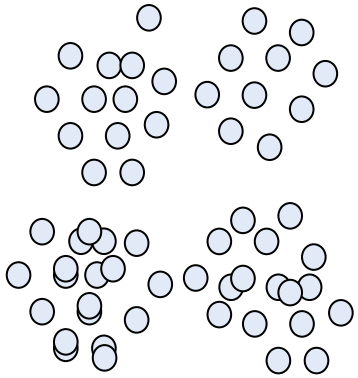
# 5 Semi-Supervised Learning

BVM Tutorial: Advanced Deep Learning Methods

David Zimmerer, Division of Medical Image Computing

# Semi-Supervised Learning



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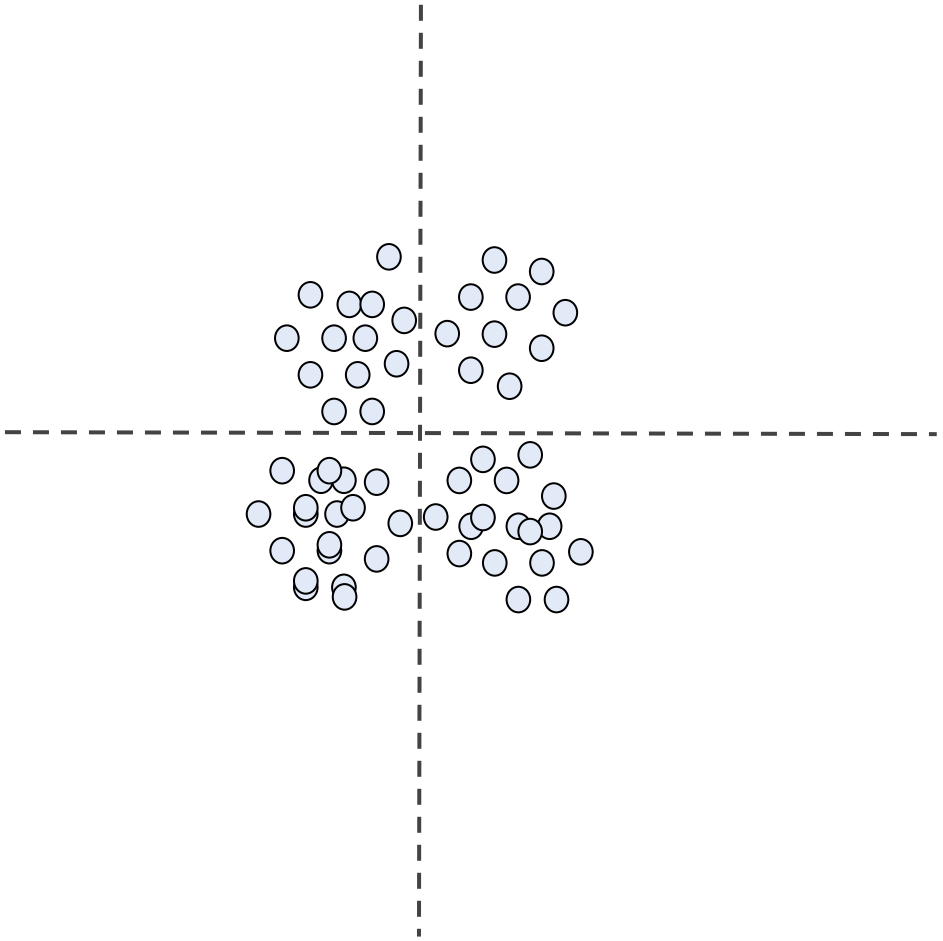

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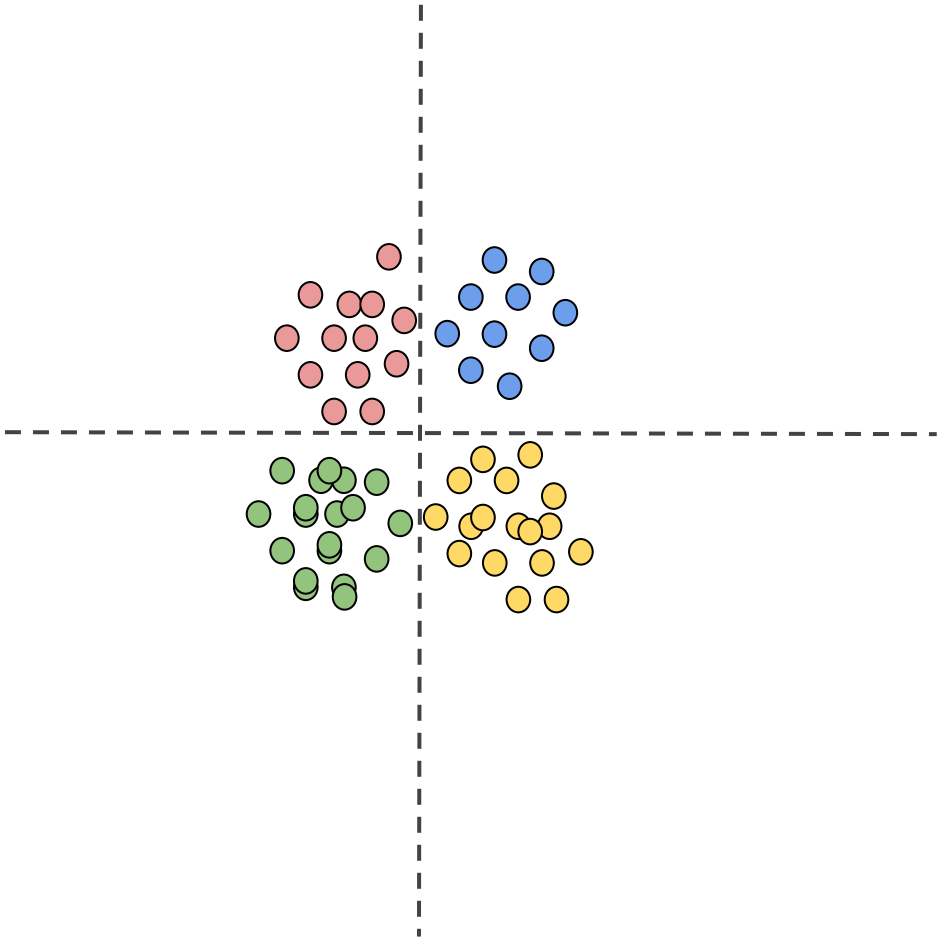

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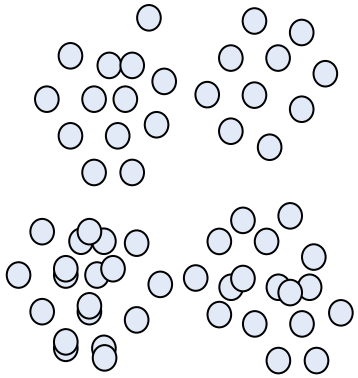

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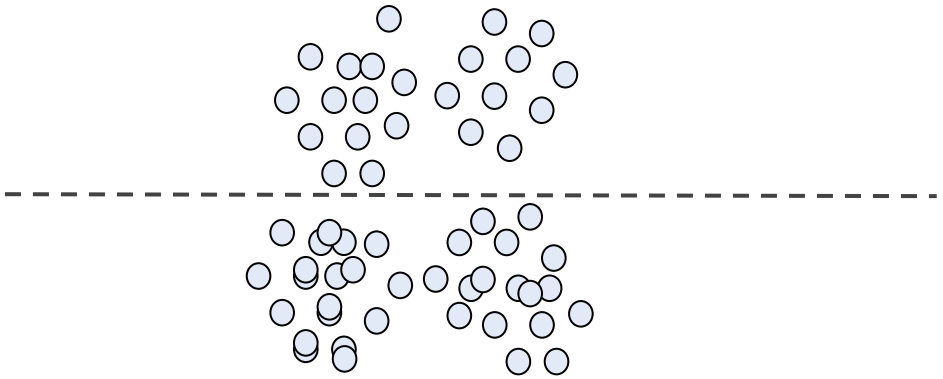

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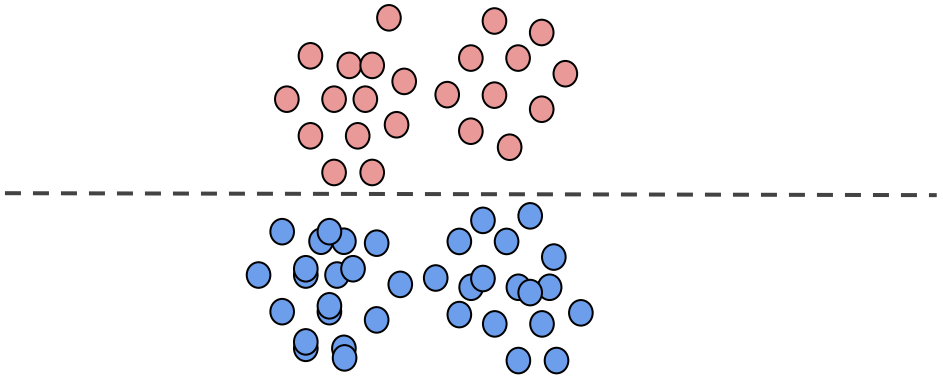

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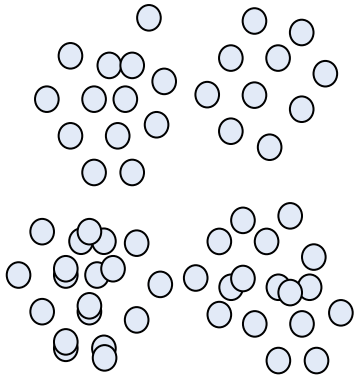

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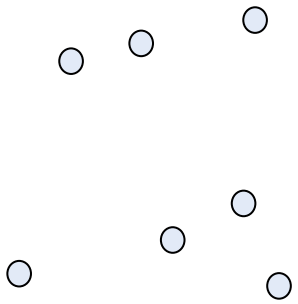

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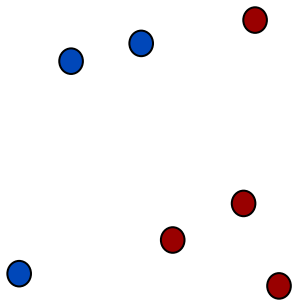

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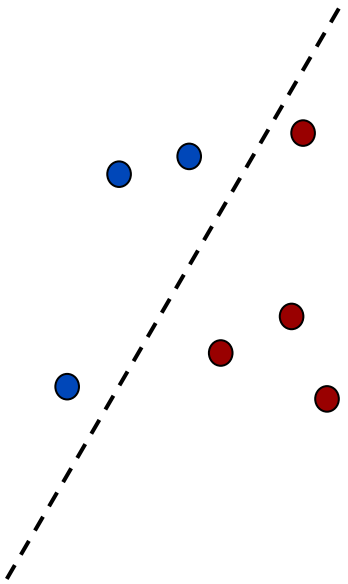

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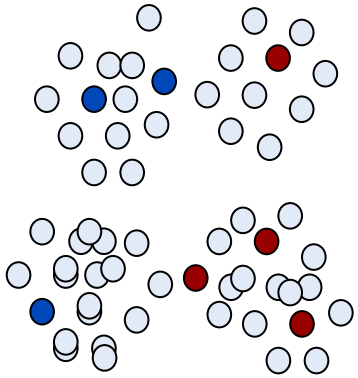

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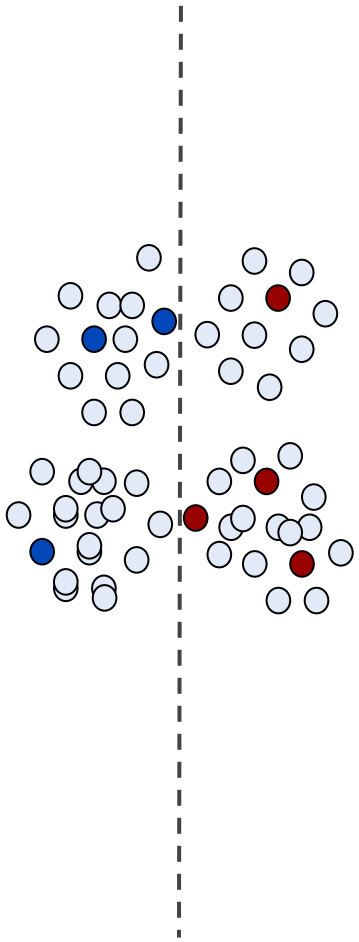

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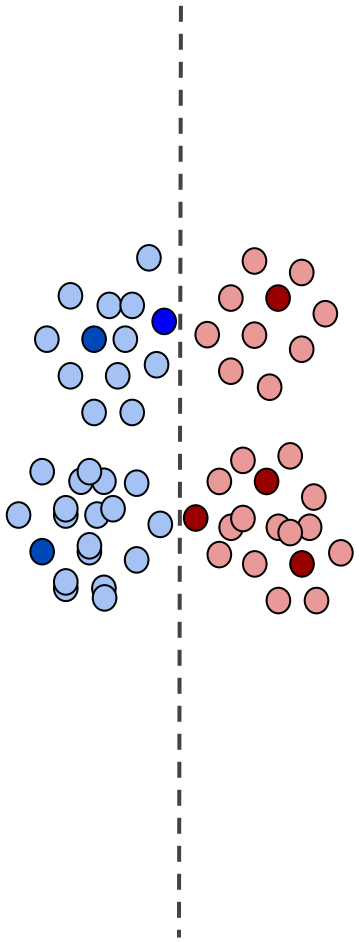

