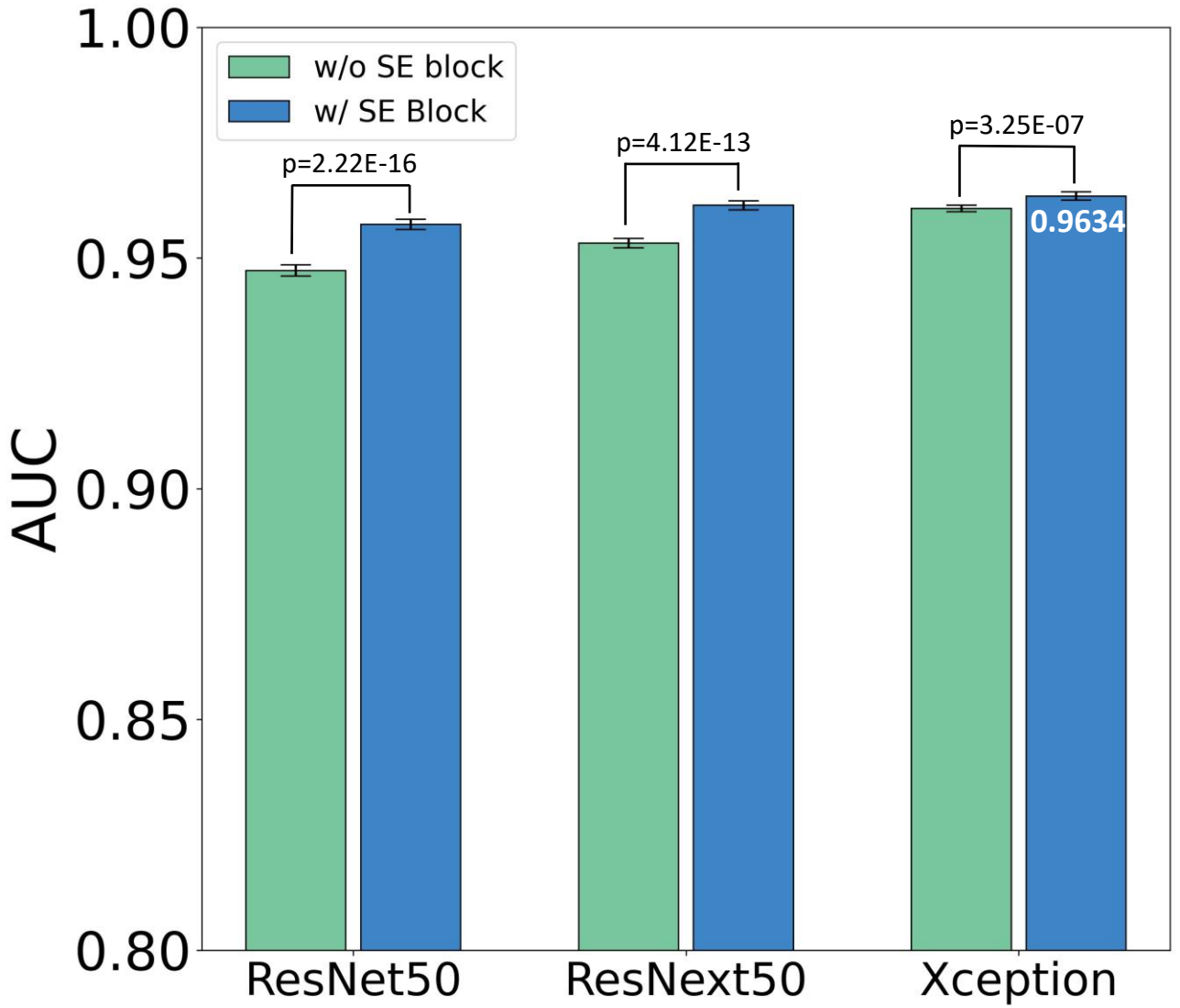




ResNet Module



SE-ResNet Module



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