Lecture Notes for

Neural Networks
and Machine Learning

Deep Transfer Learning
and Demo

Logistics and Agenda

- Logistics
  - Welcome back from Snow days… Updated Schedule!
- Agenda
  - Transfer Learning in Deep Learning
  - Transfer Learning Demo
  - Town Hall
- Next Time:
  - Transformers for Text and Vision
- Next Next Time
  - Self-Supervised Learning and Consistency Loss

Last Time, ConceptNet and Transfer Learning

$$X = x_1, x_2, \ldots x_N \in \mathcal{X}$$

$$\mathscr{D} = \{\mathcal{X}, p(X)\}$$

Domain **Feature Space** **Probability Observation**

- Image Pixels
- Sensor Readings
- Natural Language
- *Almost anything that we can represent as a feature*

$$Y = y_1, y_2, \ldots y_N \in \mathcal{Y}$$

$$\mathscr{T} = \{\mathcal{Y}, p(Y|X)\}$$

Task **Label Space** **Learned Probability**

- Object Classification
- Dolphin/Shark Classification
- Sentiment Analysis
- *Any labeled task for which we might be able to build a classifier*

Transfer learning be like

Custom layers

Pretrained layers

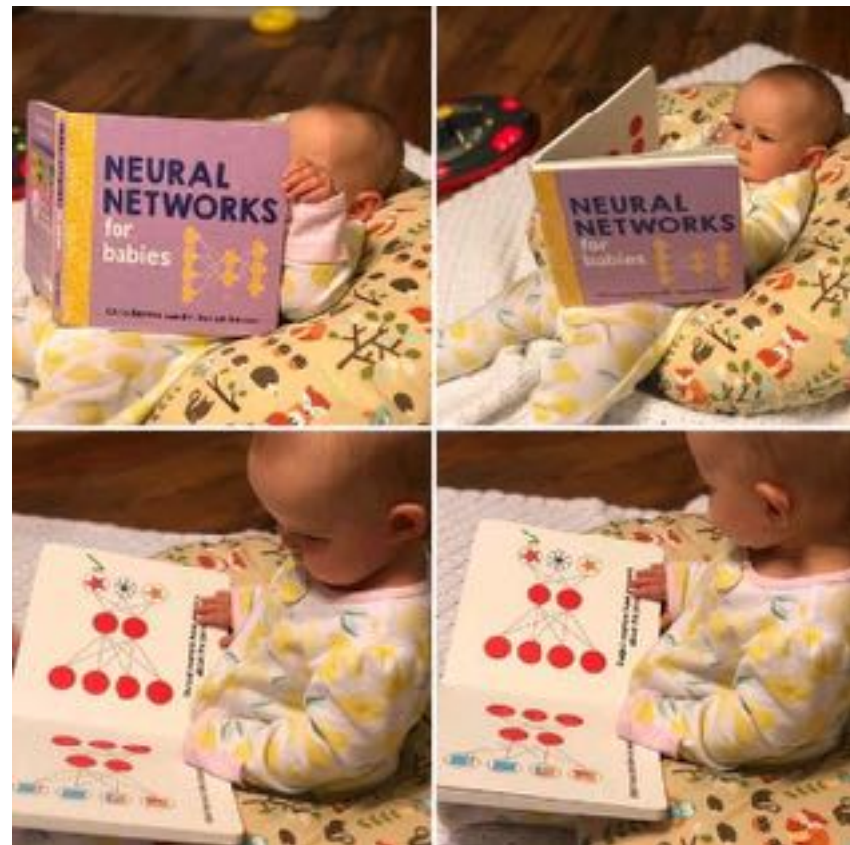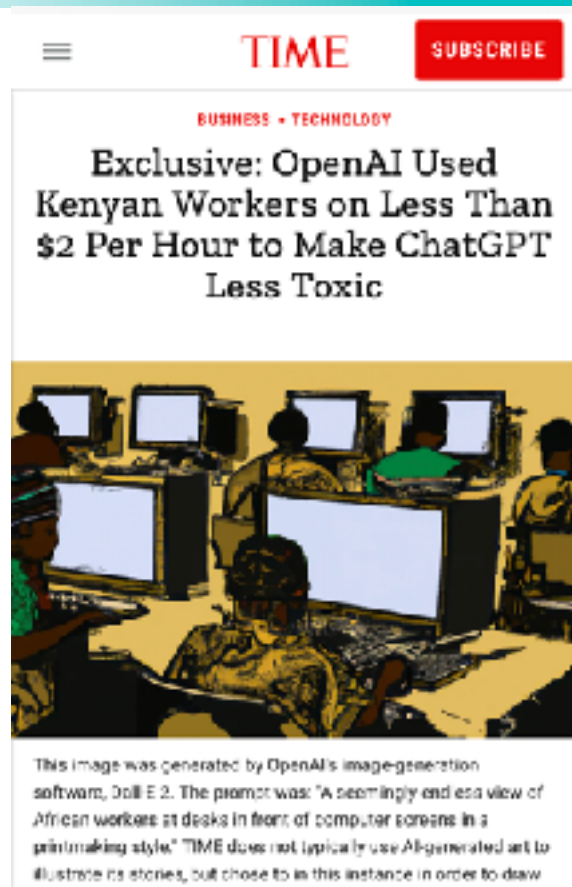# How to Make a Racist AI without Really Trying