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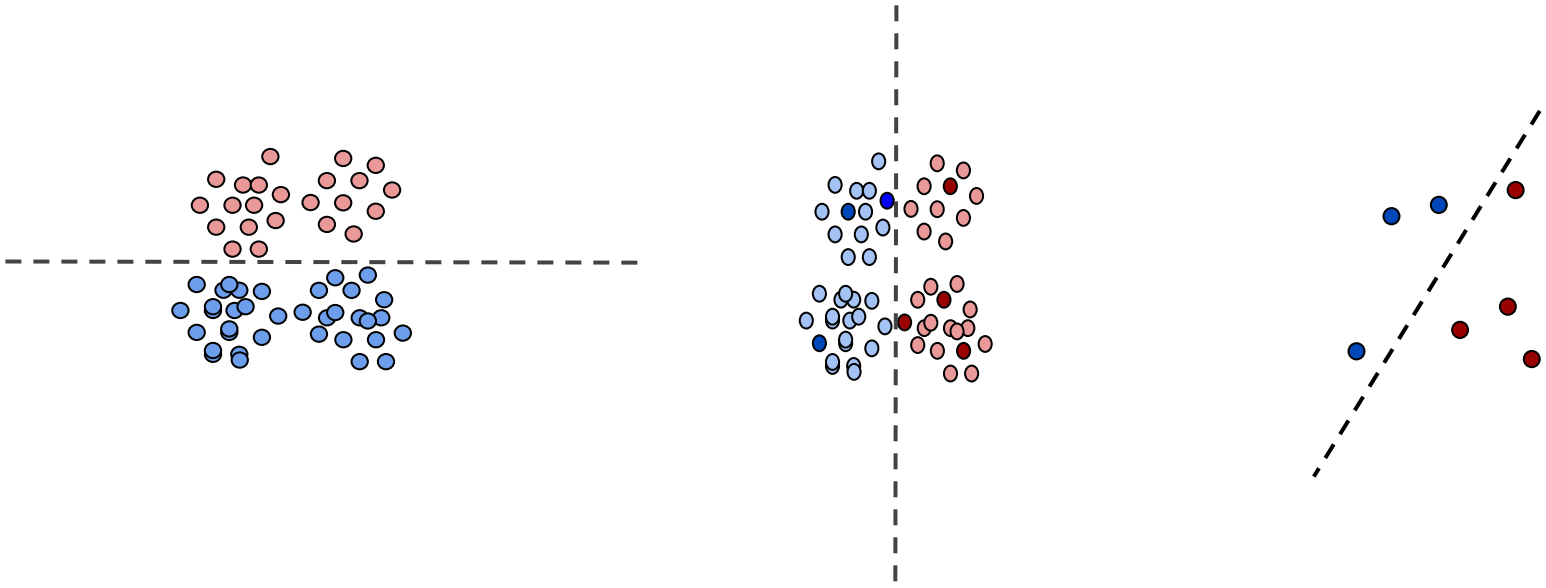

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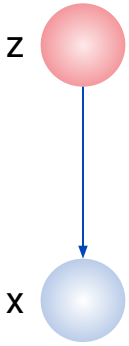


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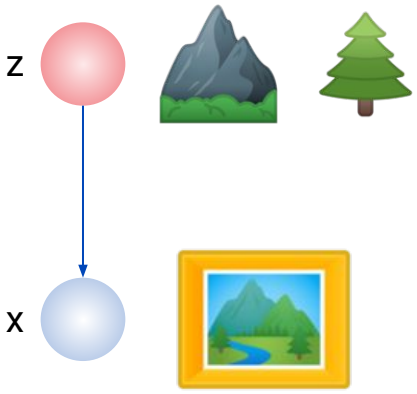


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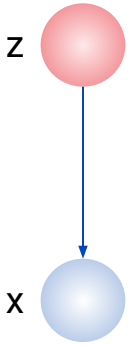


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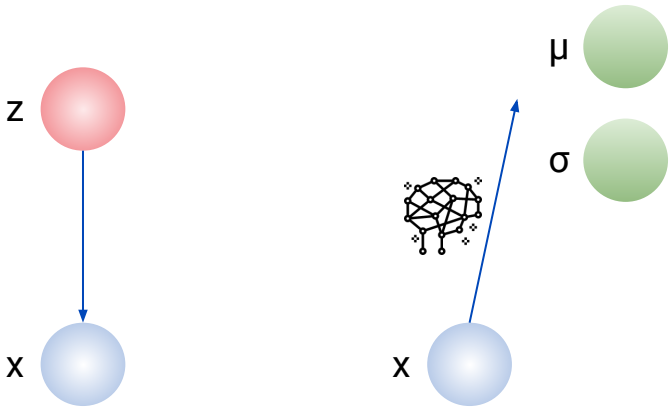


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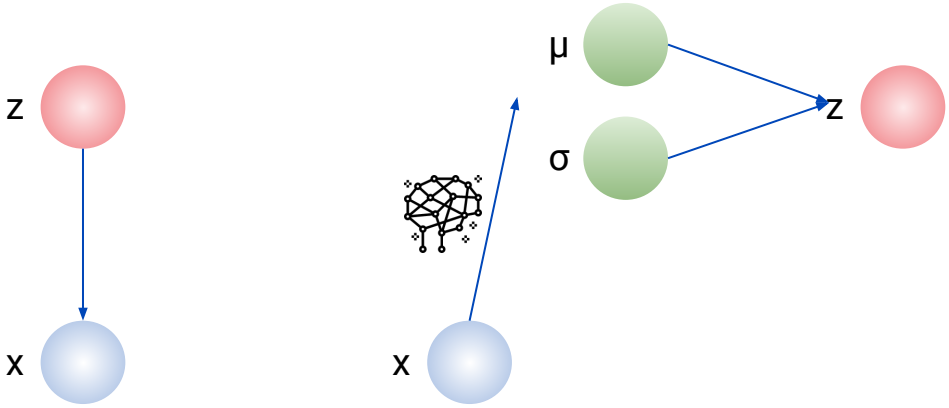


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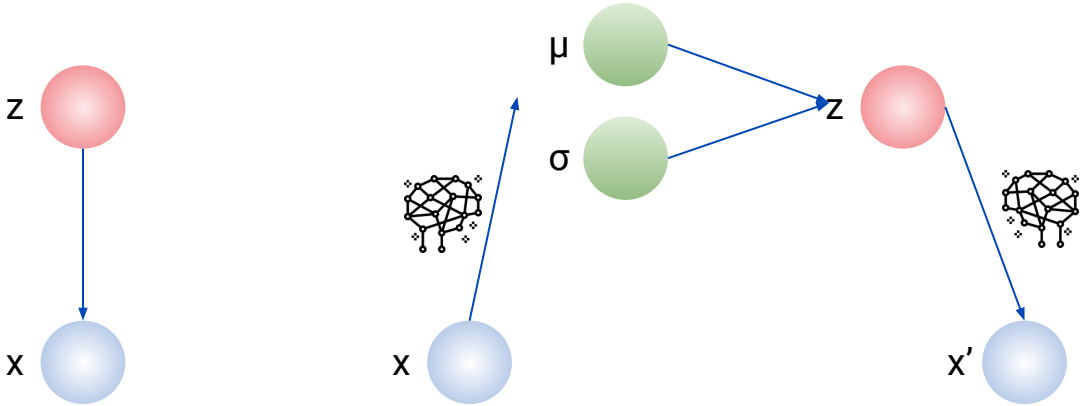


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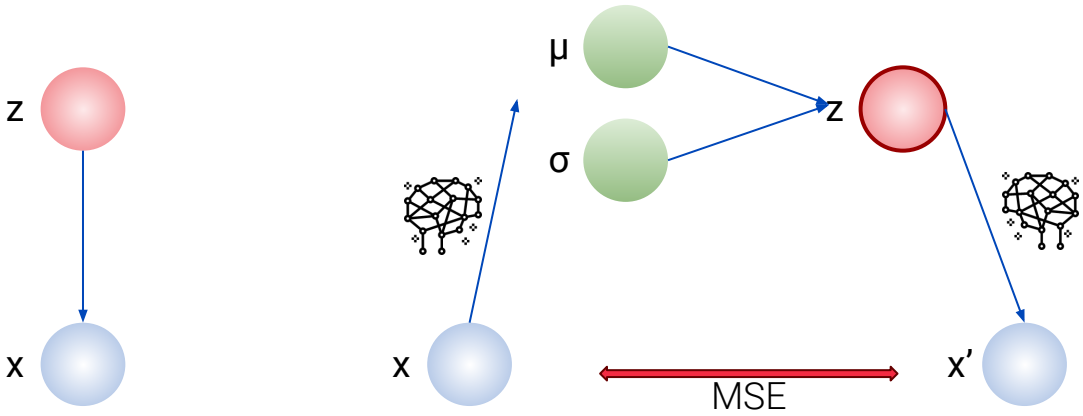


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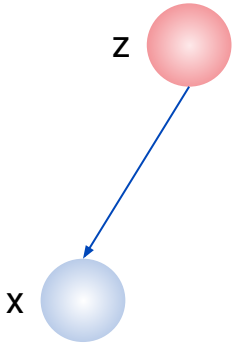


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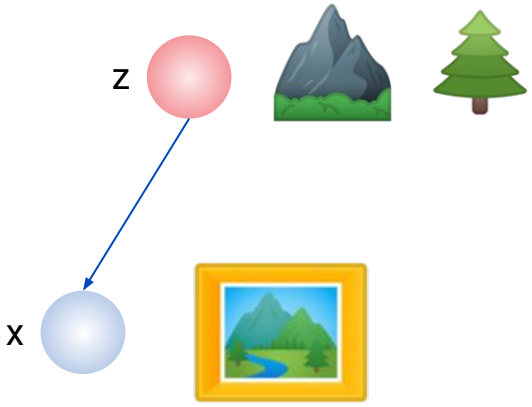


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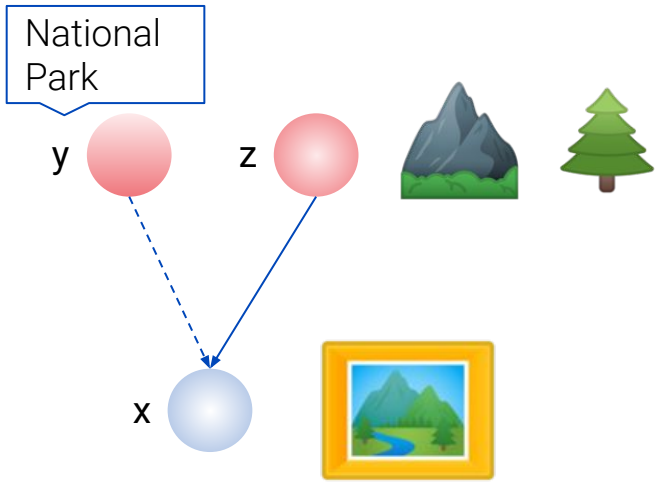


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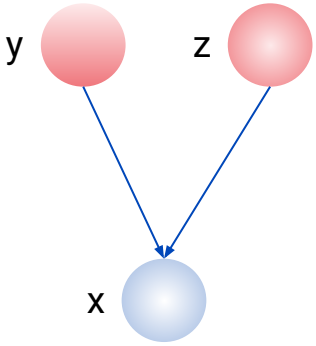


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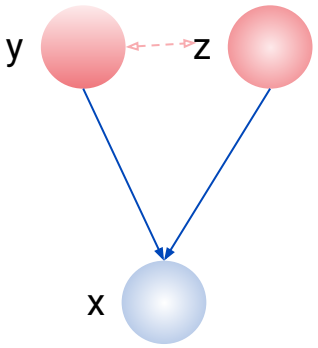


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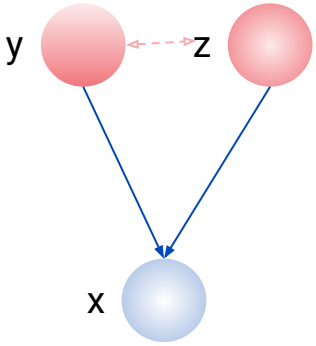


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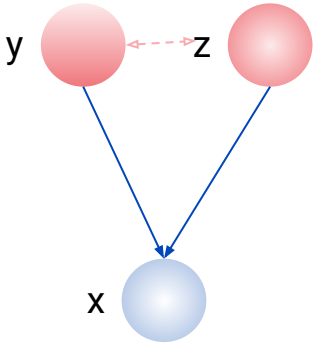


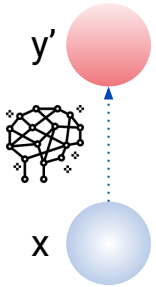


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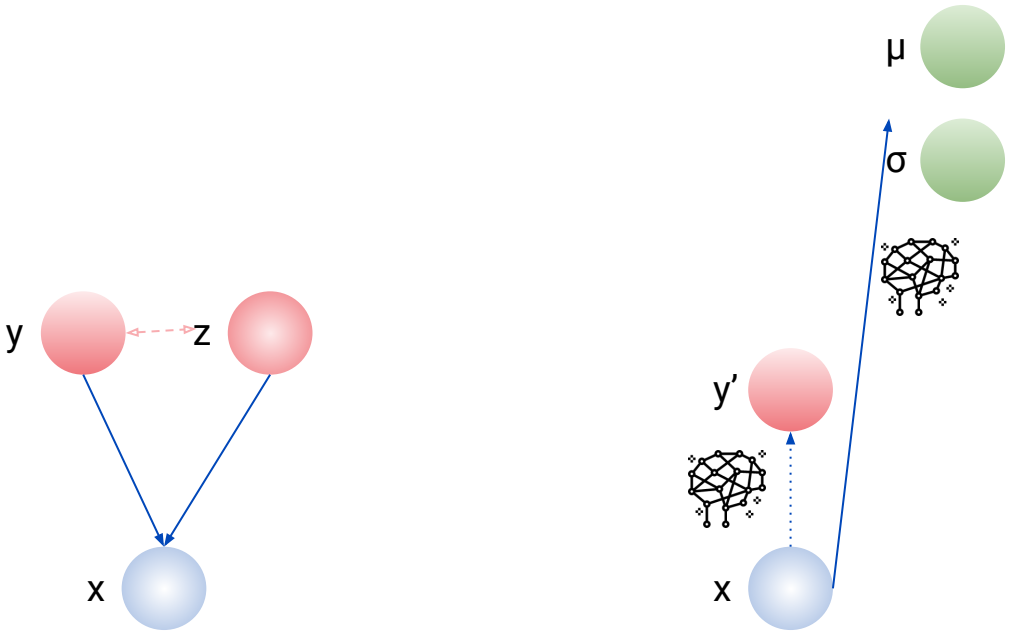


