Single GPU Classifier

Deep Learning / AI Tasks

- OCR and scene text
- visual object recognition
- speech recognition
- medical classification and prediction
- stock market classification and prediction
- image synthesis / graphics
- control and robotics

Example: Imagenet

- data
  - collection of 1 million images (from the web)
  - 1000 labels (manually labeled)
- task
  - predict the label from the image
  - supervised training
- model
  - deep convolutional neural network

Deep Learning Training Steps

- data collection
- data labeling
- data augmentation
- model training
- model validation
- model deployment

Model Structure

- deep learning models are composed of *layers*
- each layer usually consists of:
  - a linear operation (matrix multiplication, convolution)
  - an element-wise nonlinearity (sigmoid, tanh, ReLU)
- it is the linear operations that are computationally expensive

Simple one hidden layer network:

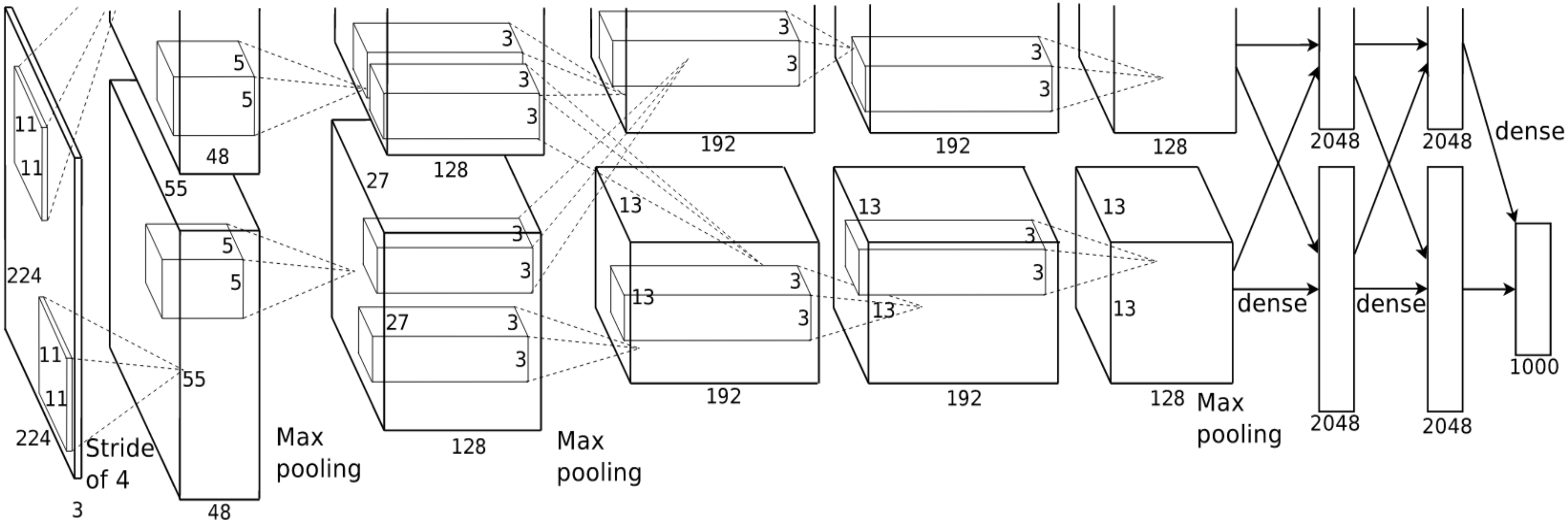
$$f(x) = \sigma(M_2 \cdot \sigma(M_1 \cdot x + b_1) + b_2)$$

Building Models from Modules in PyTorch

```
model = Sequential(
    Conv2d(3, 20),
    ReLU(),
    Conv2d(20, 40),
    ReLU(),
    Flatten(),
    Linear(40*24*24),
    ReLU()
)
```

