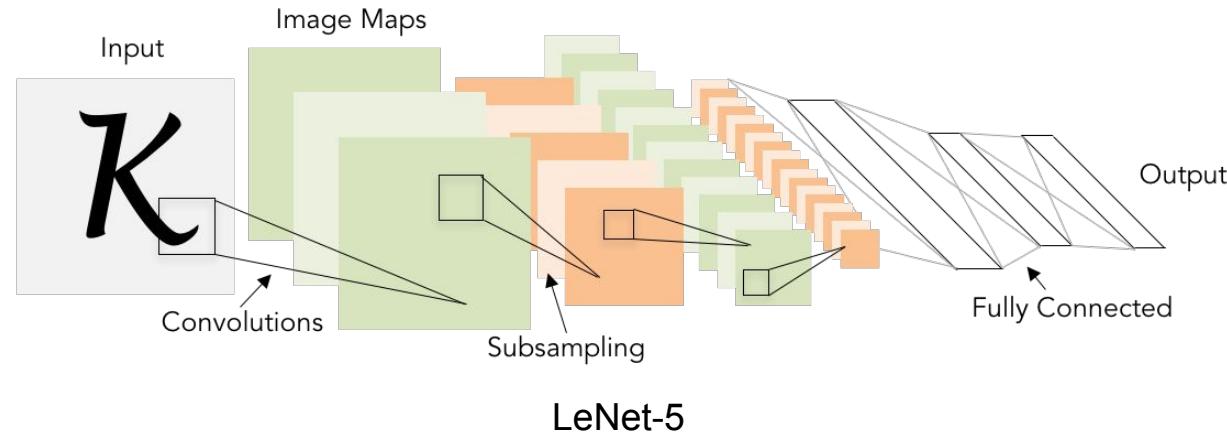


Lecture 5: Convolutional Neural Networks

A bit of history: Gradient-based learning applied to document recognition

[LeCun, Bottou, Bengio, Haffner 1998]



A bit of history: ImageNet Classification with Deep Convolutional Neural Networks *[Krizhevsky, Sutskever, Hinton, 2012]*

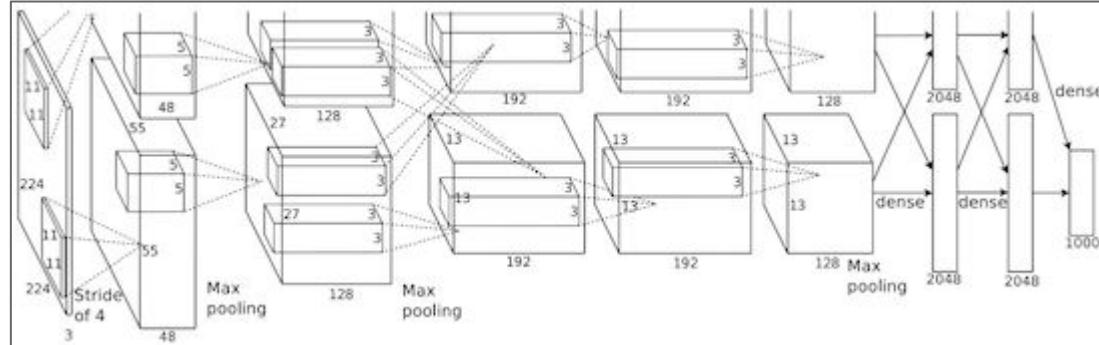


Figure copyright Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton, 2012. Reproduced with permission.

“AlexNet”