Robyn Speer, 2017
http://blog.conceptnet.io/posts/2017/how-to-make-a-racist-ai-without-really-trying/

Lab One Town Hall

Ethical Machine Learning Bias Reduction with Neural Networks

Transfer Learning with Neural Networks

Found in a recent paper:

6   Unrelated Work

This paper is not related to [8, 23, 48, 13, 35] in any way, but we think everyone should read these papers because: (1) they're real good, (2) my friends also need those citations.

7   Related Work

Deep Transfer Learning

- Almost always **Inductive Transfer**
  - (new task , same domain, or domain adaptation)
- Almost always **Feature Representation Transfer**
  - like image pre-training
- All other topics are mostly open research topics that maybe one of you will solve!

Domain 1

Domain 2

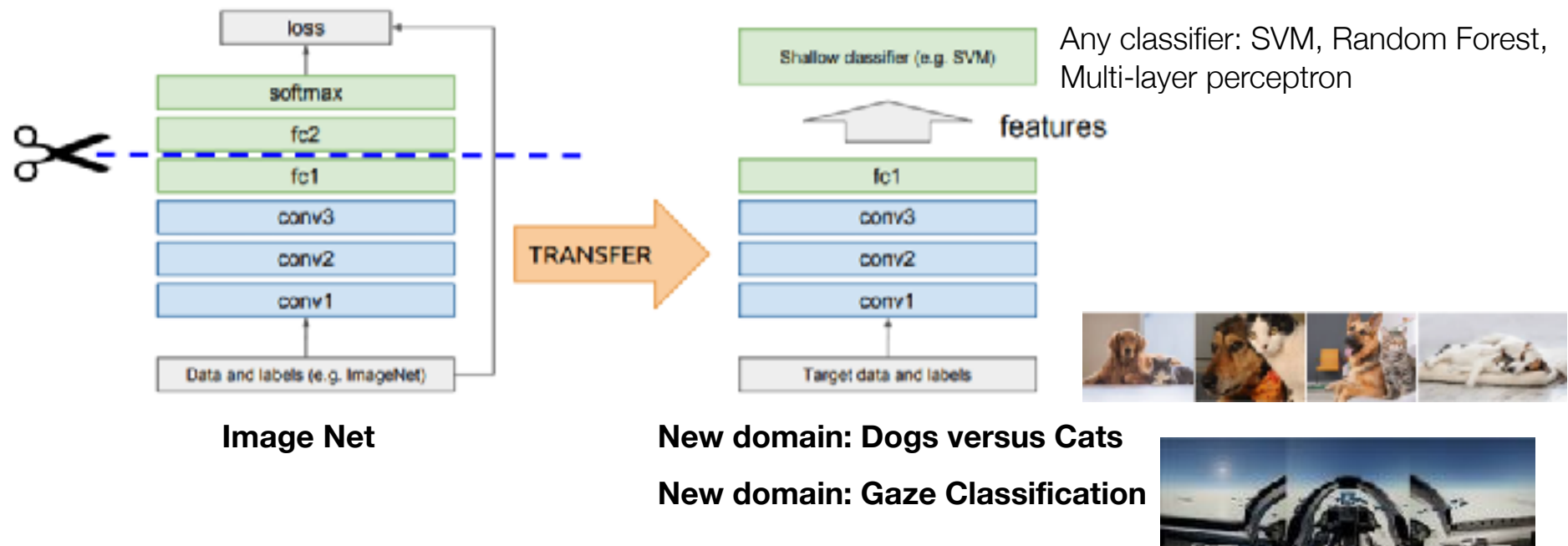(Sun, B., Feng, J., & Saenko, K. (2016). Return of Frustratingly Easy Domain Adaptation)
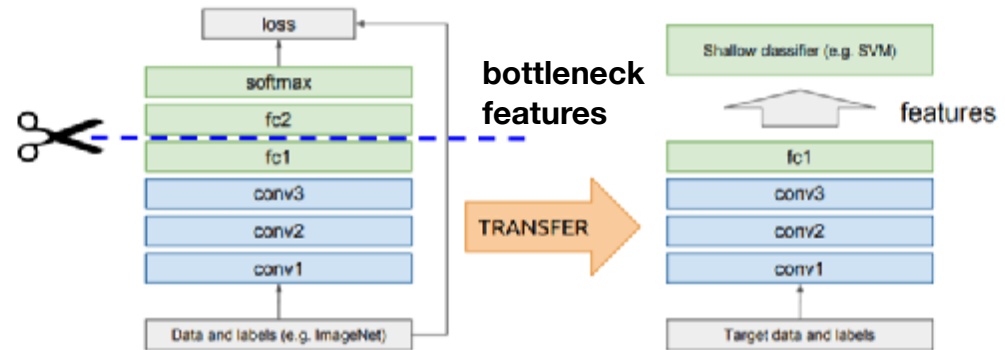
Approaches with Deep Learning

- **Feature Extraction Transfer**
    - Most well known: use learned parameters from one task in another task in same domain
    - Most useful when labels for target domain are sparse