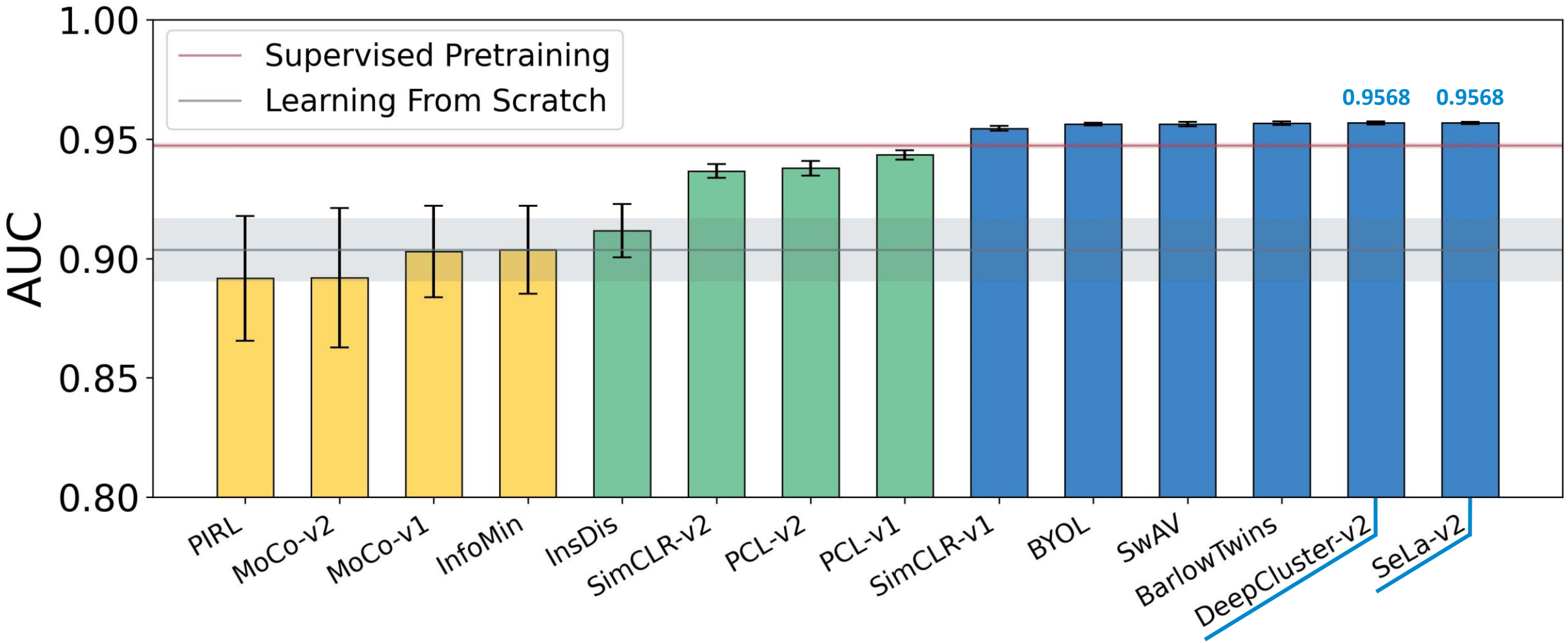
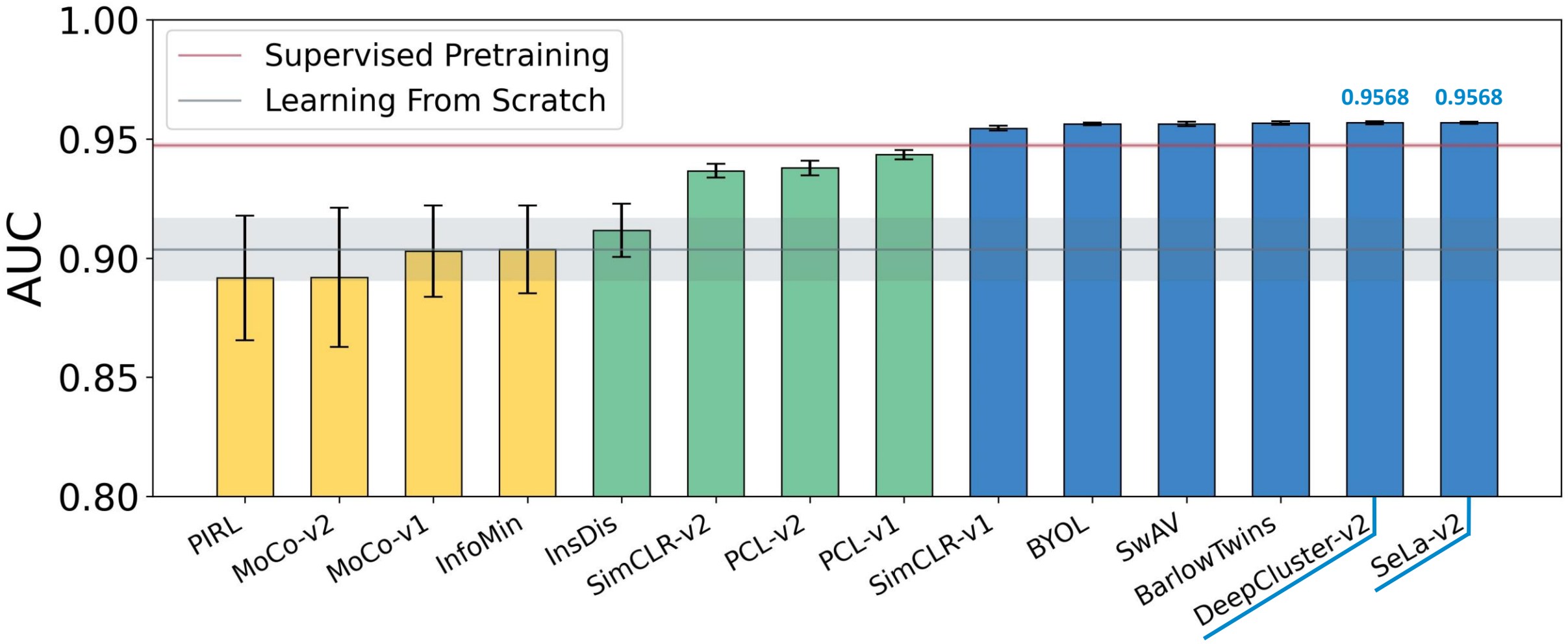
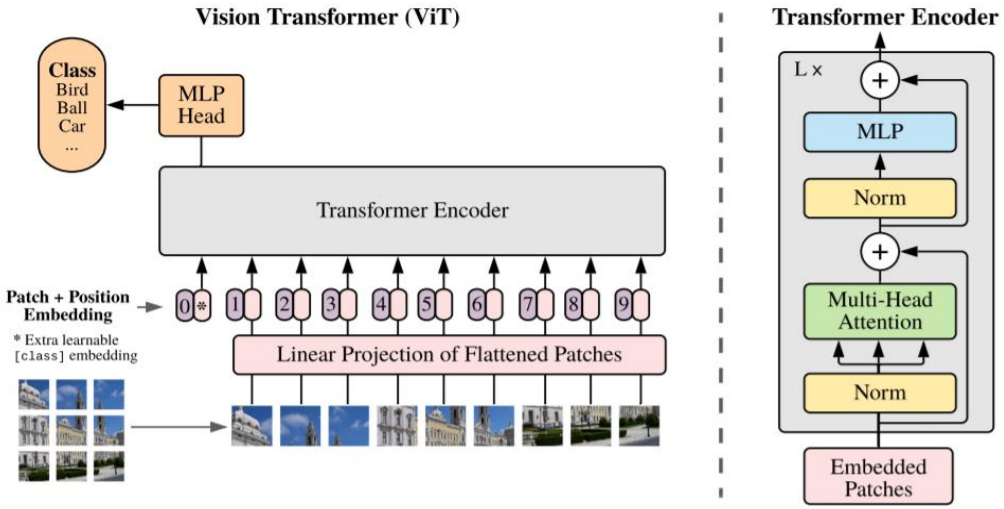