Fast-forward to today: ConvNets are everywhere

Classification



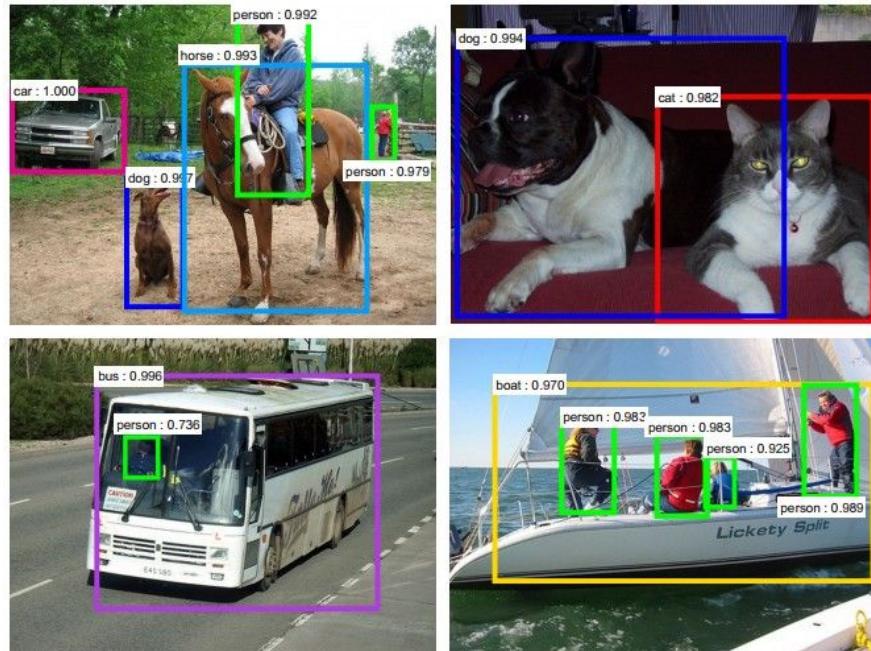
Retrieval



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Fast-forward to today: ConvNets are everywhere

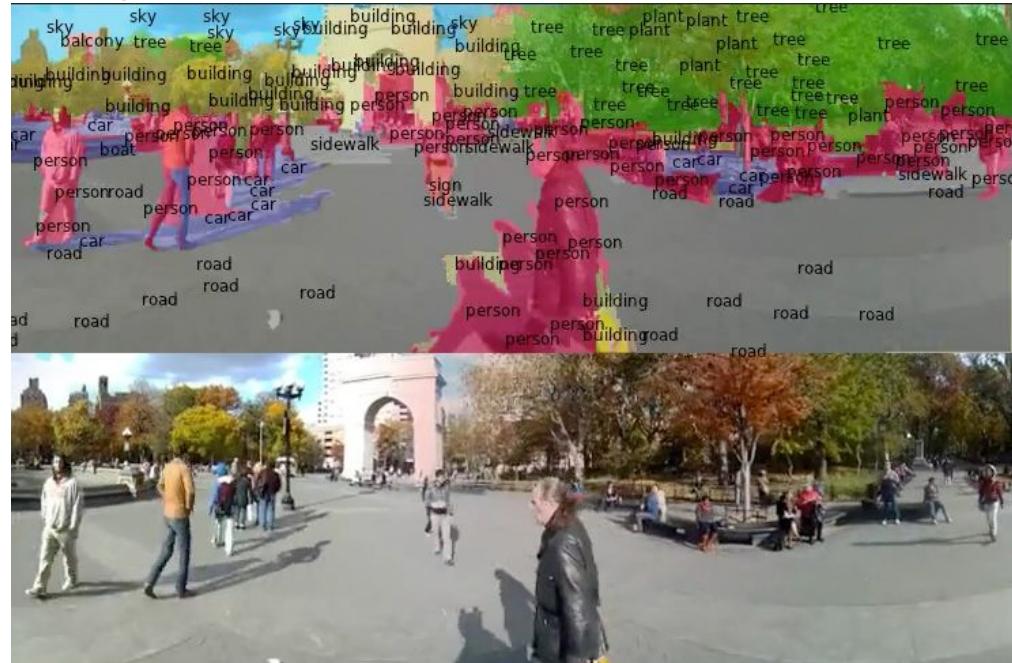
Detection



Figures copyright Shaoqing Ren, Kaiming He, Ross Girshick, Jian Sun, 2015. Reproduced with permission.

[*Faster R-CNN: Ren, He, Girshick, Sun 2015*]

Segmentation



Figures copyright Clement Farabet, 2012.
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[*Farabet et al., 2012*]

Fast-forward to today: ConvNets are everywhere



self-driving cars

Photo by Lane McIntosh. Copyright CS231n 2017.