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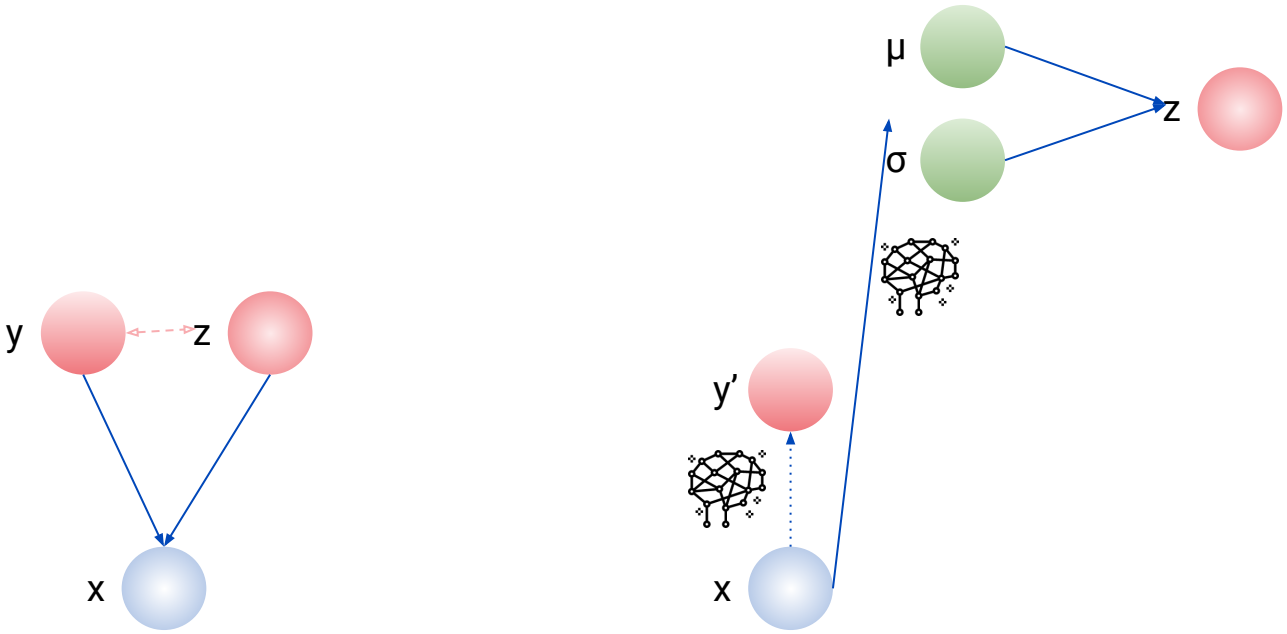


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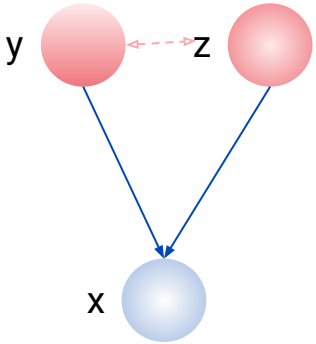


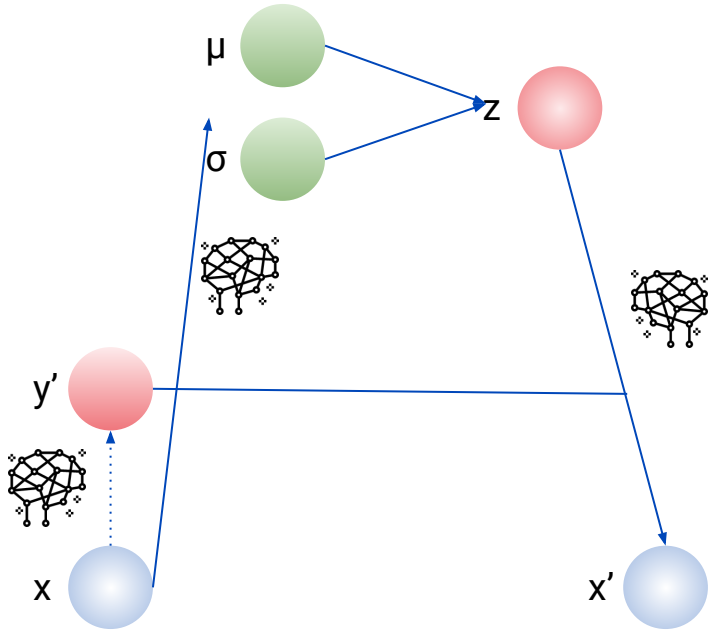


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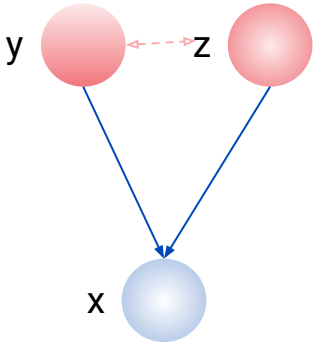


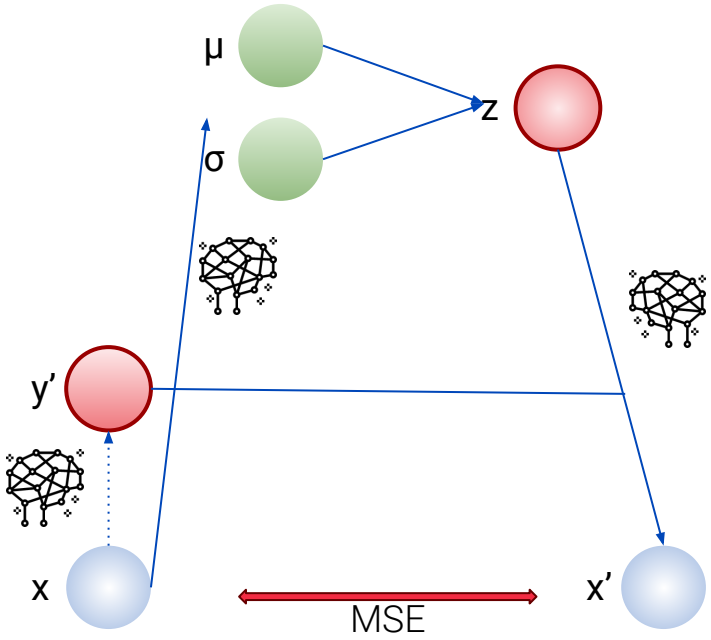


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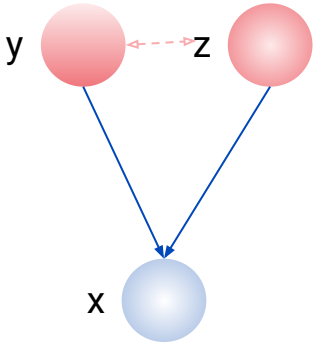


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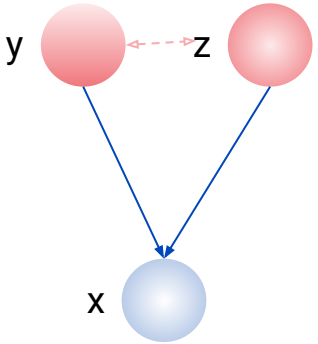



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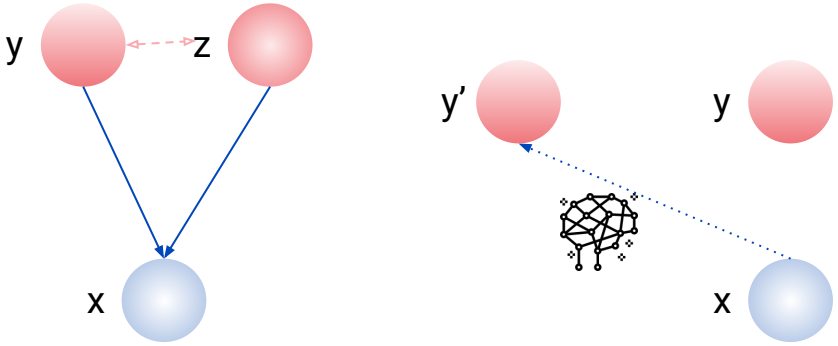


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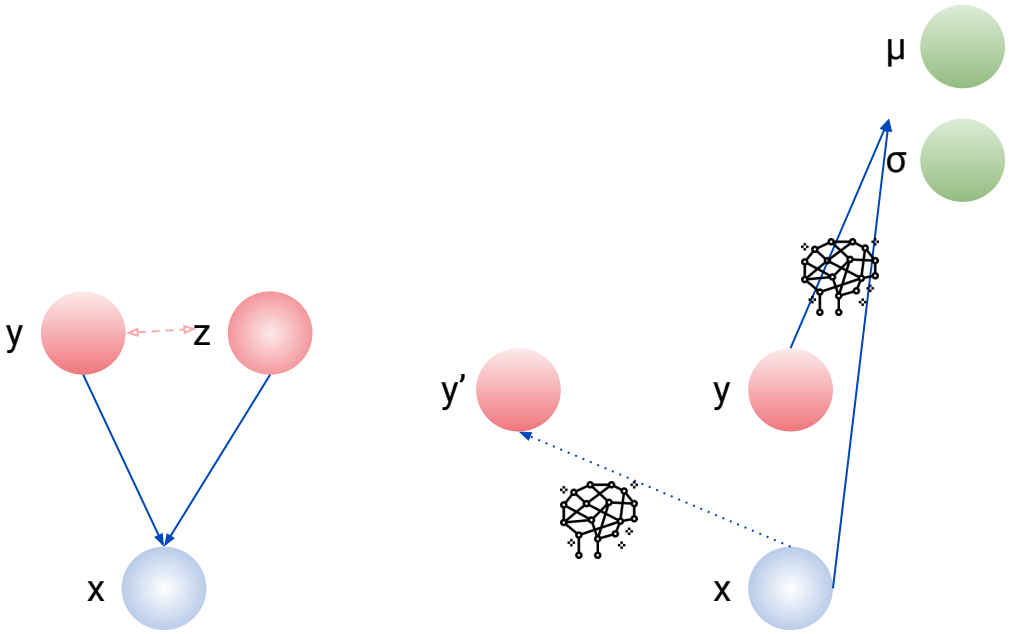


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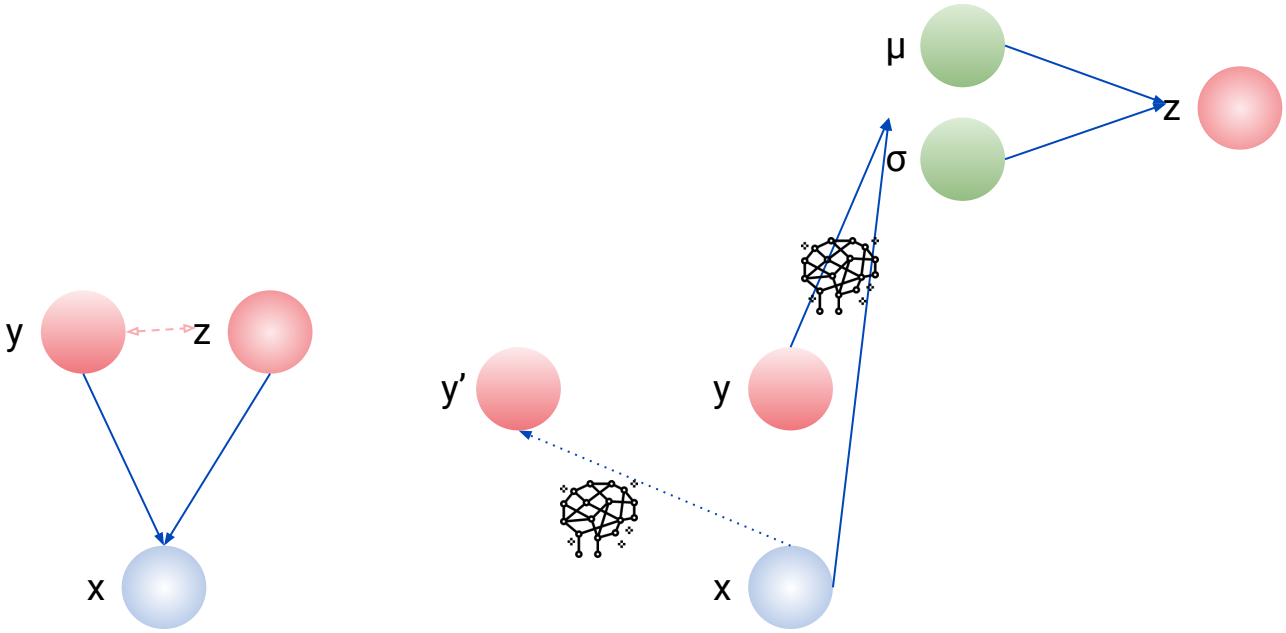


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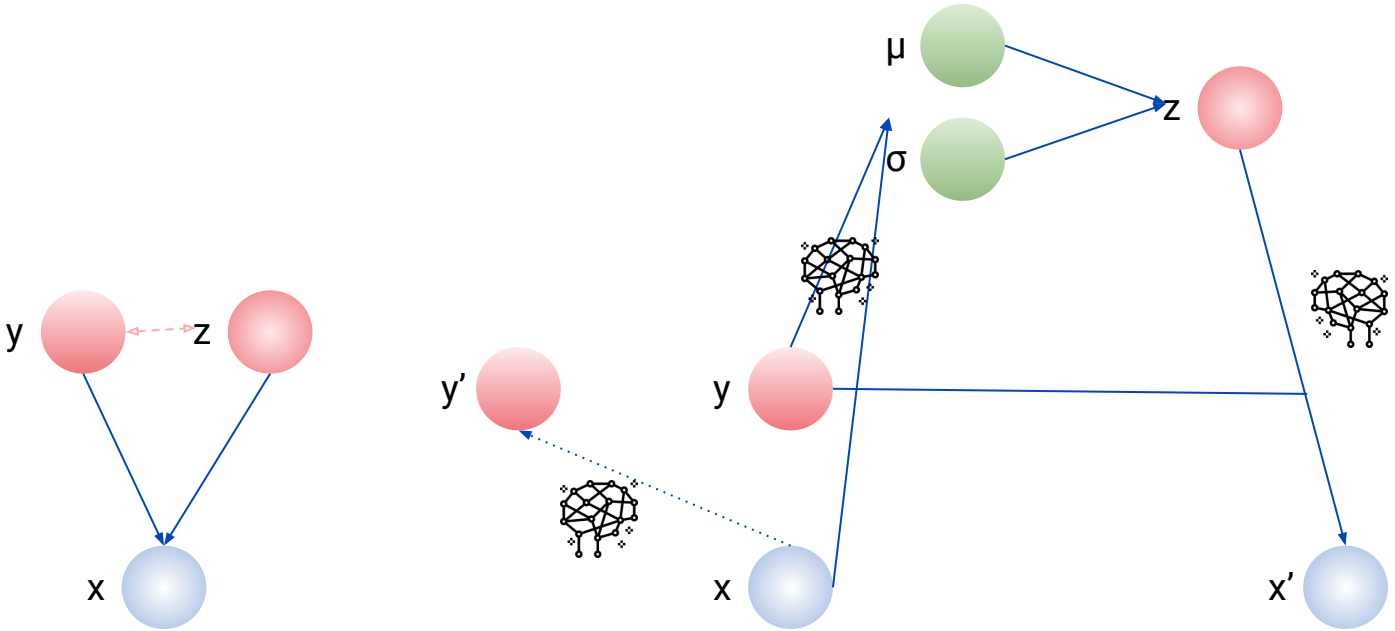