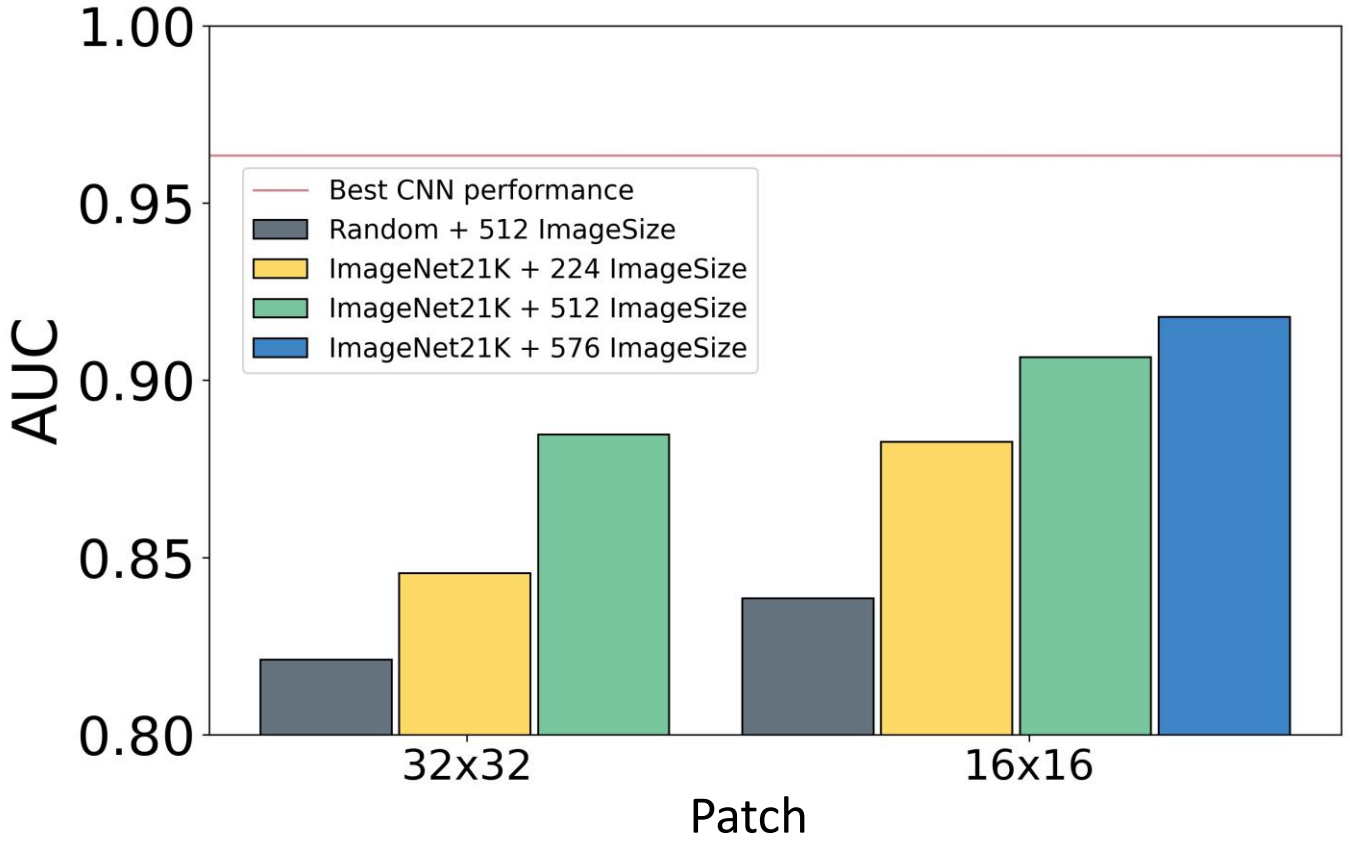
Ericsson, L., Gouk, H., & Hospedales, T. M. (2021). How Well Do Self-Supervised Models Transfer?. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 5414-5423).