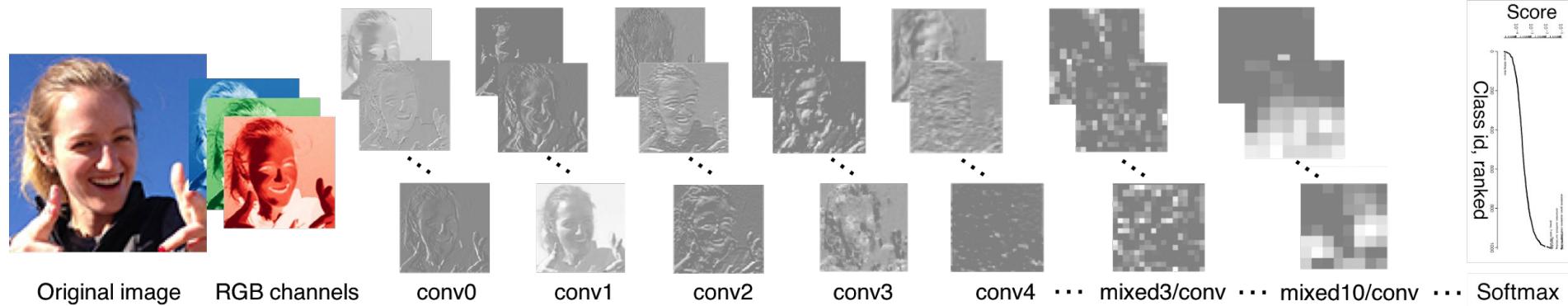
[This image](#) by GBPublic_PR is licensed under [CC-BY 2.0](#)

NVIDIA Tesla line

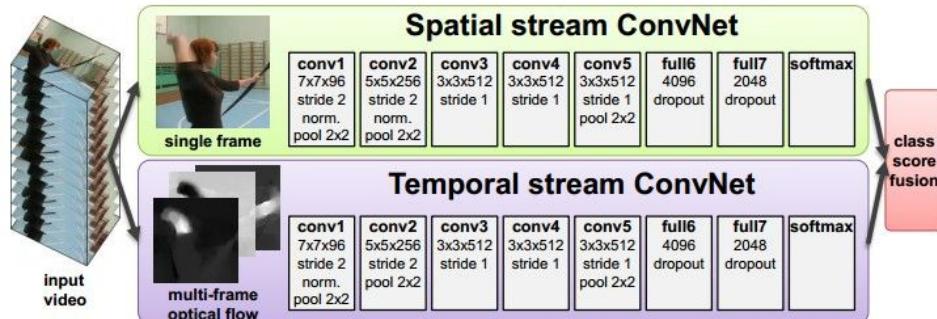
(these are the GPUs on rye01.stanford.edu)

Note that for embedded systems a typical setup would involve NVIDIA Tegras, with integrated GPU and ARM-based CPU cores.

Fast-forward to today: ConvNets are everywhere



[Taigman et al. 2014]

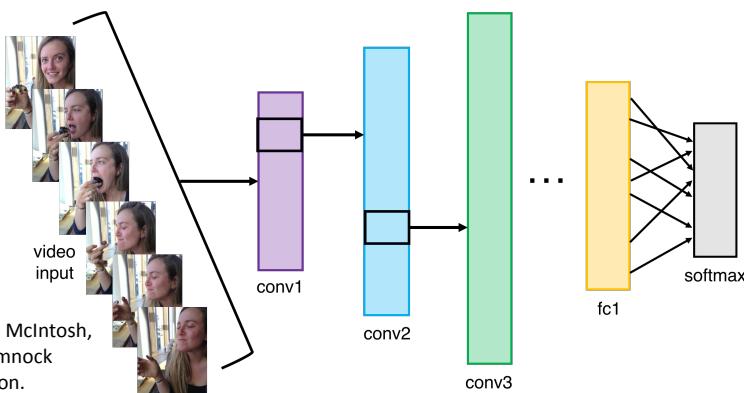


[Simonyan et al. 2014]

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Activations of [inception-v3 architecture](#) [Szegedy et al. 2015] to image of Emma McIntosh, used with permission. Figure and architecture not from Taigman et al. 2014.

Illustration by Lane McIntosh,
photos of Katie Cumnock
used with permission.