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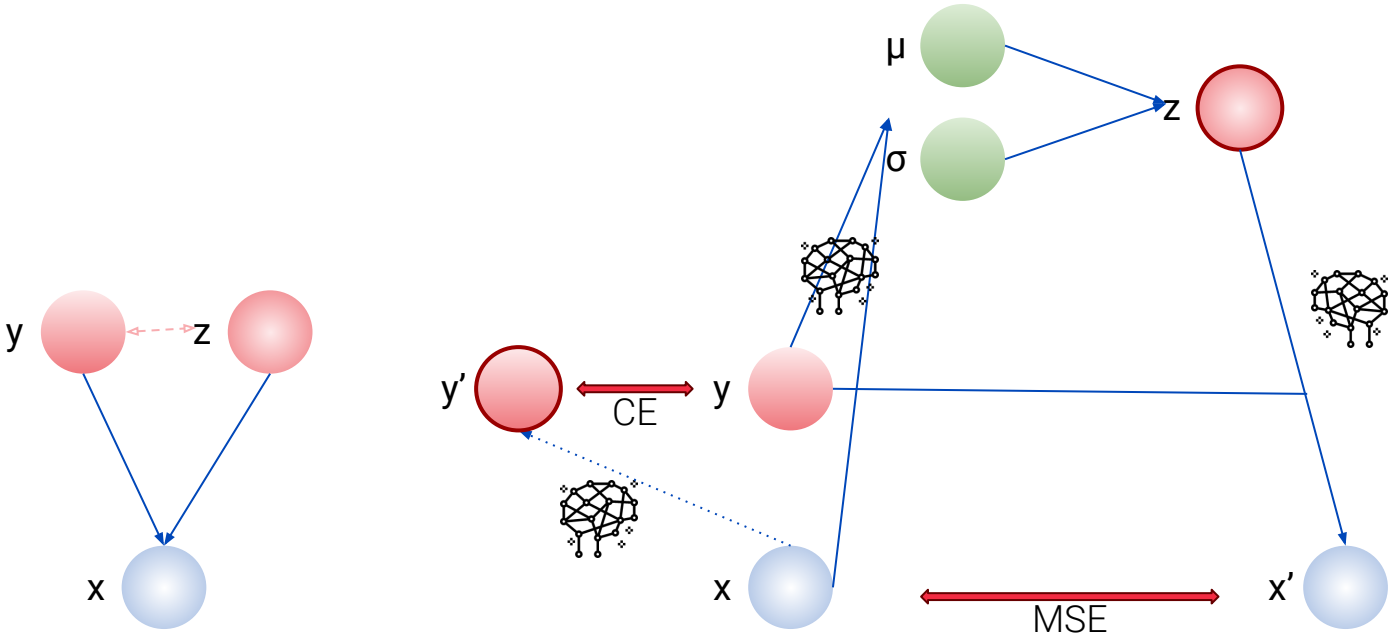


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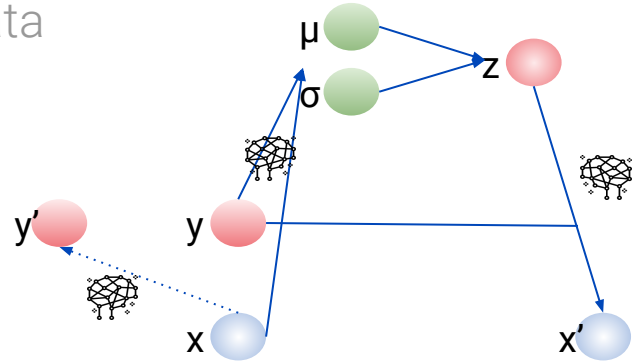


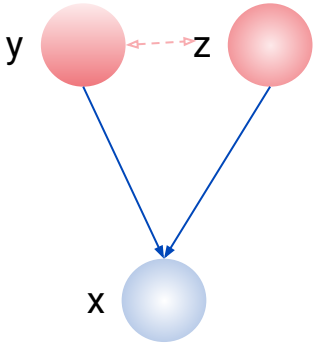


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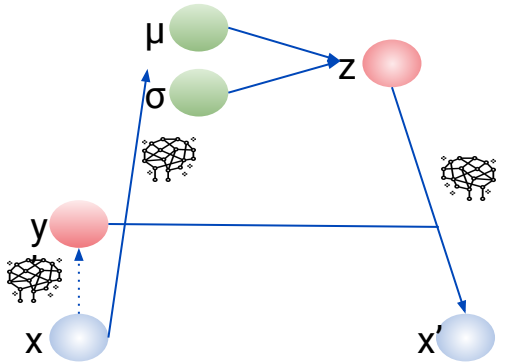


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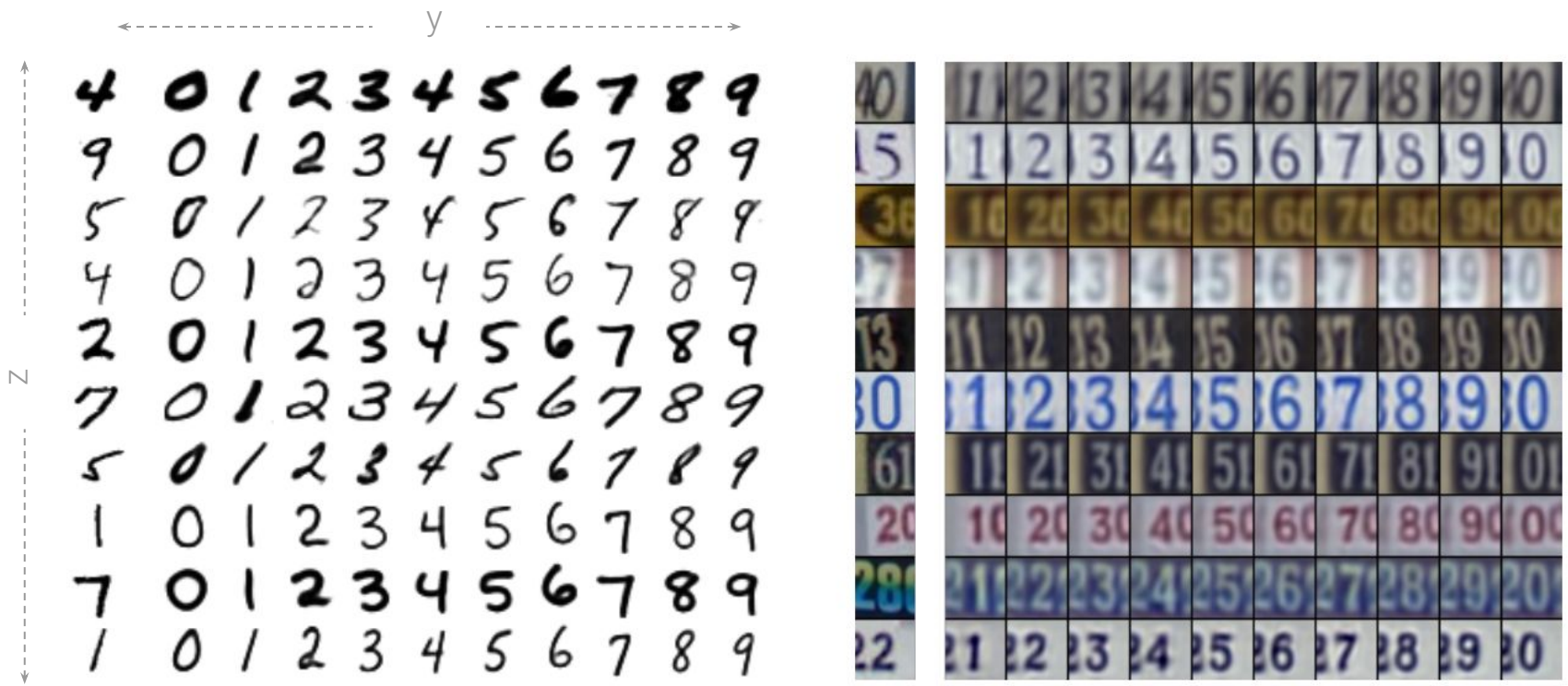


| KNN | VAE + KNN | Semi-Sup. VAE |
|---|---|---|
| 22.07 | 34.37 | 63.98 |

Classification Accuracy on the SVHN dataset with 1000 labels

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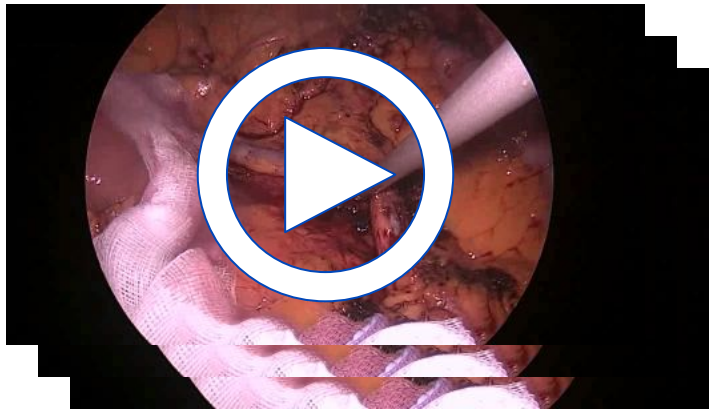
|---|---|---|
| 22.07 | 34.37 | 63.98 |

Classification Accuracy on the SVHN dataset with 1000 labels

Kingma, Diederik P., et al. "Semi-supervised learning with deep generative models." Advances in Neural Information Processing Systems. 2014.

# Self-Supervised Learning



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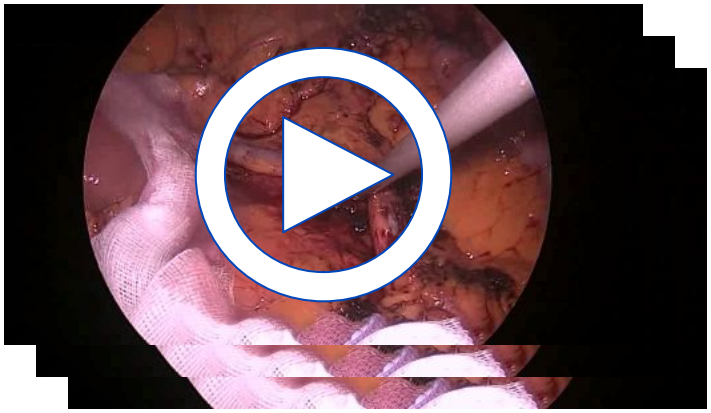

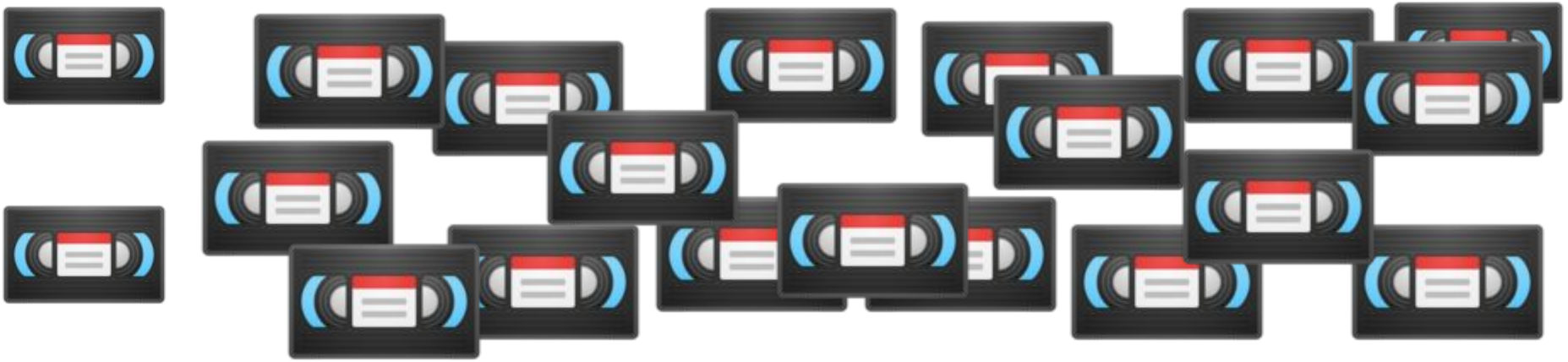

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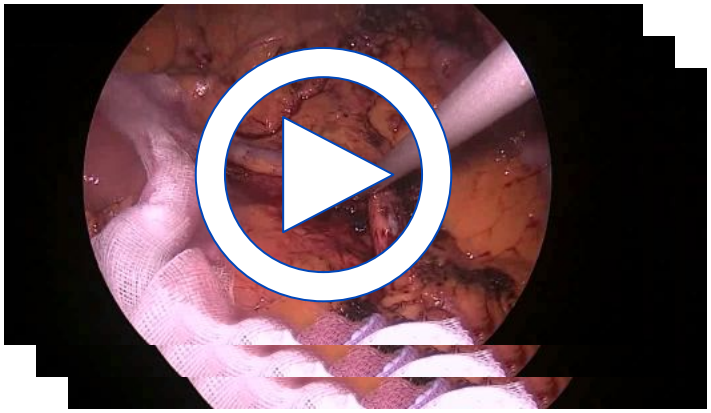


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# Self-Supervised Learning

→ Use an auxiliary task for unlabeled data

# Self-Supervised Learning

→ Use an auxiliary task for unlabeled data

*Semi-Supervised Variational Autoencoder ?*

Problem: Reconstruction is a “weak” task

# Self-Supervised Learning

→ Use an auxiliary task for unlabeled data

*Semi-Supervised Variational Autoencoder ?*

Problem: Reconstruction is a “weak” task

→ What is a good auxiliary task ?