Self-supervised pre-training overtakes (fully) supervised pre-training



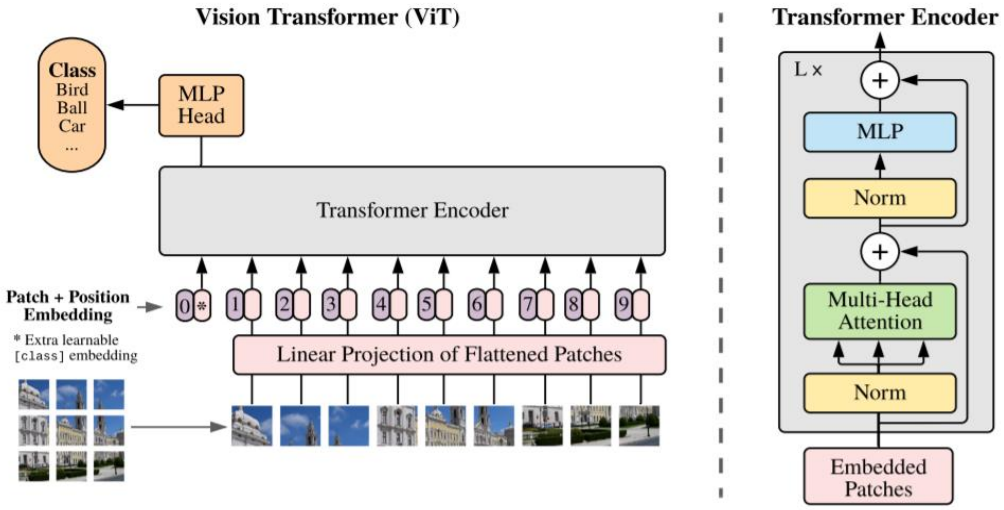
Ericsson, L., Gouk, H., & Hospedales, T. M. (2021). How Well Do Self-Supervised Models Transfer?. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 5414-5423).

