2017 Summer Institute
Scalable Machine Learning

SDSC SAN DIEGO SUPERCOMPUTER CENTER

UC San Diego

Transfer Learning with CNN

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What is Transfer Learning?

- **To overcome challenges of training model from scratch:**
  - Insufficient data
  - Very long training time
- **Use pre-trained model**
  - Trained on another dataset
  - This serves as starting point for model
  - Then train model on current dataset for current task

Transfer Learning Approaches

- **Feature extraction**
  - Remove last fully connected layer from pre-trained model
  - Treat rest of network as feature extractor
  - Use features to train new classifier (“top model”)
- **Fine tuning**
  - Tune weights in some layers of original model (along with weights of top model)
  - Train model for current task using new dataset

CNNs for Transfer Learning

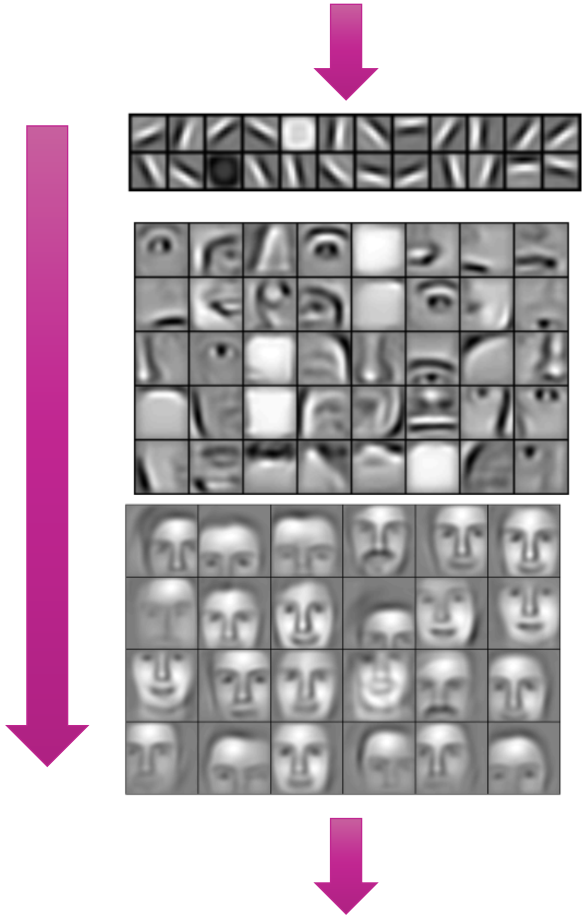
- **Popular architectures**
  - AlexNet
  - GoogLeNet
  - VGGNet
  - ResNet
- **All winners of ILSVRC**
  - ImageNet Large Scale Visual Recognition Challenge
  - Annual competition on vision tasks on ImageNet data

ImageNet

- **Database**
  - Developed for computer vision research
  - > 14,000,000 images hand-annotated
  - > 22,000 categories
- **ILSVRC History**
  - Started in 2010
  - Various vision tasks on 1,000 object categories
  - Object classification error rate
    - 2011: ~25%
    - 2012: 15.3% (AlexNet)
    - 2015: 3.57% (ResNet; better than human performance)
    - 2016: 2.99% (ensemble CNNs)

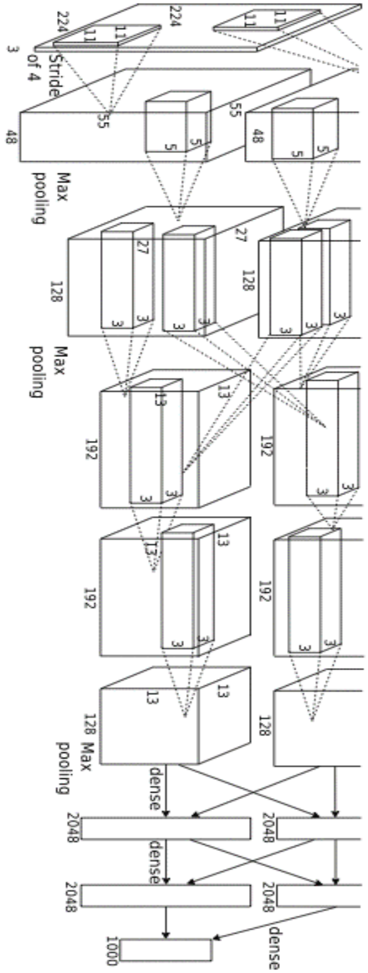
Why Does Transfer Learning Work?