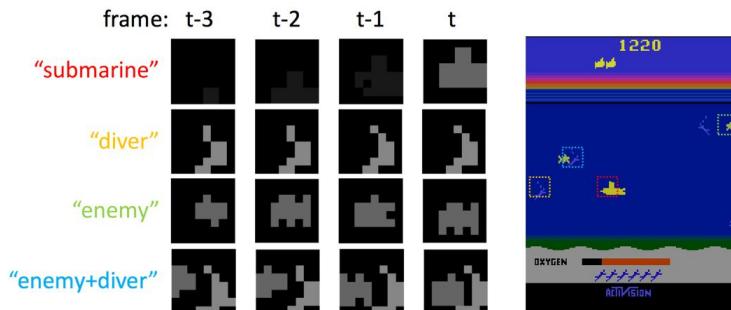


Fast-forward to today: ConvNets are everywhere



Images are examples of pose estimation, not actually from Toshev & Szegedy 2014. Copyright Lane McIntosh.

[Toshev, Szegedy 2014]

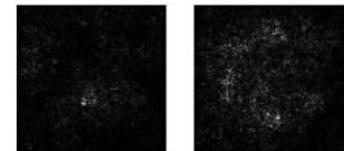
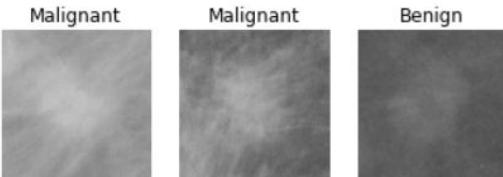
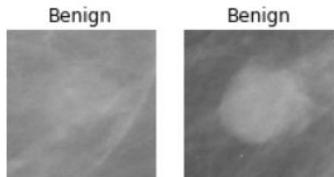


[Guo et al. 2014]



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Fast-forward to today: ConvNets are everywhere



[Levy et al. 2016]

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[Dieleman et al. 2014]

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Photos by Lane McIntosh.
Copyright CS231n 2017.

[Sermanet et al. 2011]
[Ciresan et al.]

[This image](#) by Christin Khan is in the public domain and originally came from the U.S. NOAA.



Whale recognition, Kaggle Challenge

Photo and figure by Lane McIntosh; not actual example from Mnih and Hinton, 2010 paper.



Mnih and Hinton, 2010

No errors



A white teddy bear sitting in the grass



A man riding a wave on top of a surfboard

Minor errors



A man in a baseball uniform throwing a ball



A cat sitting on a suitcase on the floor

Somewhat related



A woman is holding a cat in her hand



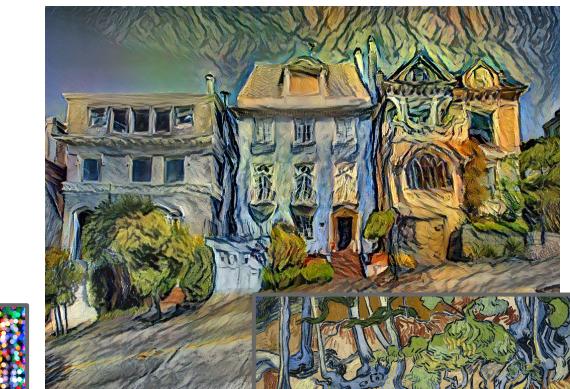
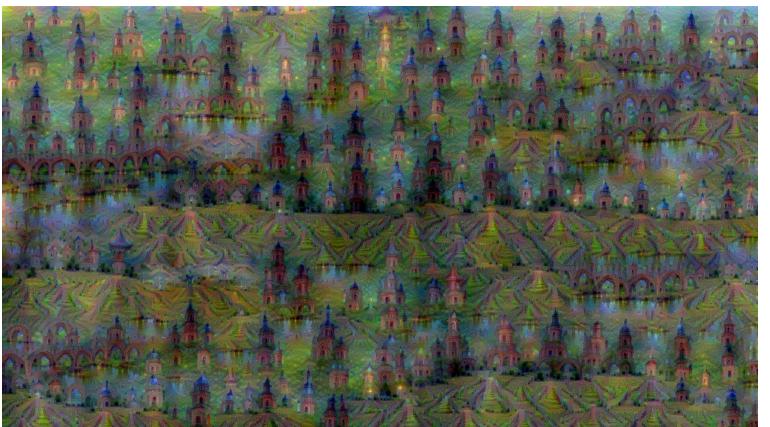
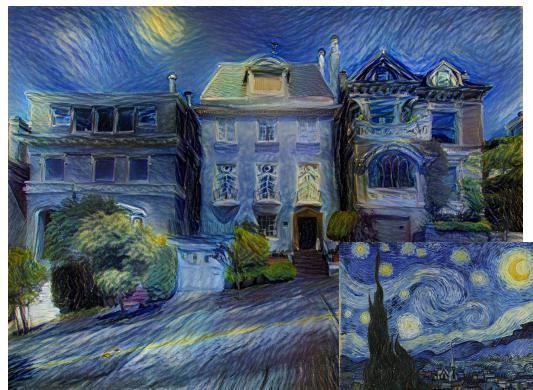
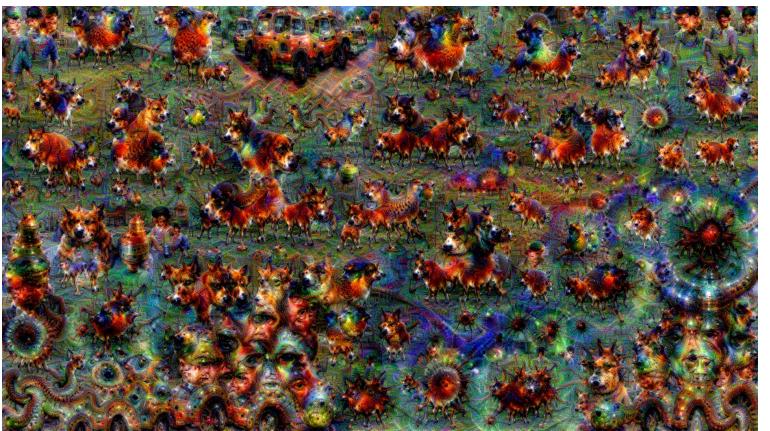
A woman standing on a beach holding a surfboard