# Self-Supervised Learning - Context Encoders

→ Use inpainting as auxiliary task


Pathak, Deepak, et al. "Context encoders: Feature learning by inpainting." Proceedings of the IEEE CVPR. 2016.

# Self-Supervised Learning - Context Encoders

→ Use inpainting as auxiliary task

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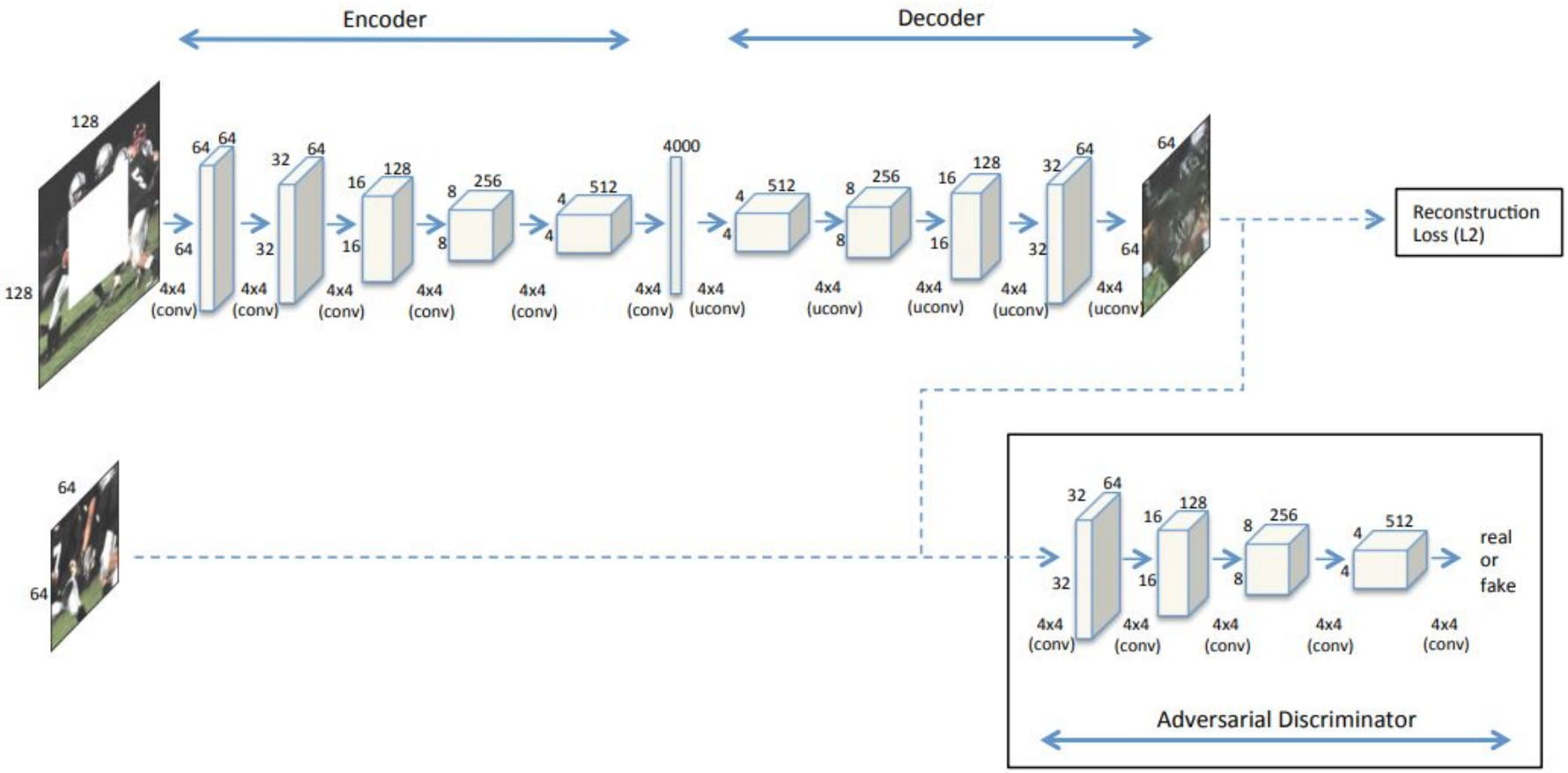


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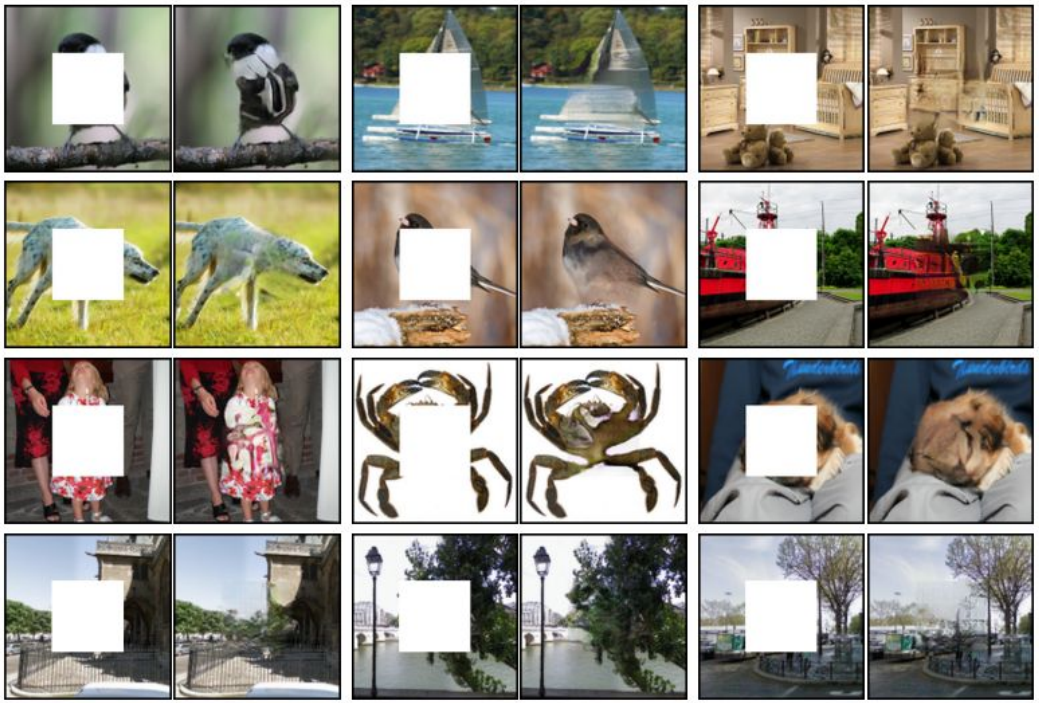

| ImageNet Pretrained | Random Initialization | Autoencoder | Context Encoders |
|---|---|---|---|
| 78.2 | 53.3 | 53.8 | 56.5 |

Classification Accuracy on the Pascal VOC dataset with different pretraining methods

Pathak, Deepak, et al. "Context encoders: Feature learning by inpainting." Proceedings of the IEEE CVPR. 2016.

# Self-Supervised Learning - Image Recolorization

→ Use image recoloriation as auxiliary task

Zhang, Richard, et al.. "Colorful image colorization." European Conference on Computer Vision. Springer, Cham, 2016.

# Self-Supervised Learning - Image Recolorization

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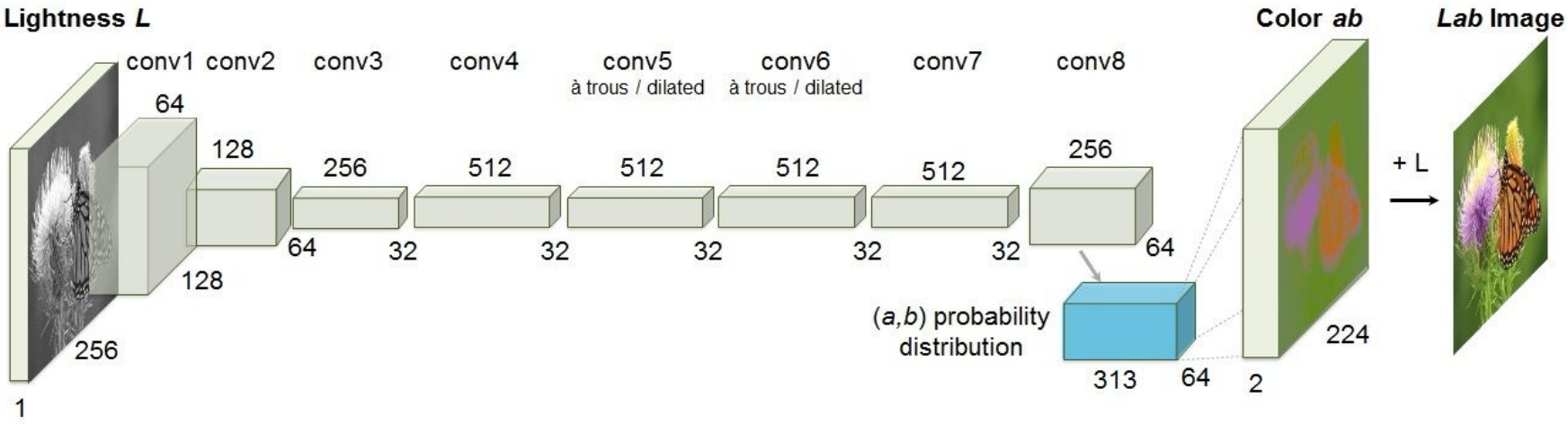


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# Self-Supervised Learning - Image Recolorization

| ImageNet Pretrained | Random Initialization | Autoencoder | Recolorization |
|---|---|---|---|
| 79.9 | 53.3 | 53.8 | 67.1 |

Classification Accuracy on the Pascal VOC dataset with different pretraining methods

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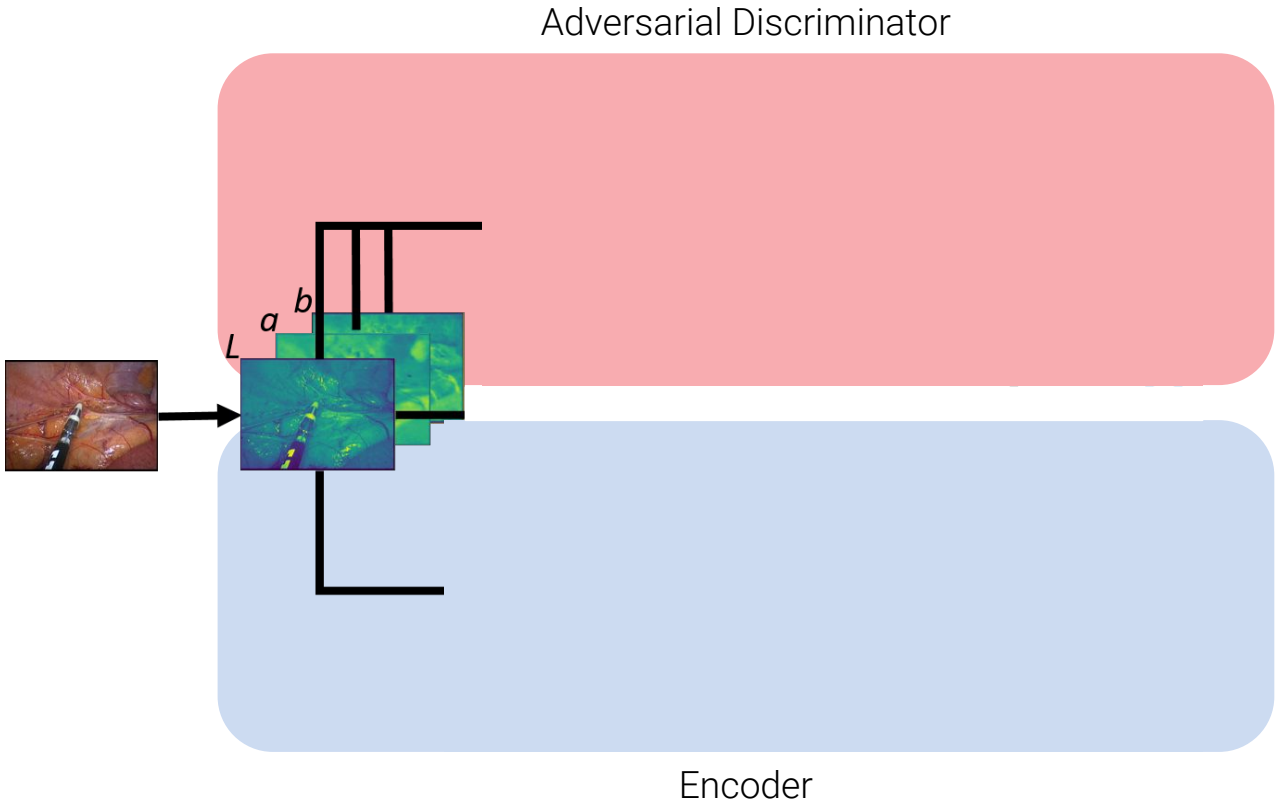
# Self-Supervised Learning - Image Recolorization