Input



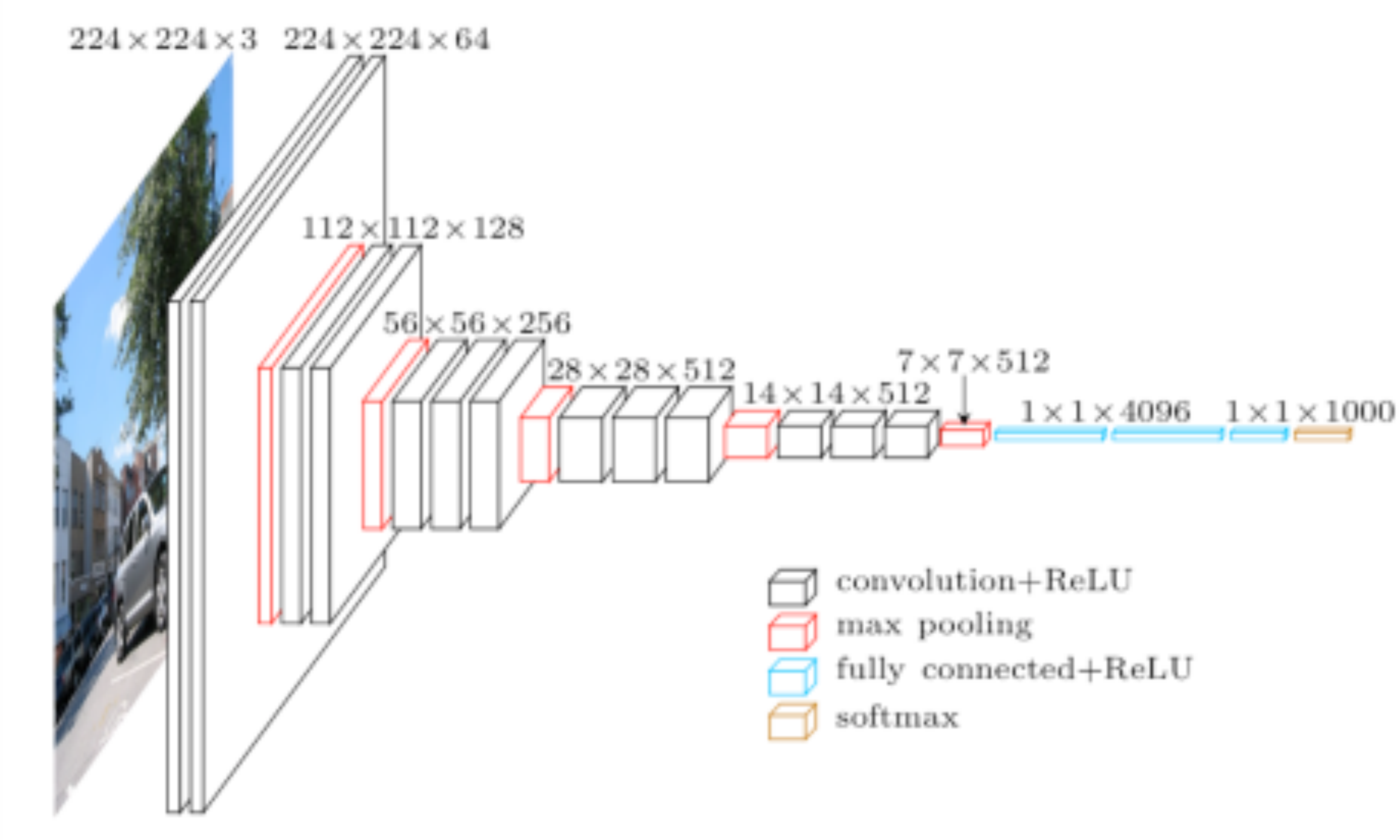
Output

Learned hierarchy



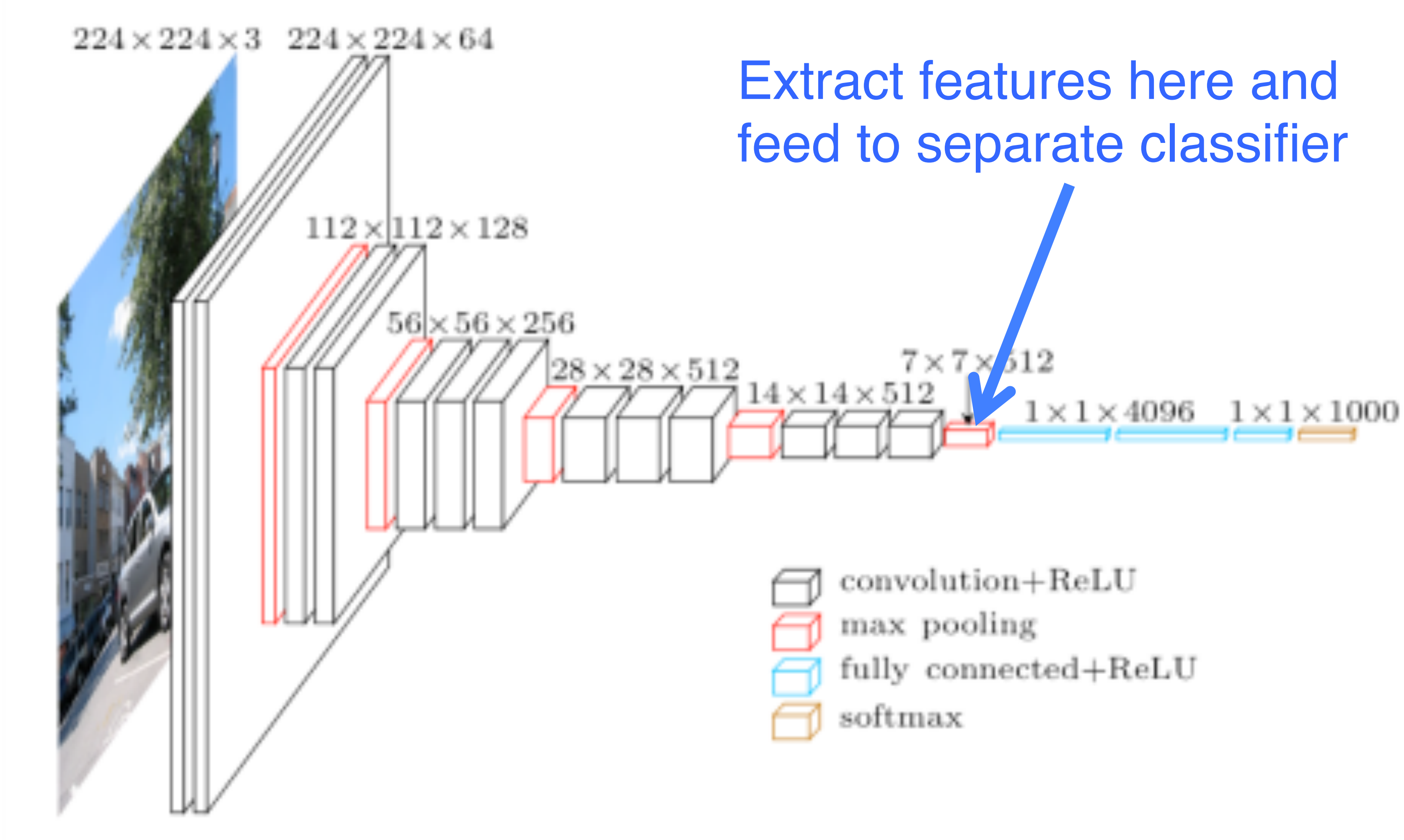
Lee et al. 'Convolutional Deep Belief Networks for Scalable Unsupervised Learning of Hierarchical Representations' ICML 2009