Any classifier: SVM, Random Forest, Multi-layer perceptron

Image Net

New domain: Dogs versus Cats

New domain: Gaze Classification

Defining the Bottleneck

- Frozen training layers before bottleneck:
    - Why waste computations?
    - Computing more than one forward pass on the same data—just save them out
    - *Unless* using augmentation
- In Keras, build multiple models with different entry points
    - **Input** to **Bottleneck**
    - **Bottleneck** to **Output**
    - **Input** to **Output**


```python
inputs = Input(shape=(IMG_SIZE, IMG_SIZE, 3))
model_base = VGG(include_top=False,
                 input_tensor=inputs, weights="imagenet")
```

```python
bottleneck = Input(shape=model_base.output.shape)
outputs = Dense(NUM_CLASSES)(bottleneck)
model_top = Model(bottleneck, outputs)
```

```python
model_total = Model(inputs, outputs)
```
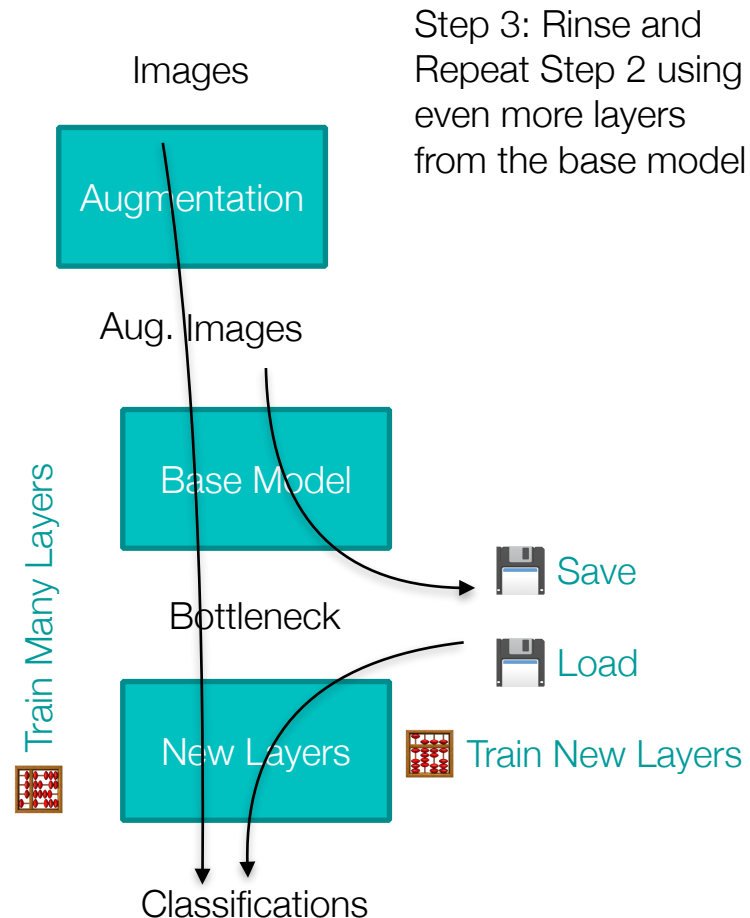
https://keras.io/examples/vision/image_classification_efficientnet_fine_tuning/

Freezing and Fine-tuning

- Step 1, Freeze base model:
  - No update during back-propagation
  - Only update layers after the bottleneck
  - *Optional: Augment a set of training data*
  - Send training dataset through base model
    - ◆ Save out bottleneck features
  - Train bottleneck features in new task
    - ◆ Typically 5-10 epochs is sufficient, easy to overfit
    - ◆ Larger training step size is okay
- Step 2, Fine-tune, unfreeze a few layers in base model:
  - *Optional: Setup images to use some type of augmentation*
  - Attach newly trained model to pre-trained model
  - Train to your hearts content, use smaller training step size

Step 3: Rinse and Repeat Step 2 using even more layers from the base model

Images

Augmentation

Aug. Images

Base Model

Bottleneck

New Layers

Classifications

Train Many Layers

💾 Save

💾 Load

Train New Layers

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Bottlenecking on a GPU

Dots versus Cats

Updated for `tf==2.9` in the Main Repository:
`02 Transfer Learning.ipynb`

Original Example: https://github.com/8000net/Transfer-Learning-Dolphins-and-Sharks

Another Great Example:
https://keras.io/examples/vision/image_classification_efficientnet_fine_tuning/

Popular Transfer Learning Models

- **Vision**:
  - Conv Architectures:
    - VGG, Inception, ResNet, Xception, EfficientNet
    - ViT: Huge ViT
- **Audio**:
  - WaveNet, VGGish
- **Text**:
  - Word Embedding
    - Glove, Word2Vec, ConceptNet
  - Sentence Embedding
    - Universal Sentence Encoders (Google)
    - BERT (Google)
    - GPT-X

- **From SMU PhD Students in my Research Lab:**
  - VGG for transferring to gaze classification
  - VGG for swapped face detection
  - Domain adaptation for speaker authentication
  - YOLO/DarkNet for surgical instrument detection
  - GLOVE for similar instructions in a maintenance manual
  - BERT for student vocabulary acquisition

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Transfer Learning

Next Time:
Transformers

Reading: None