Image Captioning

[Vinyals et al., 2015]
[Karpathy and Fei-Fei, 2015]

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<https://pixabay.com/en/luggage-antique-cat-1643010/>
<https://pixabay.com/en/teddy-plush-bears-cute-teddy-bear-1623436/>
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Captions generated by Justin Johnson using [Neuraltalk2](#)



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[Starry Night](#) and [Tree Roots](#) by Van Gogh are in the public domain

[Bokeh image](#) is in the public domain

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Gatys et al, "Image Style Transfer using Convolutional Neural Networks", CVPR 2016
Gatys et al, "Controlling Perceptual Factors in Neural Style Transfer", CVPR 2017

One more thing: Transfer Learning

“You need a lot of data if you want to
train/use CNNs”

One more thing: Transfer Learning

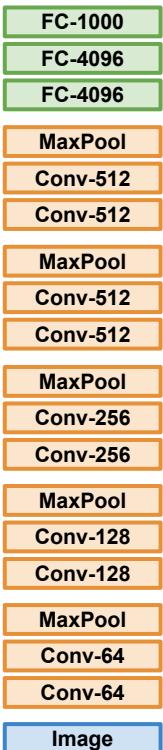
“You need a lot of data if you want to
train/use CNNs”

BUSTED

Transfer Learning with CNNs

Donahue et al, "DeCAF: A Deep Convolutional Activation Feature for Generic Visual Recognition", ICML 2014
Razavian et al, "CNN Features Off-the-Shelf: An Astounding Baseline for Recognition", CVPR Workshops 2014