VGG as Pre-Trained Network



Source: https://www.cs.toronto.edu/~frossard/post/vgg16/

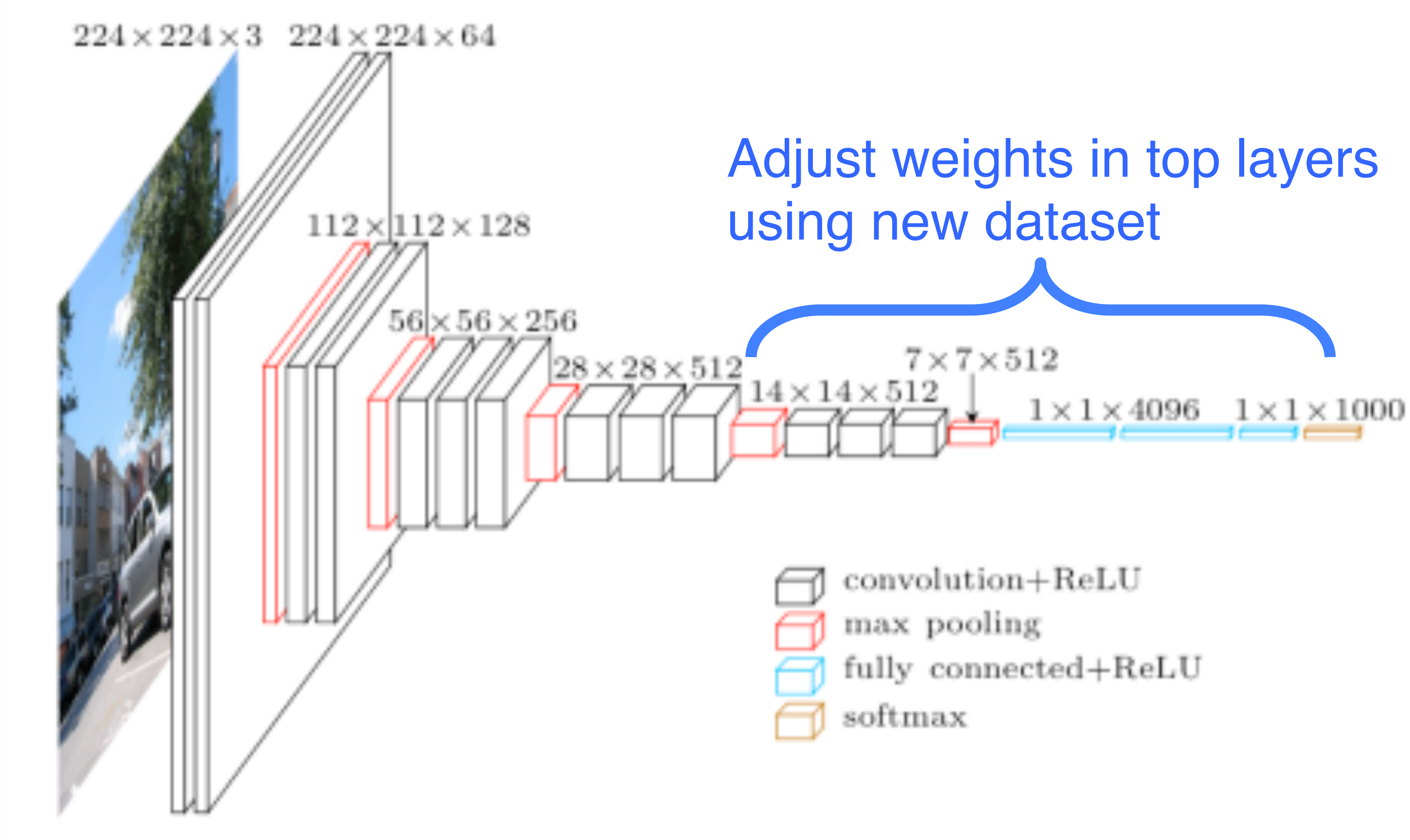
Transfer Learning – Feature Extraction



Extract features here and feed to separate classifier

Source: https://www.cs.toronto.edu/~frossard/post/vgg16/

Transfer Learning – Fine Tuning



Adjust weights in top layers using new dataset

Source: https://www.cs.toronto.edu/~frossard/post/vgg16/

When & How to Fine Tune

- **New dataset is small & similar to original dataset**
  - Extract features from higher layer and feed to separate classifier
- **New dataset is large & similar to original dataset**
  - Fine tune top or all layers
- **New dataset is small & different from original dataset**
  - Extract features from lower layer and feed to separate classifier
- **New dataset is large & different from original dataset**
  - Fine tune top or all layers

Other Practical Tips

- **Learning rate**
  - Use very small learning rate for fine tuning. Don’t want to destroy what was already learned.
- **Start with properly trained weights**
  - Train top-level classifier first, then fine tune lower layers.
  - Top model with random weights may have negative effects on when fine tuning weights in pre-trained model
- **Data augmentation**
  - Simple ways to slightly alter images
    - Horizontal/vertical flips, random crops, translations, rotations, etc.
  - Use to artificially expand your dataset

References

- F. Chollet. The Keras Blog. https://blog.keras.io/building-powerful-image-classification-models-using-very-little-data.html
- ImageNet. http://www.image-net.org/
- Transfer Learning. http://cs231n.github.io/transfer-learning/

Additional CNN Resources

- Caffe Model Zoo. http://caffe.berkeleyvision.org/model_zoo.html
- CS231n Convolutional Neural Networks for Visual Recognition. http://cs231n.github.io/
- Keras Documentation. https://keras.io/
- TensorFlow Getting Started. https://www.tensorflow.org/get_started/
- TensorFlow Neural Network Playground. http://playground.tensorflow.org/

Questions?