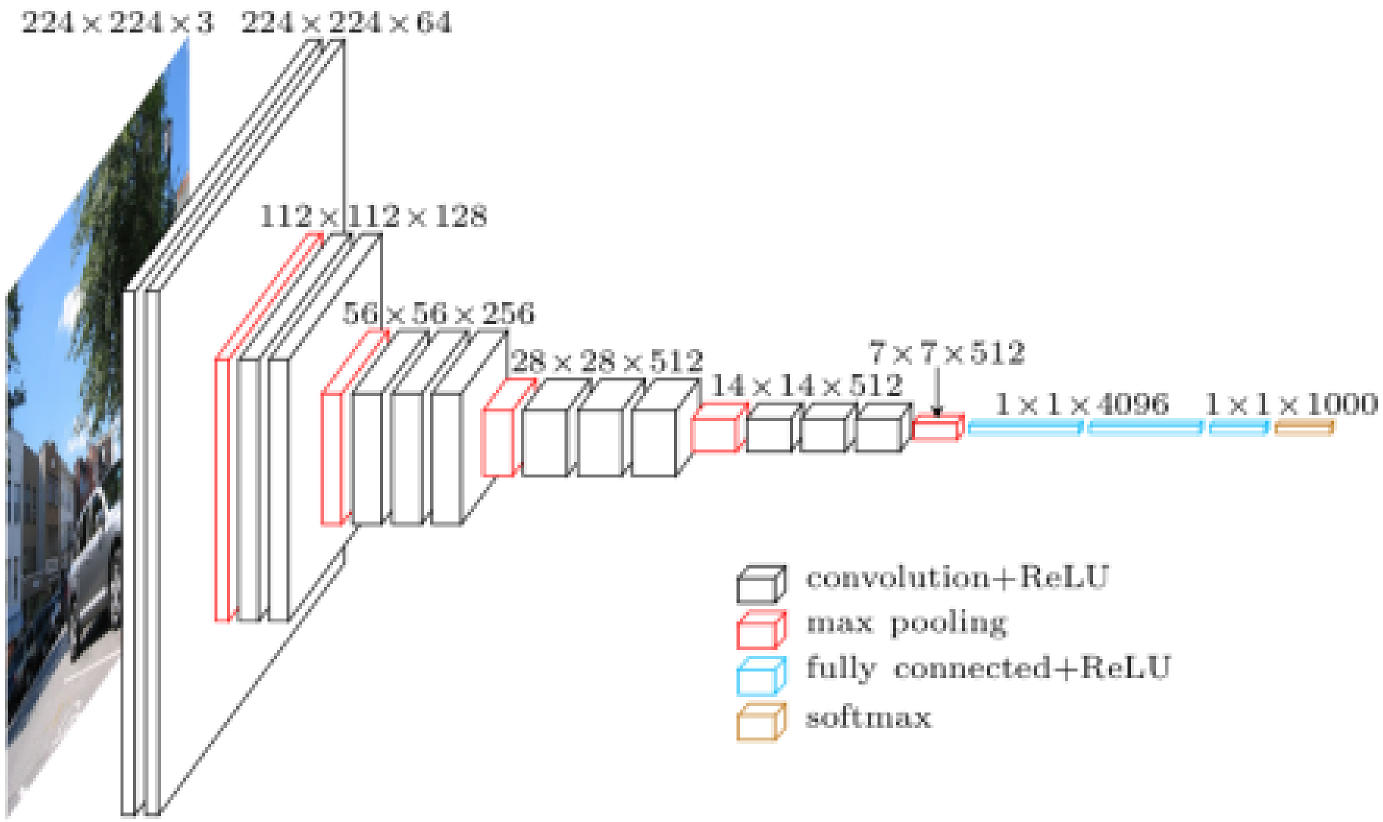
Other styles: functional computations, mixed, ...

Alexnet



11
11
224
11
11
224
3
Stride
of 4
5
5
48
55
5
5
55
48
Max
pooling
3
3
3
27
128
3
3
27
3
3
128
Max
pooling
3
3
192
13
13
3
3
192
3
3
192
13
13
3
3
192
128
13
13
128
Max
pooling
dense
2048
2048
dense
2048
2048
dense
1000