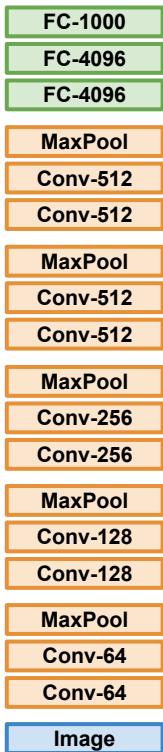
1. Train on Imagenet



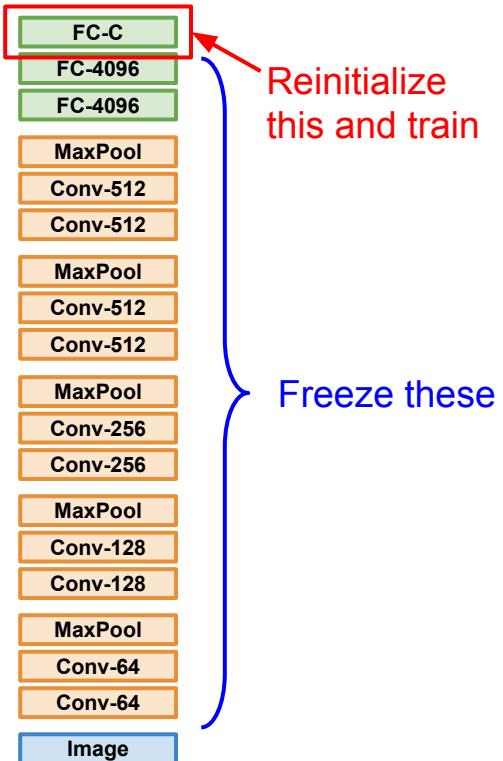
Transfer Learning with CNNs

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1. Train on Imagenet

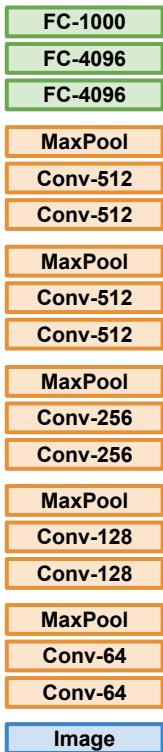


2. Small Dataset (C classes)

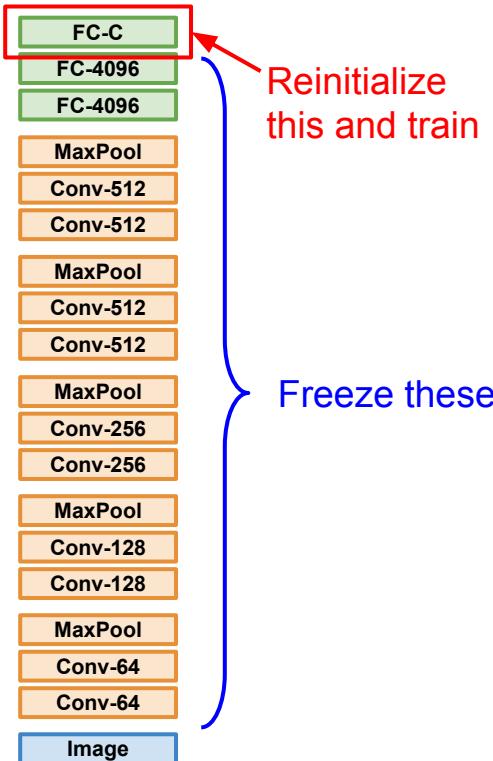


Transfer Learning with CNNs

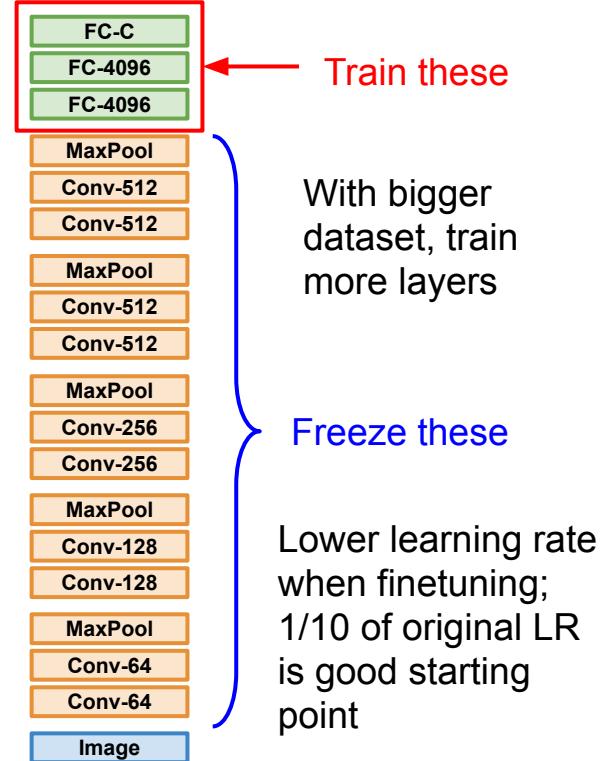
1. Train on Imagenet

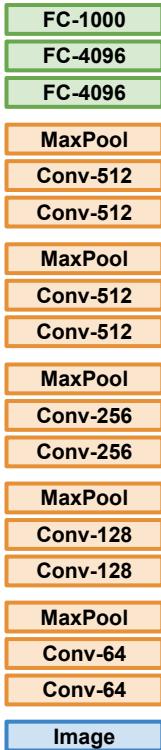


2. Small Dataset (C classes)

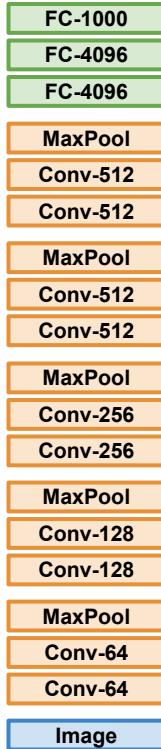


3. Bigger dataset





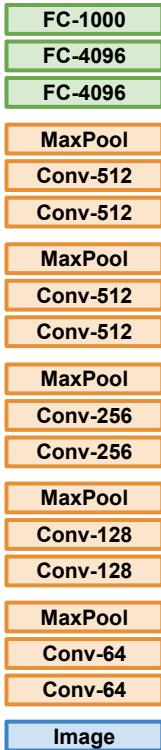
	very similar dataset	very different dataset
very little data	?	?
quite a lot of data	?	?



More specific

More generic

	very similar dataset	very different dataset
very little data	Use Linear Classifier on top layer	?