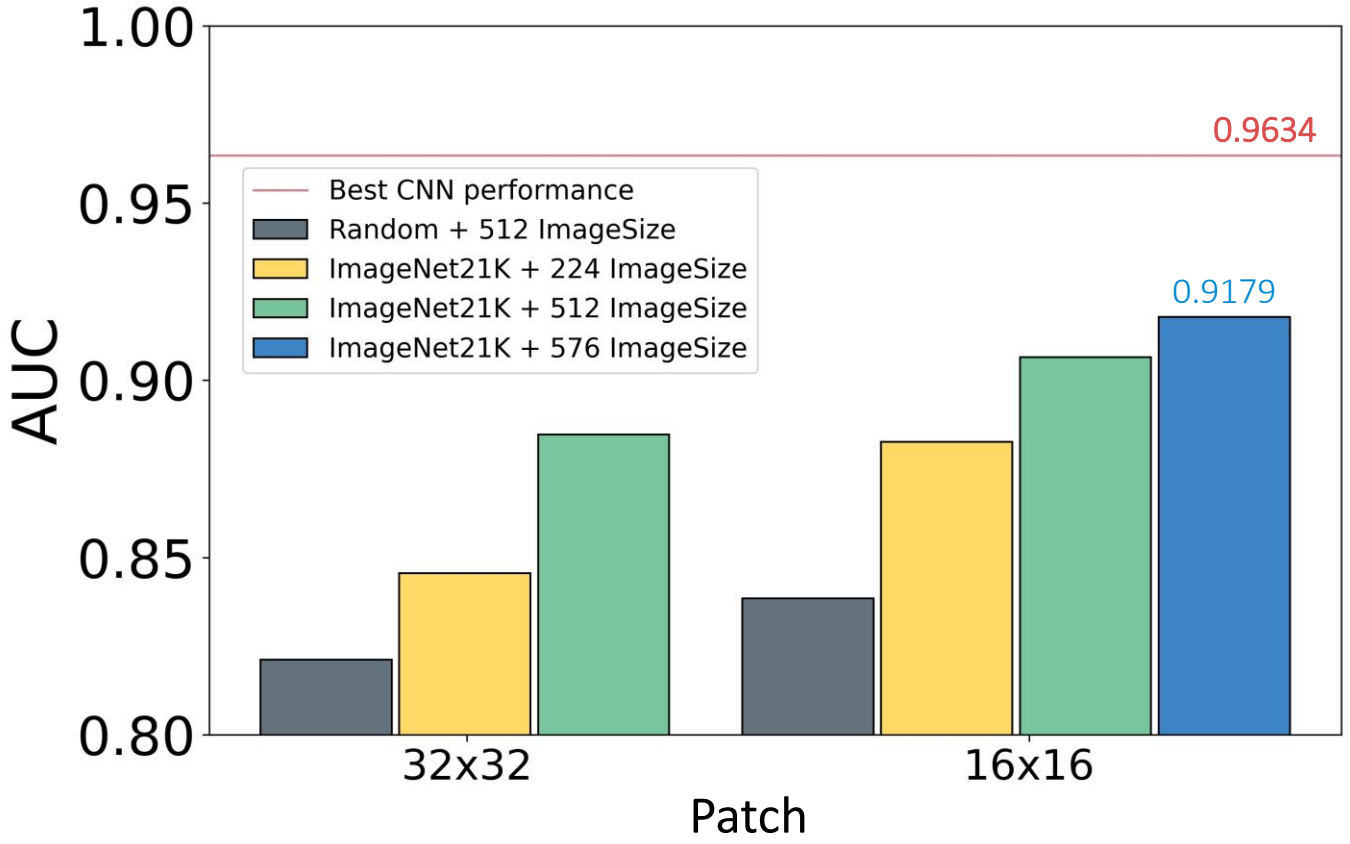




Dosovitskiy, A., Beyer, L., Kolesnikov, A., Weissenborn, D., Zhai, X., Unterthiner, T., ... & Houlsby, N. (2020). An image is worth 16x16 words: Transformers for image recognition at scale. *arXiv preprint arXiv:2010.11929*.