→ Application to medical

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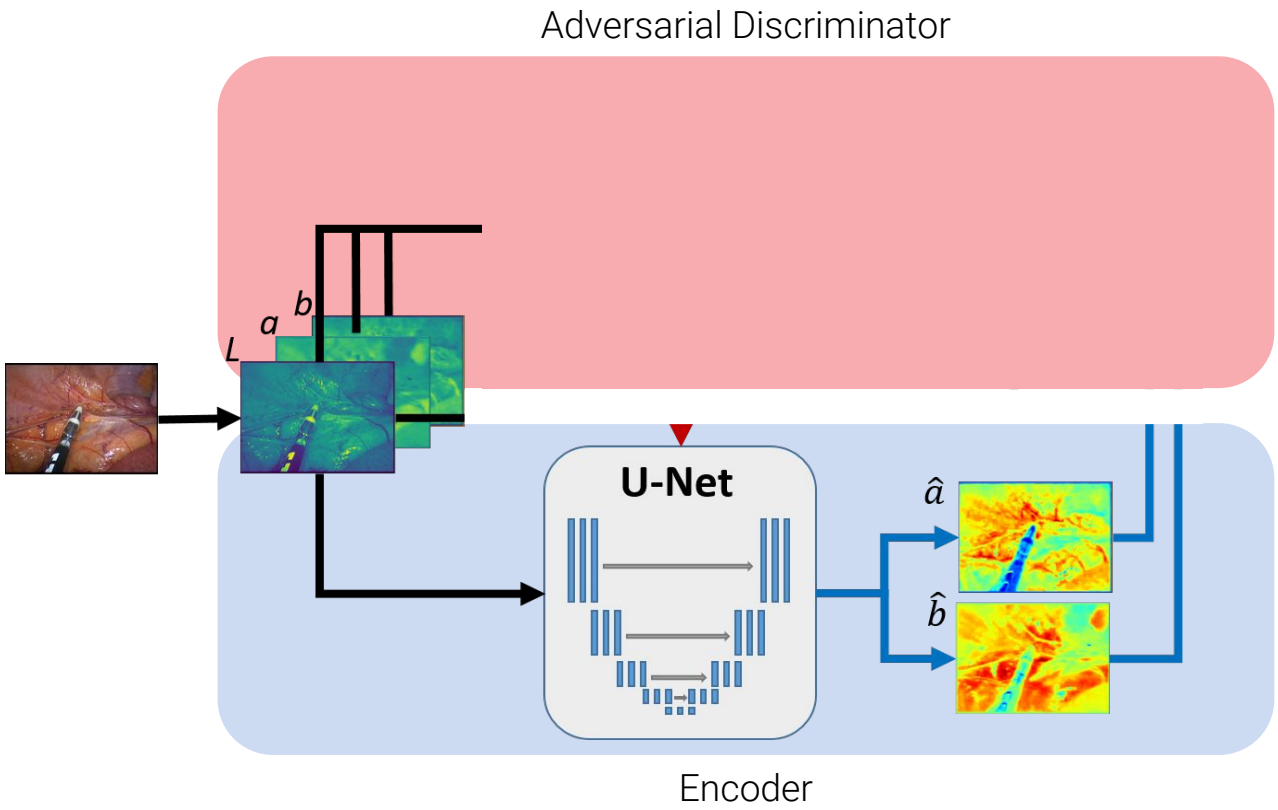


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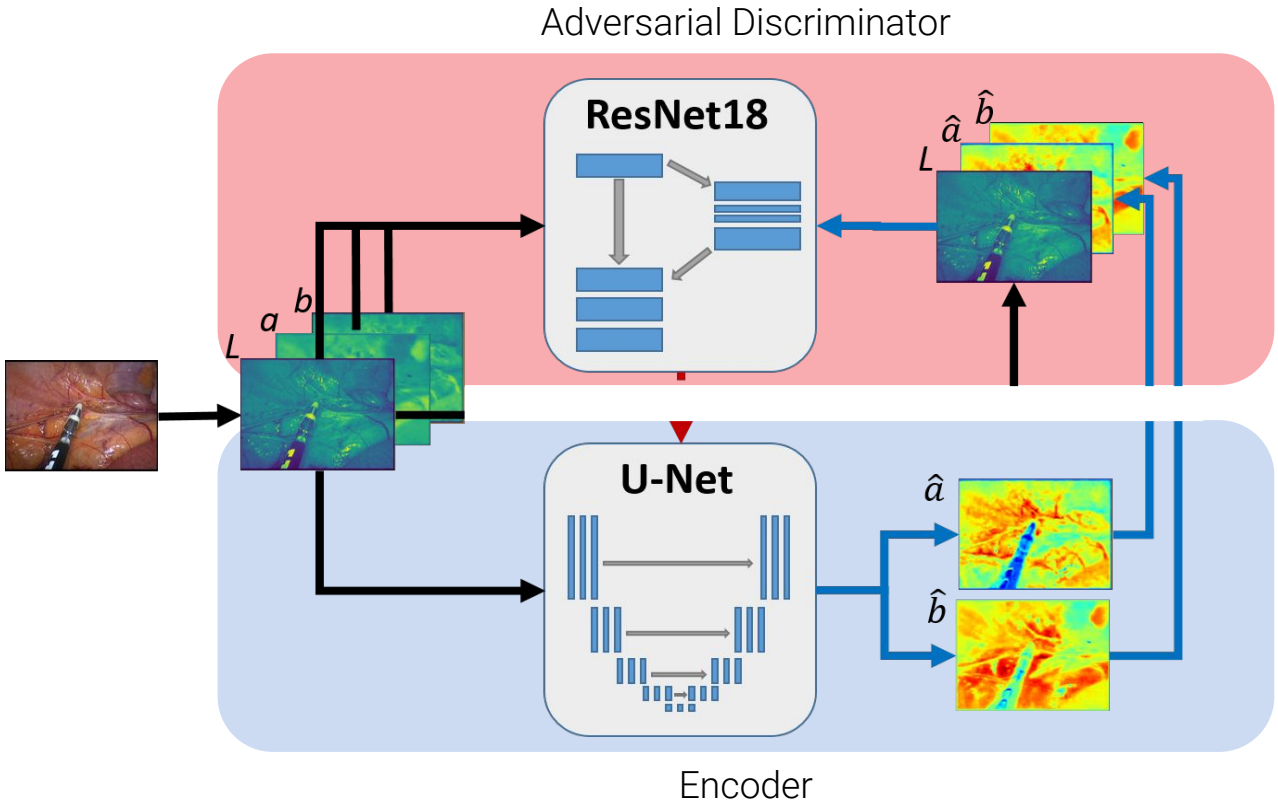


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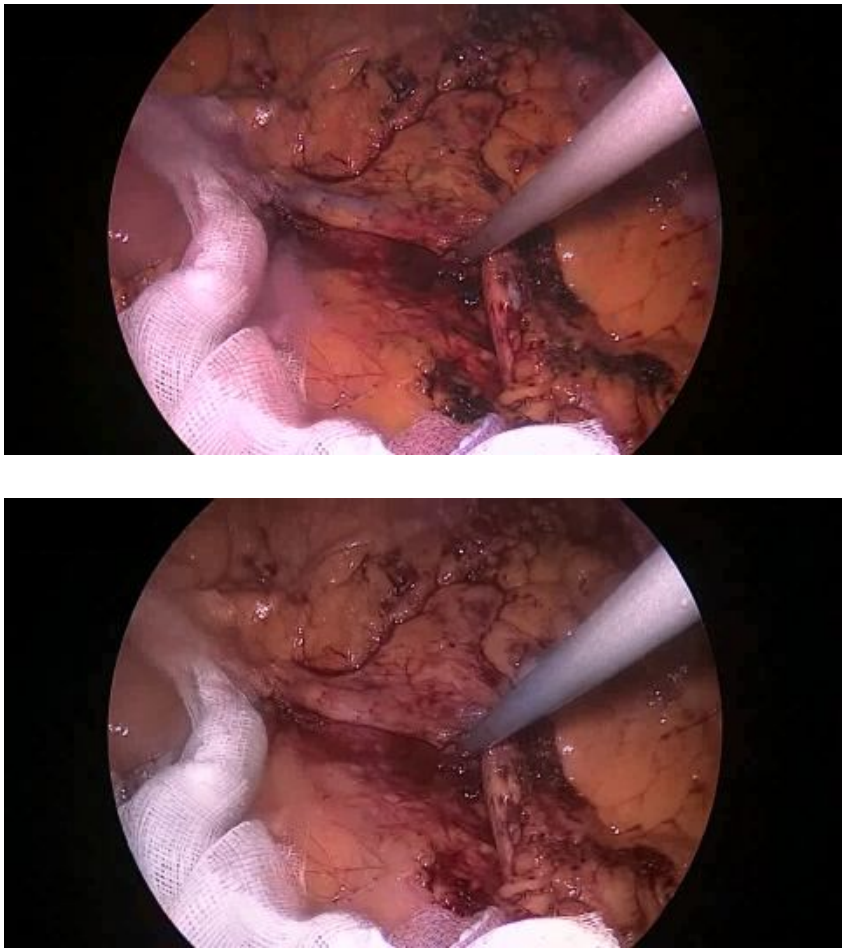

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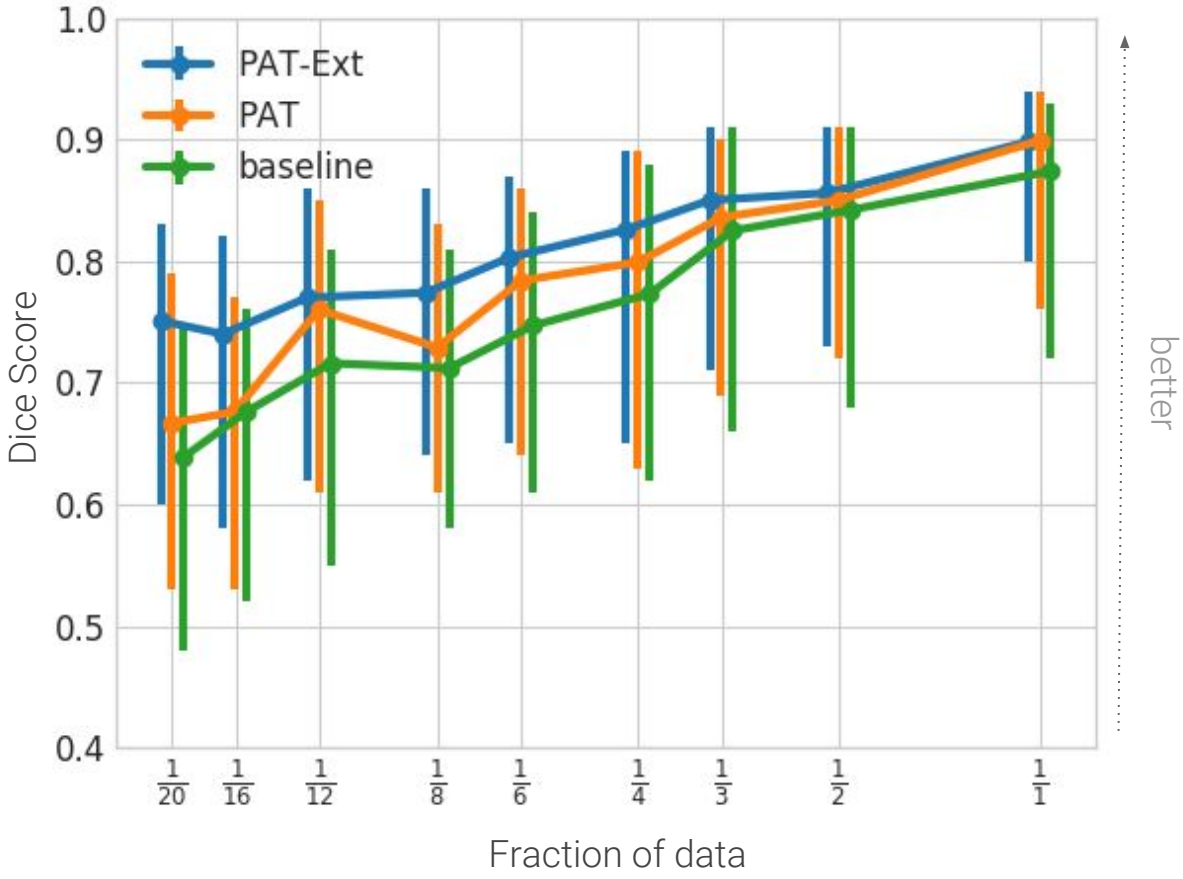


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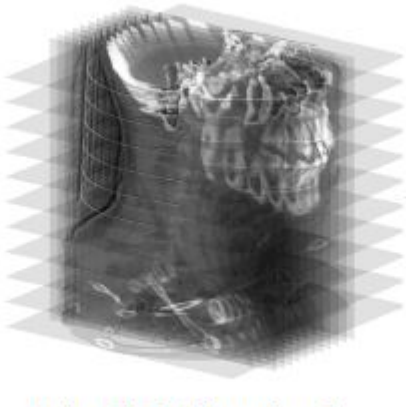
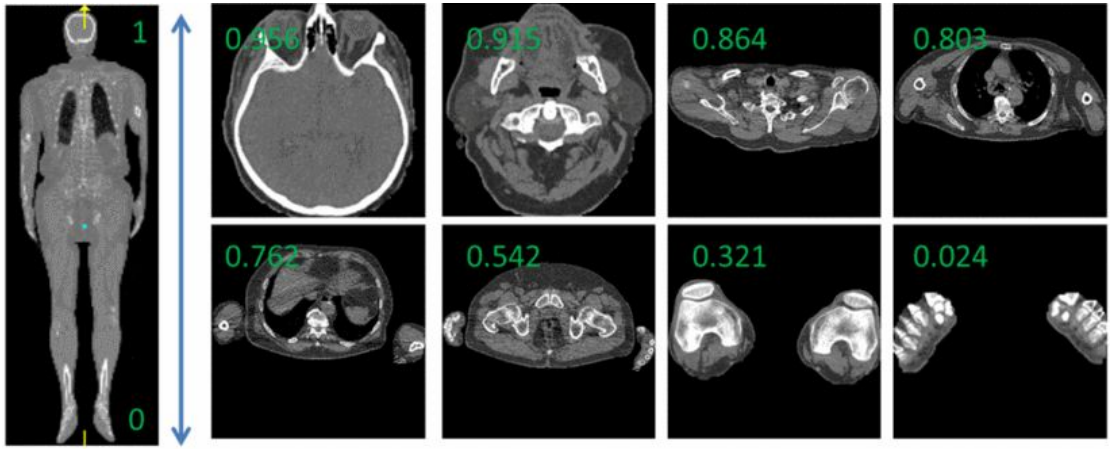
# Self-Supervised Learning - Medical Applications

→ Medical Images



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# Self-Supervised Learning - Medical Applications

→ Sorting body part (from top to toe)