quite a lot of data	Finetune a few layers	?



	very similar dataset	very different dataset
very little data	Use Linear Classifier on top layer	You're in trouble... Try linear classifier from different stages
quite a lot of data	Finetune a few layers	Finetune a larger number of layers

Transfer learning with CNNs is pervasive... (it's the norm, not an exception)

Object Detection
(Fast R-CNN)

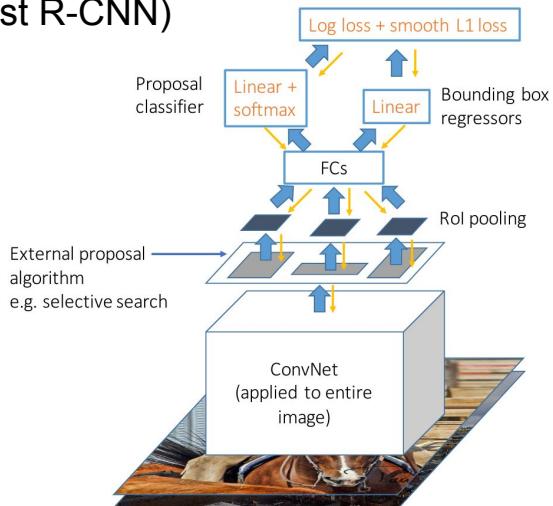
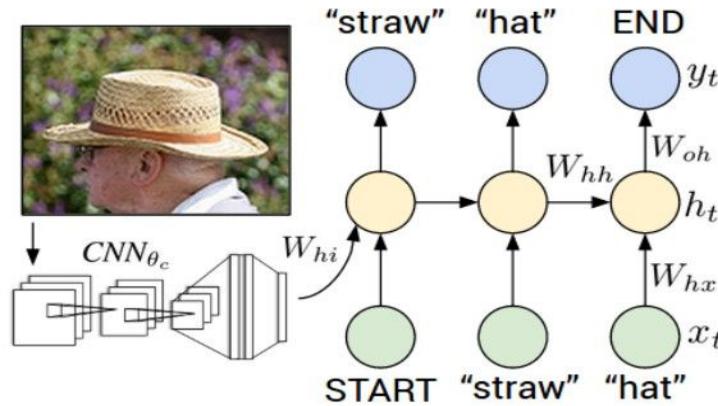


Image Captioning: CNN + RNN

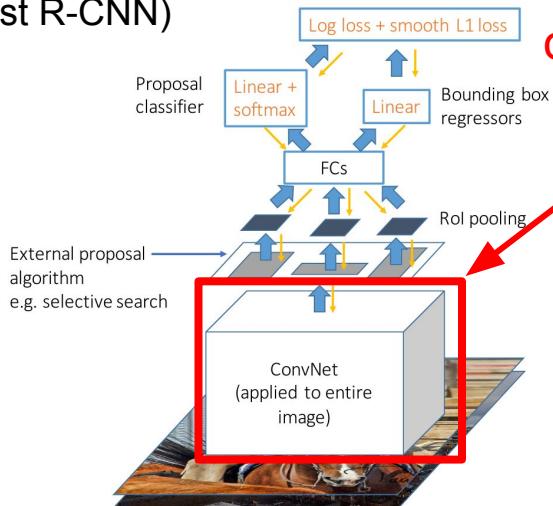


Girshick, "Fast R-CNN", ICCV 2015
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Karpathy and Fei-Fei, "Deep Visual-Semantic Alignments for Generating Image Descriptions", CVPR 2015
Figure copyright IEEE, 2015. Reproduced for educational purposes.