Vision transformers (ViT) underperform CNNs





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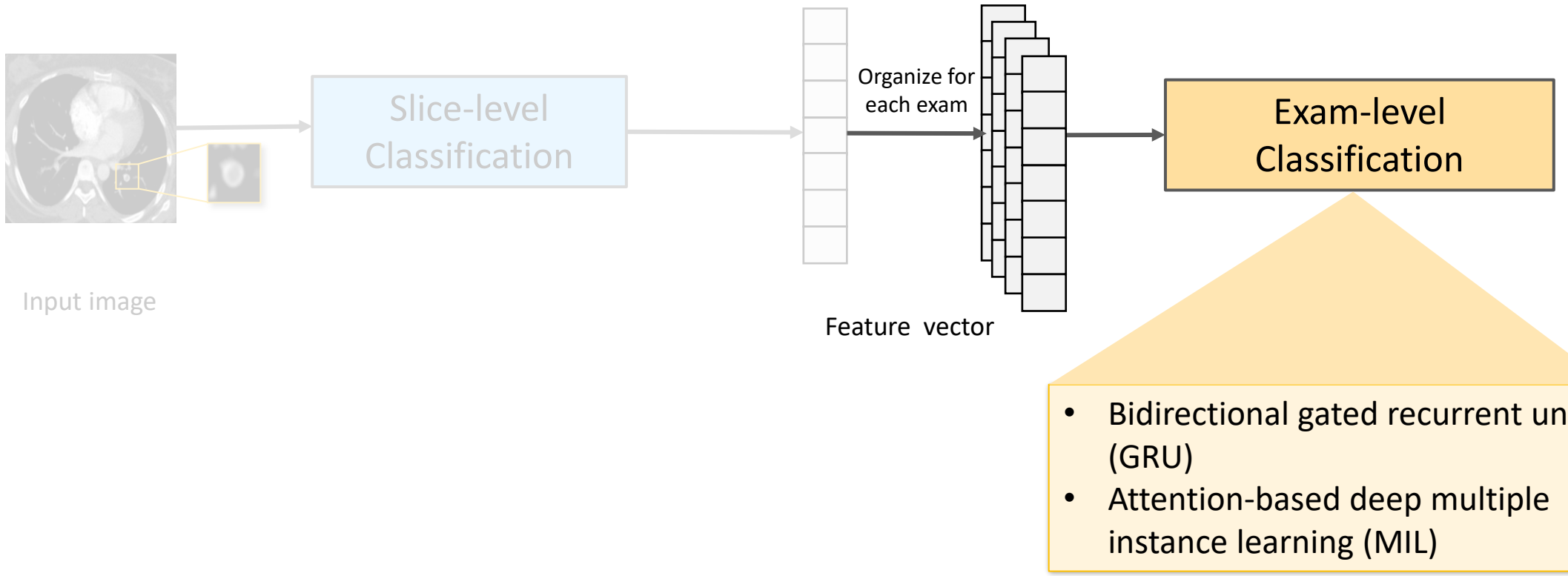
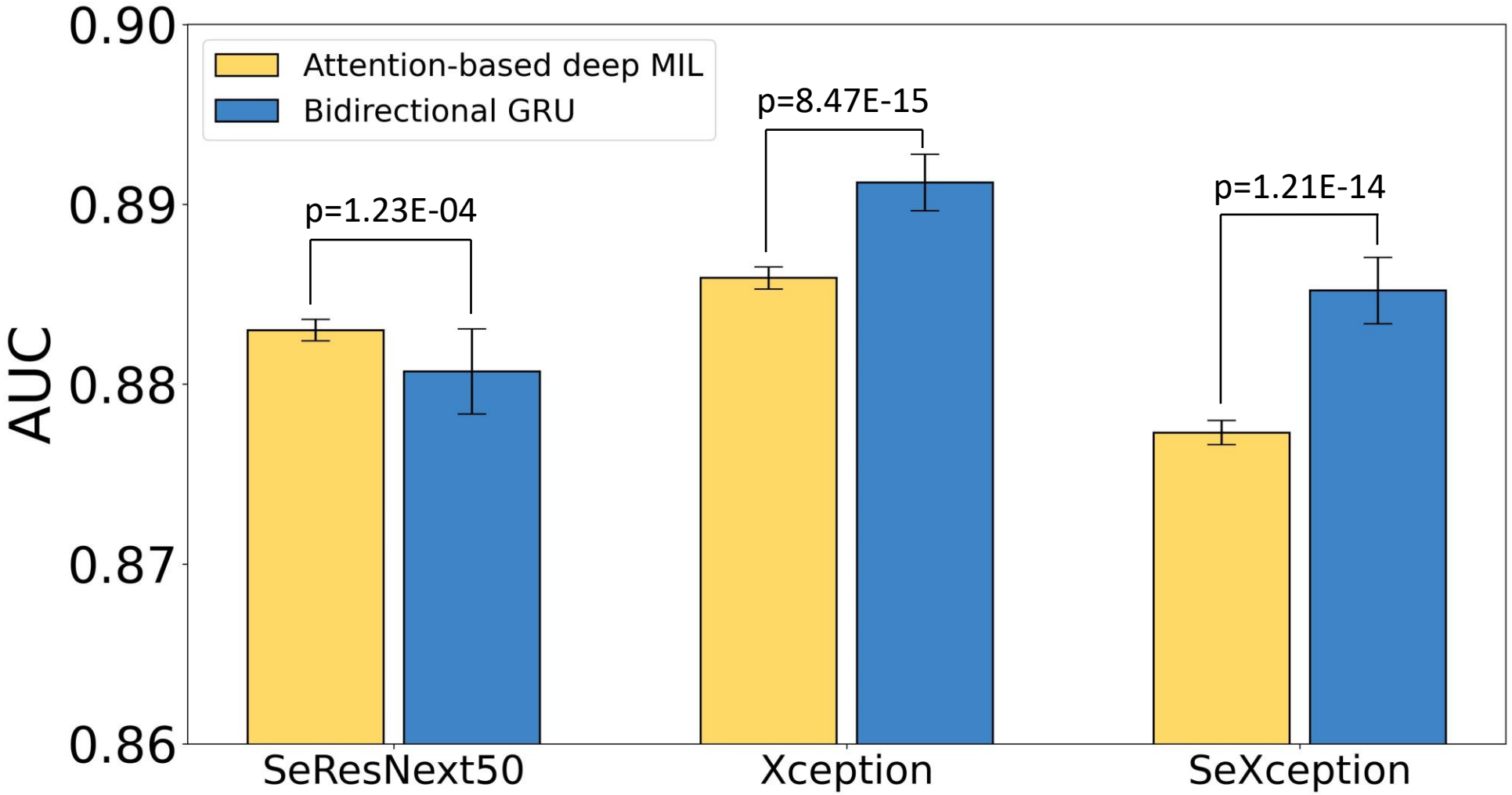
Second Stage