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# Self-Supervised Learning - Medical Applications

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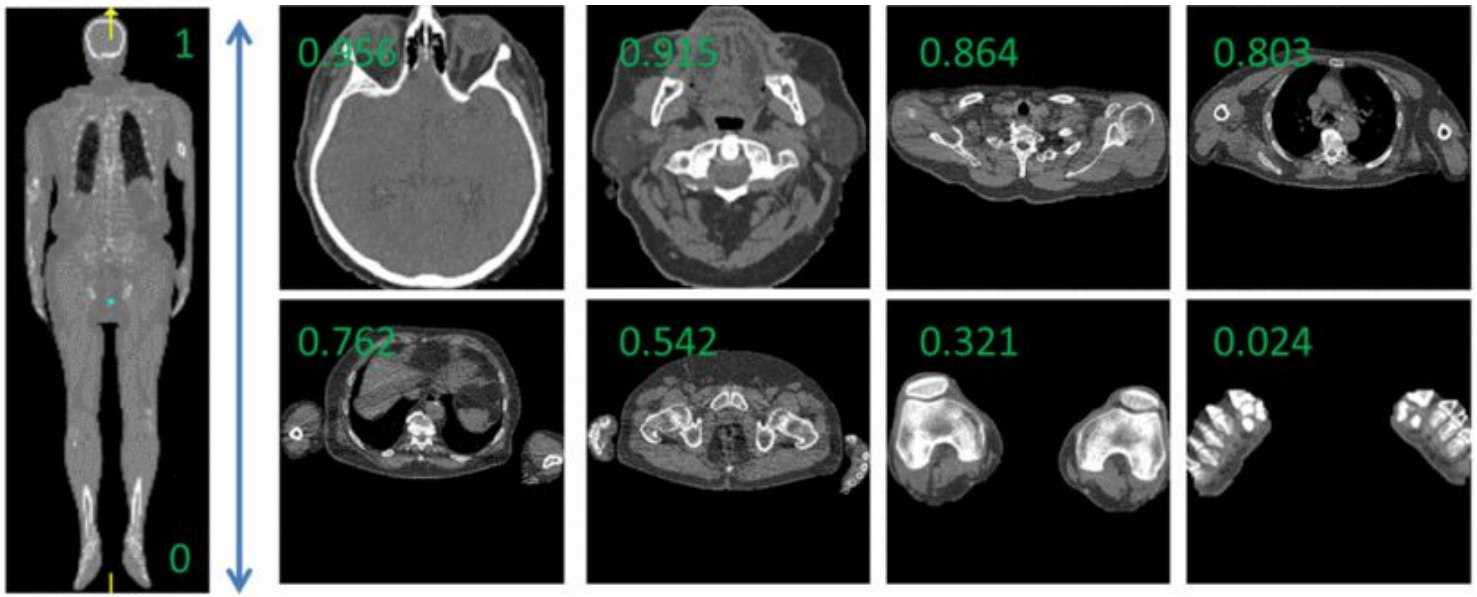


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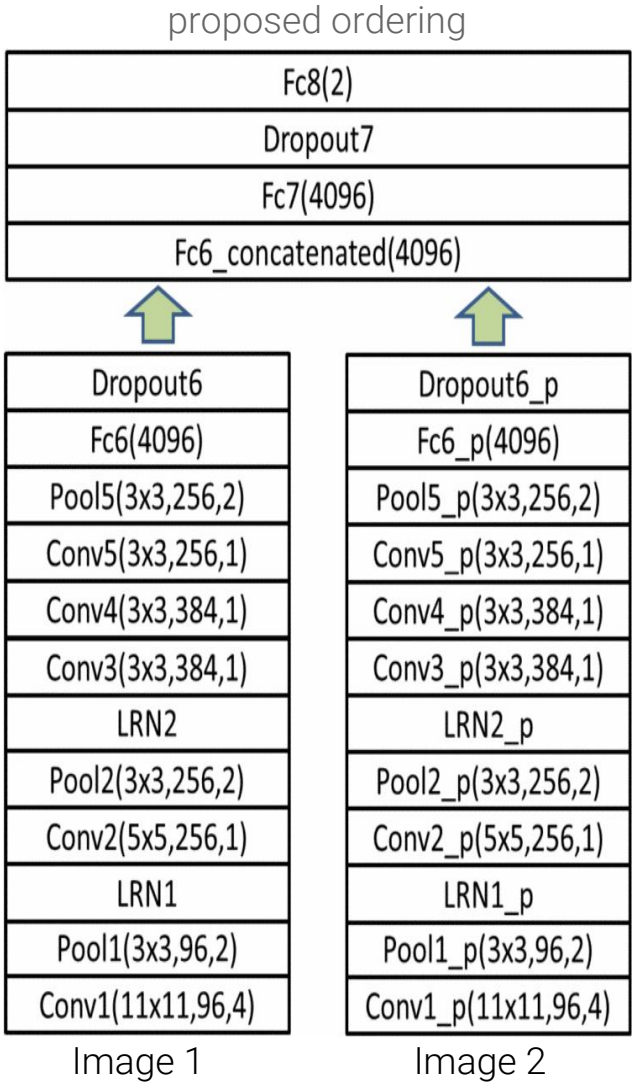


| | CT data | | | MR data | | |
|---|---|---|---|---|---|---|
| Portion of Training Set | 100% | 50% | 25% | 100% | 50% | 25% |
| AlexNet-S | **21.6** | 86.1 | 288.3 | 20.9 | 24.4 | 41.8 |
| AlexNet-F | 72.0 | 163.3 | 272.5 | 56.4 | 50.3 | 76.5 |
| Ours (P-CNN) | 25.3 | **81.2** | **229.8** | **20.1** | **24.3** | **34.9** |

Recognition error (in mm) of body part recognition on CT and MR data

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| Ours (P-CNN) | 25.3 | **81.2** | **229.8** | **20.1** | **24.3** | **34.9** |

Recognition error (in mm) of body part recognition on CT and MR data (lower is better)

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# Self-Supervised Learning - Medical Applications




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|---|---|---|---|---|---|---|
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# Self-Supervised Learning - Medical Applications

→ Differentiate between subjects




Jamaludin, Amir, et al.. "Self-Supervised Learning for Spinal MRIs." Deep Learning in Medical Image Analysis and Multimodal Learning for Clinical Decision Support. Springer, Cham, 2017. 294-302.

# Self-Supervised Learning - Medical Applications

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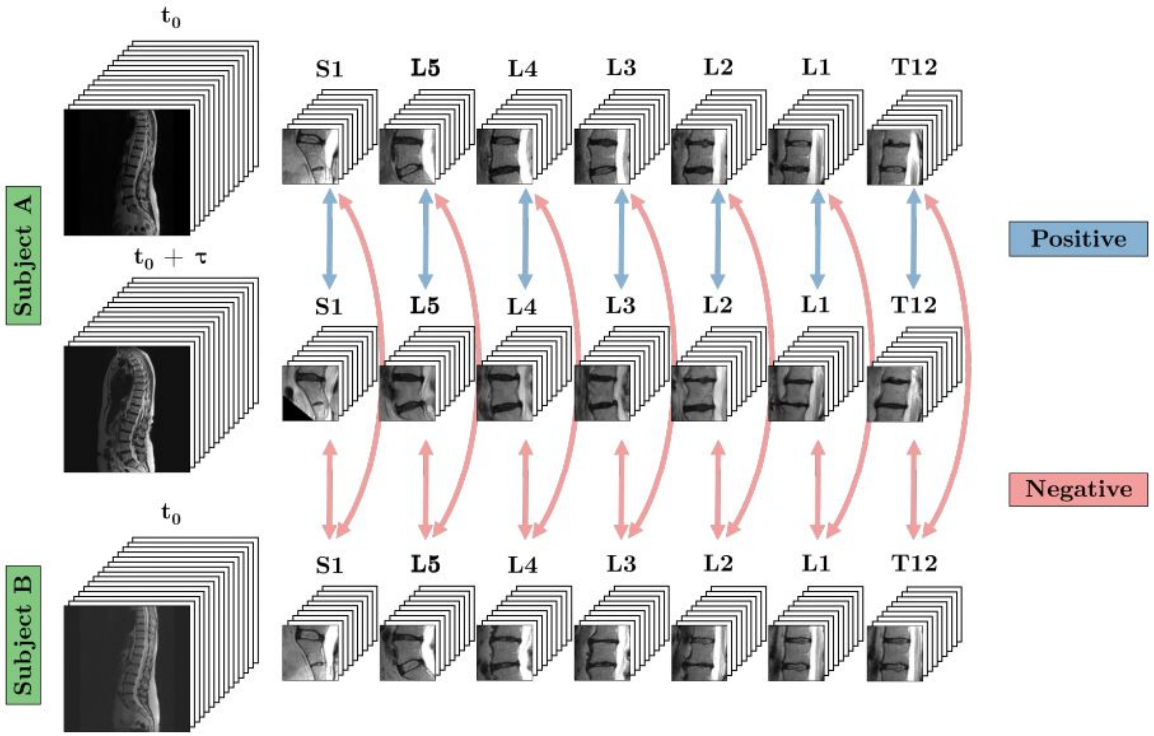


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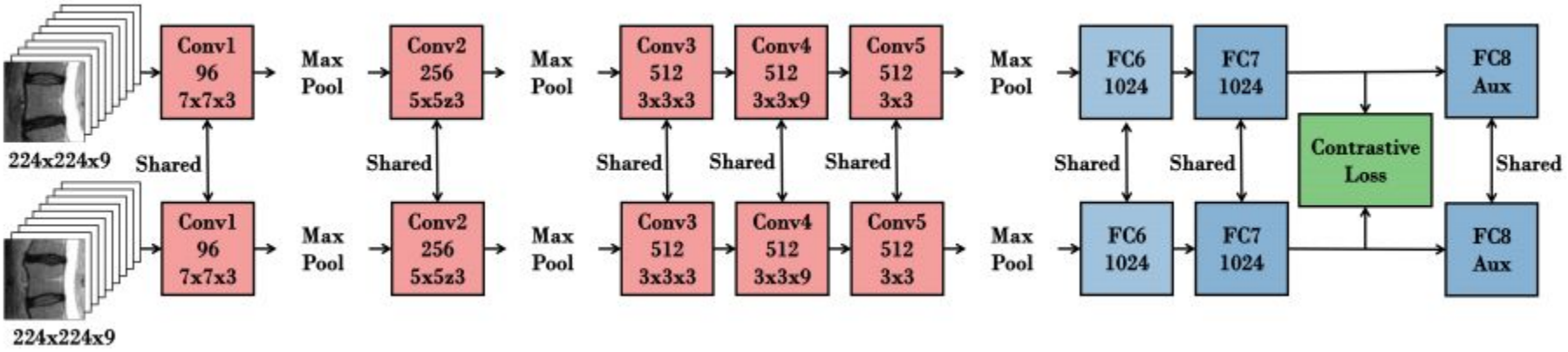


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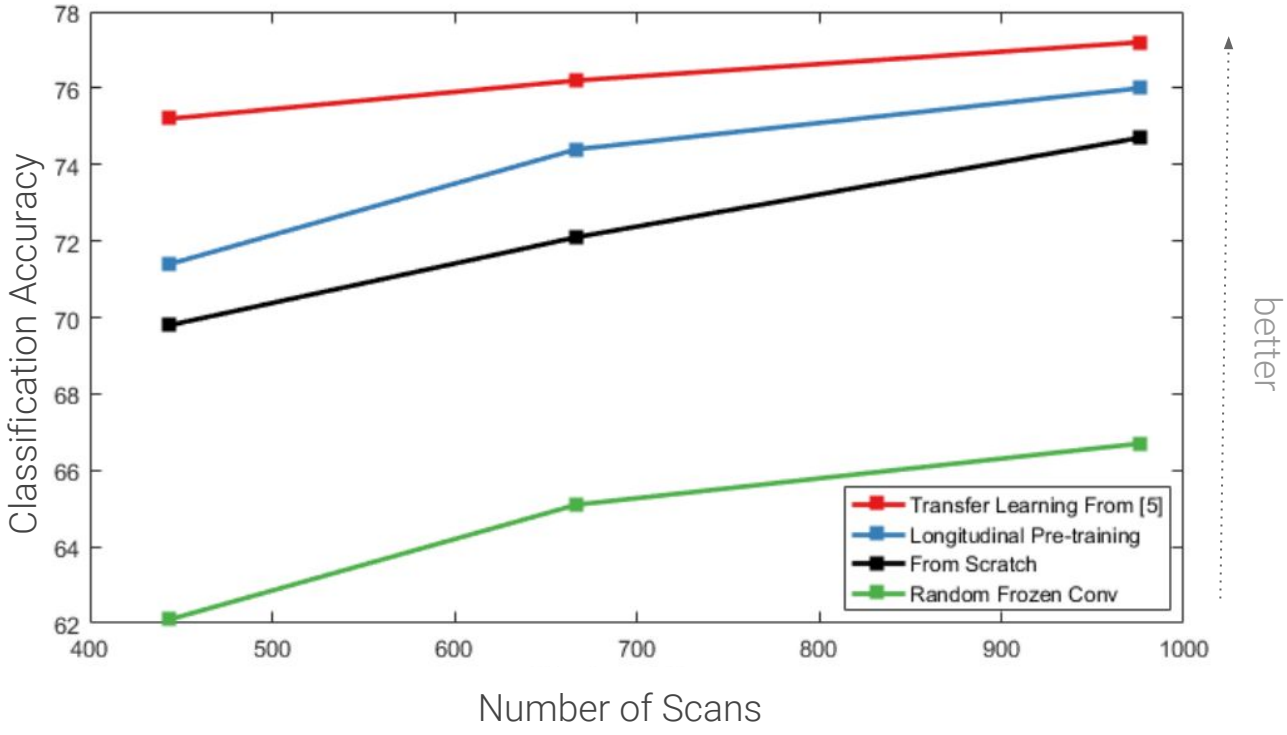


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# Semi-Supervised Learning - 🔥💩

*“Mean teachers are better role models”*

Tarvainen, Antti, and Harri Valpola. "Weight-averaged consistency targets improve semi-supervised deep learning results."arXiv:1703.01780 (2017).