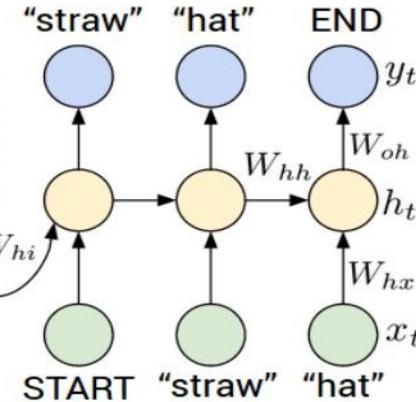
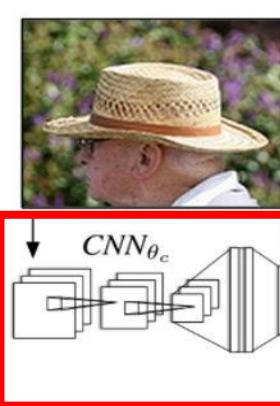
Transfer learning with CNNs is pervasive... (it's the norm, not an exception)

Object Detection
(Fast R-CNN)



CNN pretrained
on ImageNet

Image Captioning: CNN + RNN

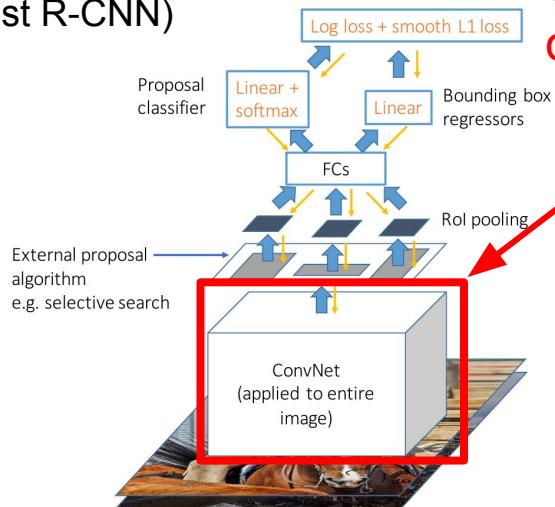


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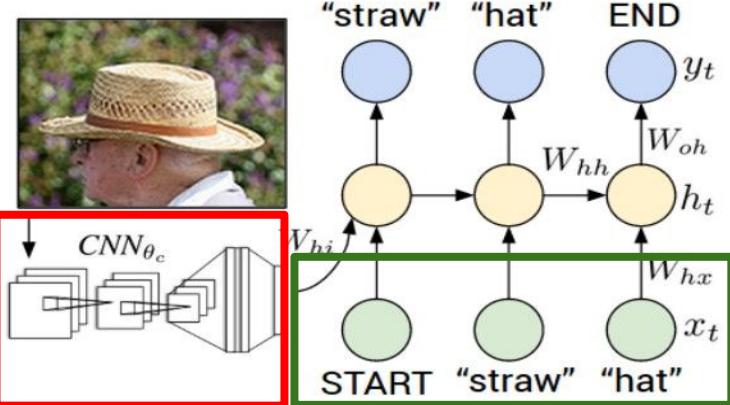
Transfer learning with CNNs is pervasive... (it's the norm, not an exception)

Object Detection
(Fast R-CNN)



CNN pretrained
on ImageNet

Image Captioning: CNN + RNN



Word vectors pretrained
with word2vec

Girshick, "Fast R-CNN", ICCV 2015
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Karpathy and Fei-Fei, "Deep Visual-Semantic Alignments for Generating Image Descriptions", CVPR 2015
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Takeaway for your projects and beyond:

Have some dataset of interest but it has < ~1M images?

1. Find a very large dataset that has similar data, train a big ConvNet there
2. Transfer learn to your dataset

Deep learning frameworks provide a “Model Zoo” of pretrained models so you don’t need to train your own

TensorFlow: <https://github.com/tensorflow/models>

PyTorch: <https://github.com/pytorch/vision>