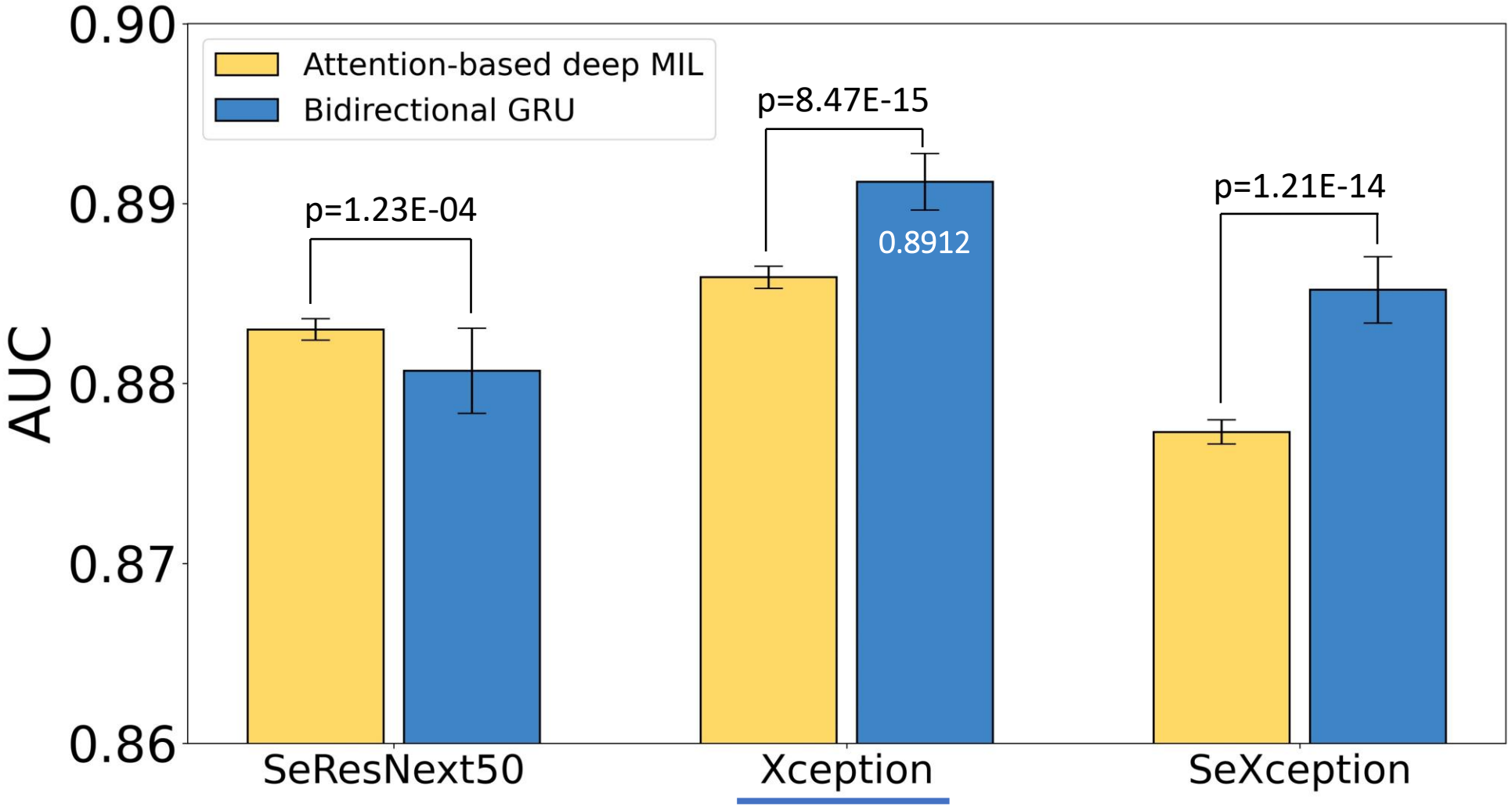


https://www.kaggle.com/c/rsna-str-pulmonary-embolism-detection/discussion/194145



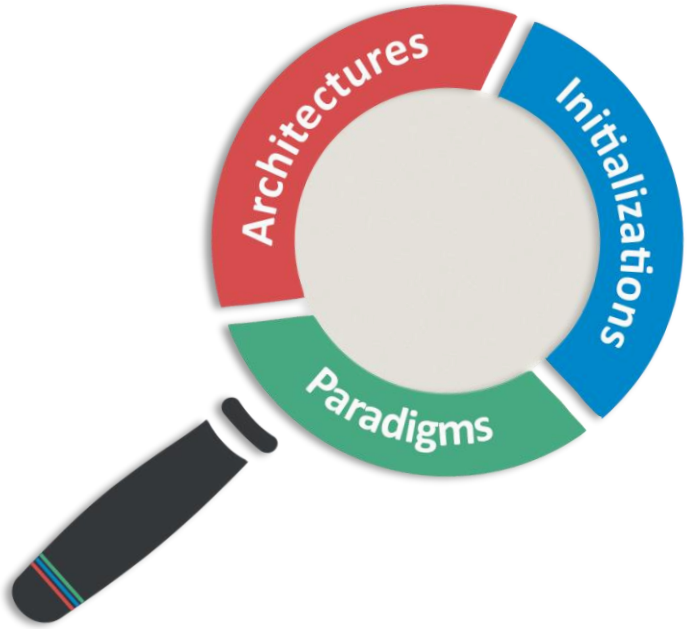
Ilse, M., Tomczak, J., & Welling, M. (2018, July). Attention-based deep multiple instance learning. In *International conference on machine learning* (pp. 2127-2136). PMLR.