# Semi-Supervised Learning - 🔥💩

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Student


Teacher

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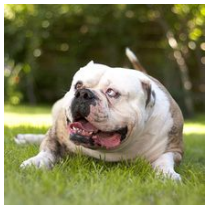

Input

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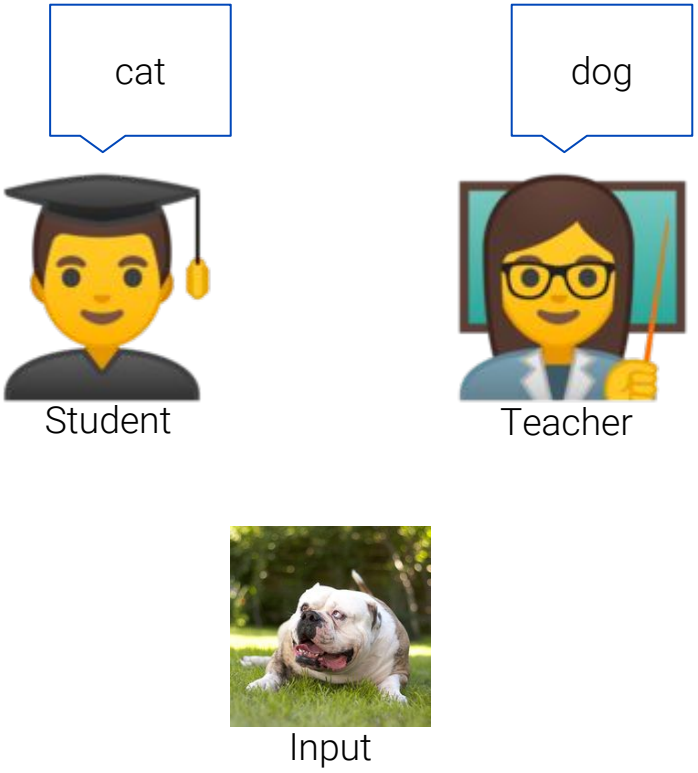


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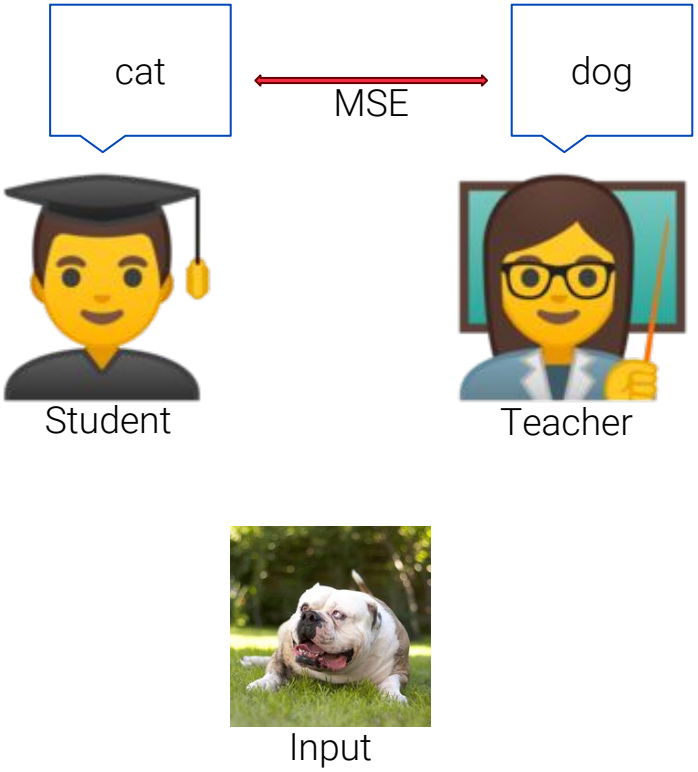


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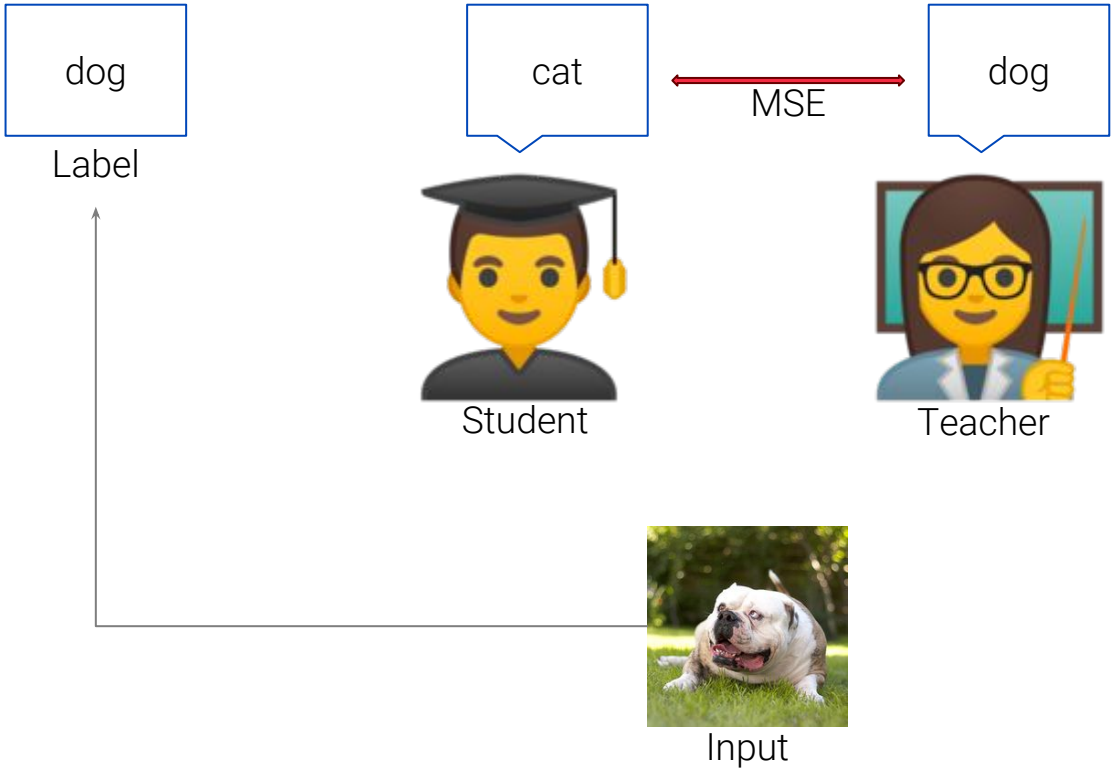


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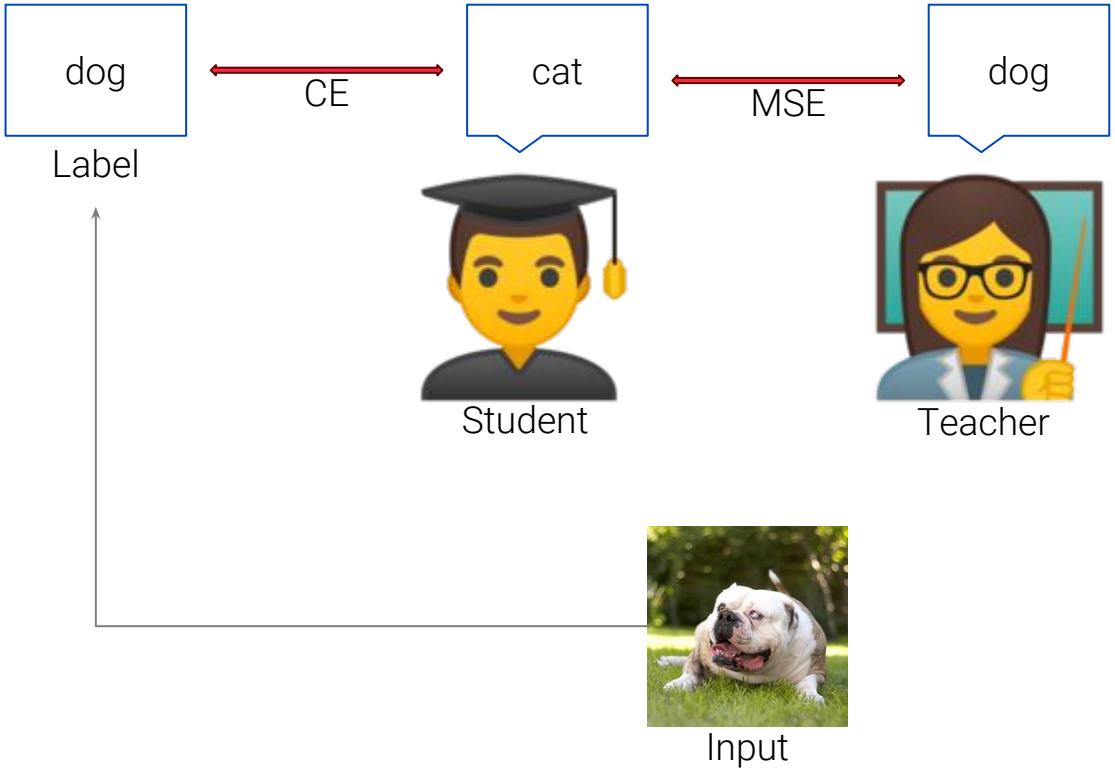


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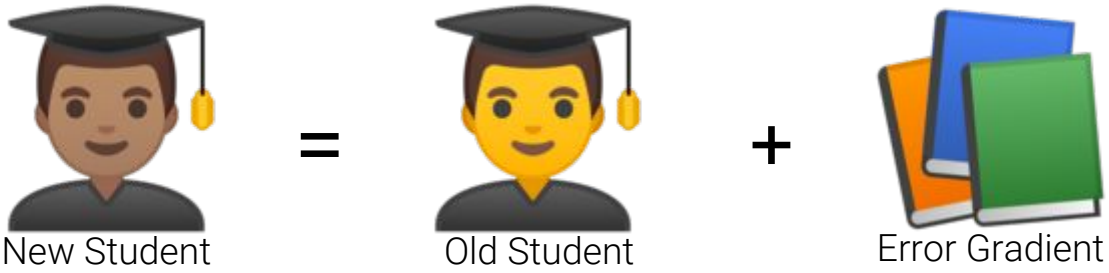


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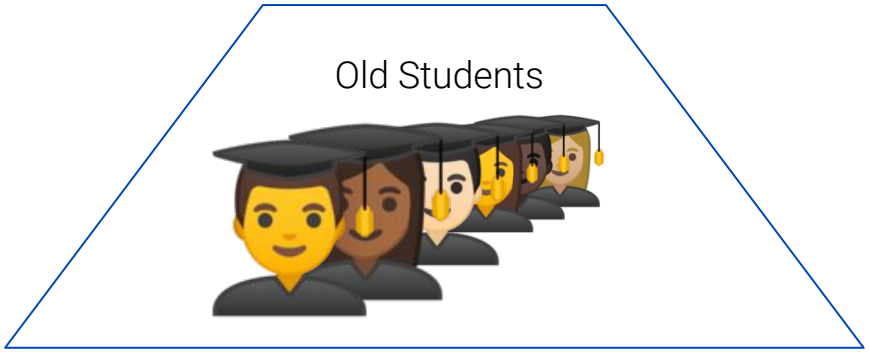
Teacher

=




Weighted Sum

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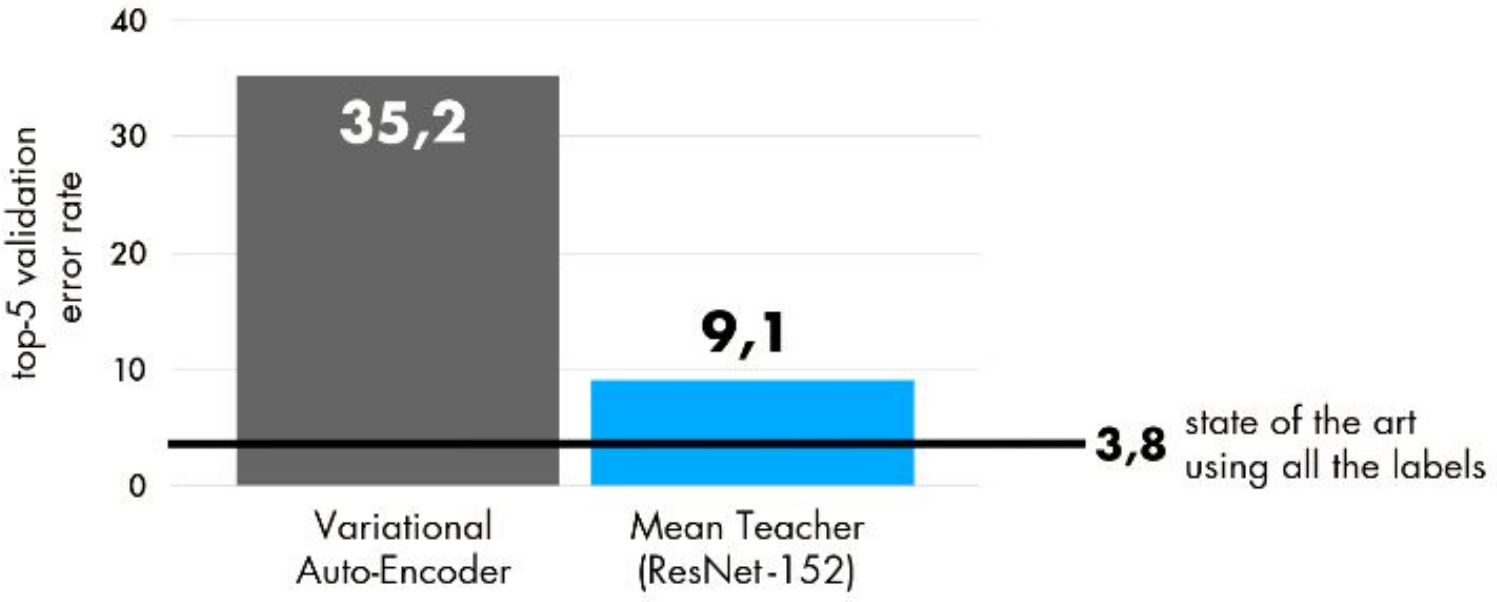


Top-5 validation error on Imagenet with 10% of the labels (lower is better)

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# Thanks !

# References


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