Bidirectional GRU marginally outperforms attention-based MIL at the exam level



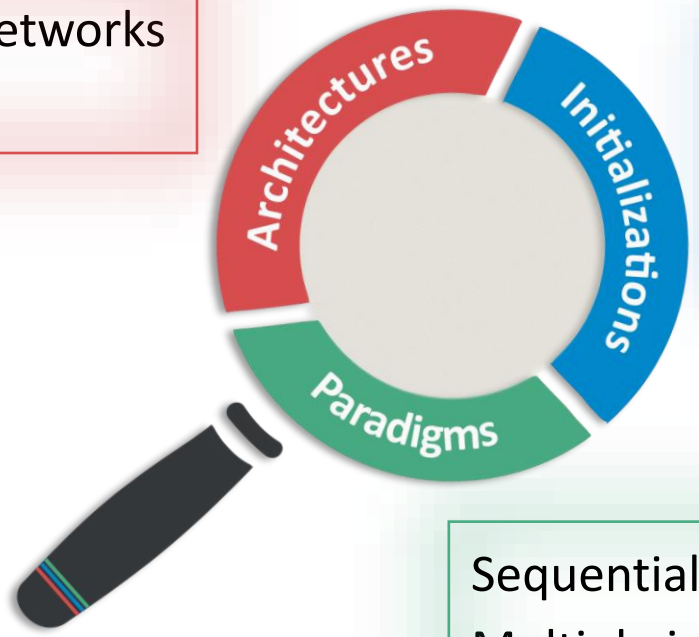
Ilse, M., Tomczak, J., & Welling, M. (2018, July). Attention-based deep multiple instance learning. In *International conference on machine learning* (pp. 2127-2136). PMLR.

Contributions



Contributions

Convolutional neural networks
Vision transformers

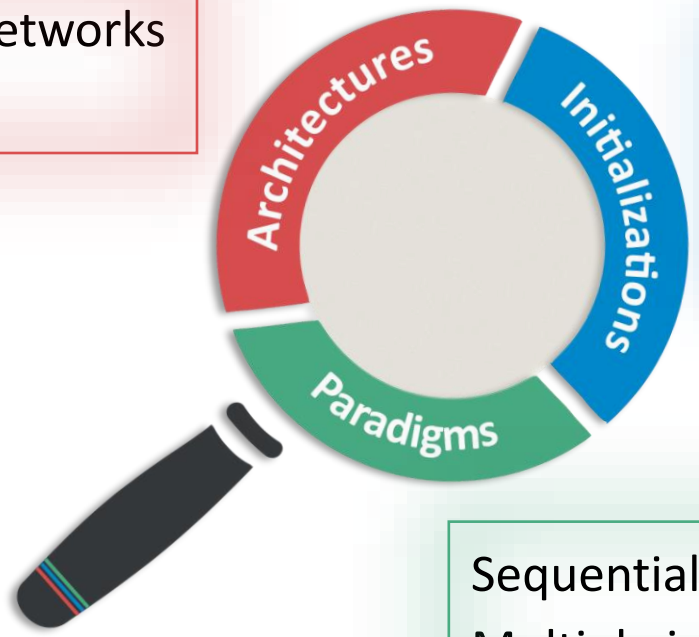


Random initialization
Supervised pre-training
Self-supervised pre-training

Sequential learning model
Multiple instance learning

Contributions

Convolutional neural networks
Vision transformers

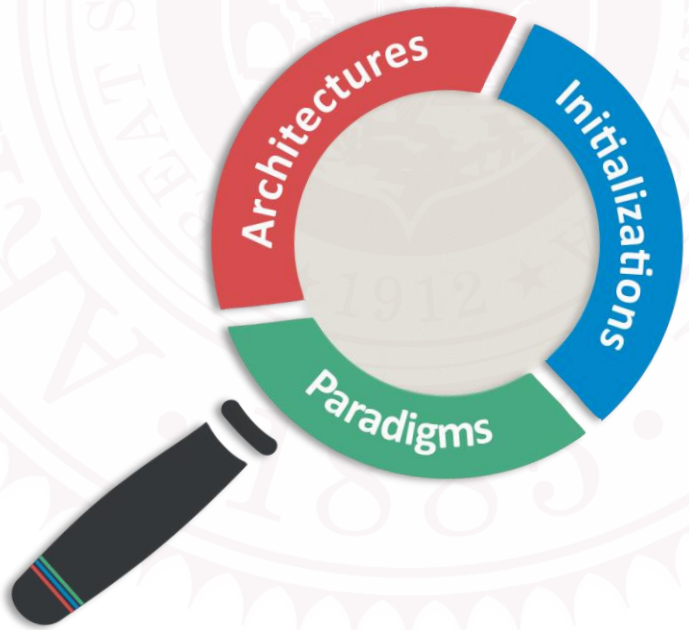


Random initialization
Supervised pre-training
Self-supervised pre-training

Sequential learning model
Multiple instance learning

Compared with the state-of-the-art, our optimal architectures for slice-level classification was **SeXception** and exam-level classification was **Xception** achieving an AUC gain of **0.2%** and **1.05%**, respectively.

Seeking an Optimal Approach for Computer-aided Pulmonary Embolism Detection



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https://github.com/JLiangLab/CAD_PE