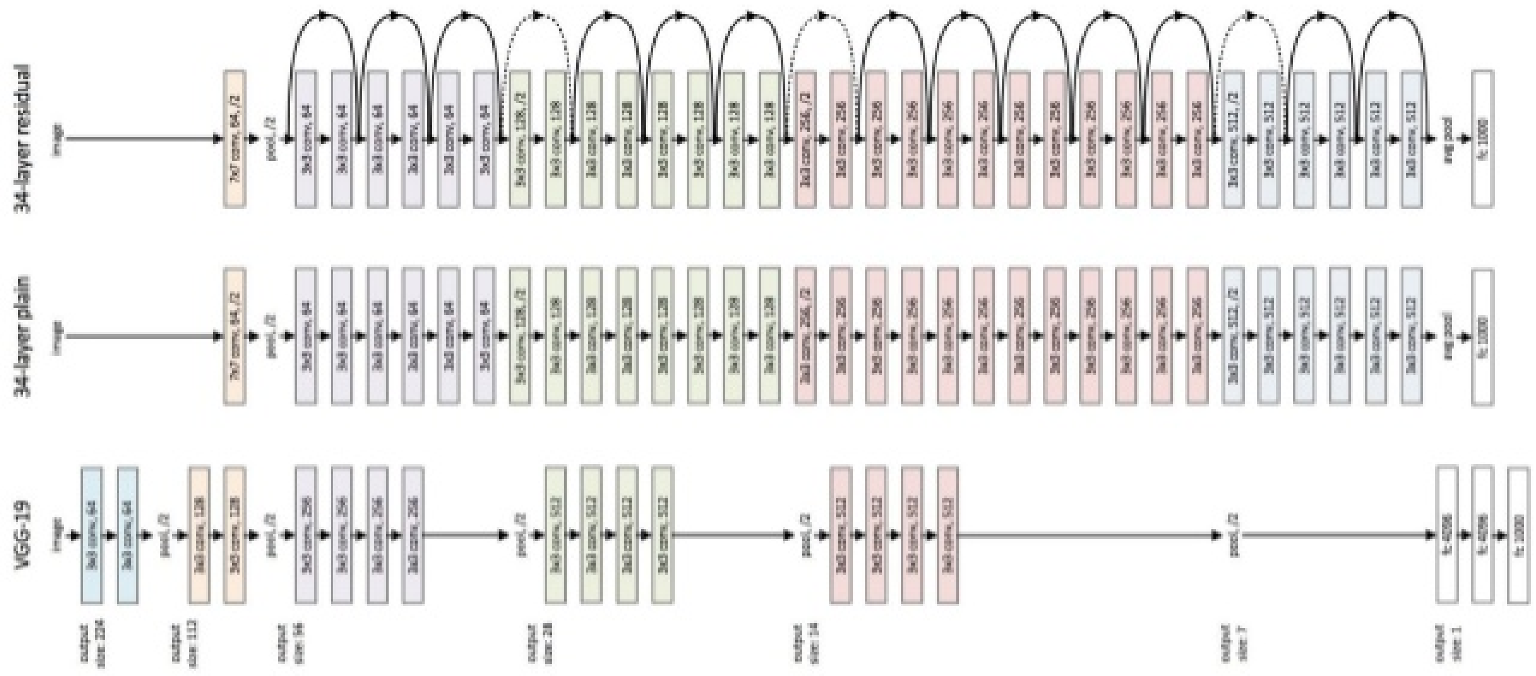
VGG16 Model



224 × 224 × 3
224 × 224 × 64
112 × 112 × 128
56 × 56 × 256
28 × 28 × 512
14 × 14 × 512
7 × 7 × 512
1 × 1 × 4096
1 × 1 × 1000
convolution+ReLU
max pooling
fully connected+ReLU
softmax

Resnet-50 Model

ResNet



Deep Learning = Stochastic Gradient Descent Optimization

- dataset consists of input, target pairs (x, y)
- the model is a function f depending on parameters θ
- repeatedly (by shuffled epoch):
  - create batches of 1-10000 (input, target) pairs
  - compute prediced output $\tilde{y}$
  - compute the derivative of the error $||y - \tilde{y}||^2$ wrt θ
  - update θ with a small multiple of the derivative

GPU Performance

GeForce RTX 2080 Ti (about $1000)

- 14.2 TFLOPS1 of peak single precision (FP32) performance
- 28.5 TFLOPS1 of peak half precision (FP16) performance
- 14.2 TIPS1 concurrent with FP, through independent integer execution units
- 113.8 Tensor TFLOPS1,2
- 10 Giga Rays/sec
- 78 Tera RTX-OPS

Forms of Parallelism

- MIMD
  - shared: memory
  - separate: fetch/decode, execute, registers
- SIMT (lockstep threads; roughly, the GPU model)
  - shared: memory, fetch/decode
  - separate: execute, registers
- SIMD
  - shared: memory, fetch/decode, registers
  - separate: execute

PyTorch Data Loading

```
def augment(image): ...

dataset = datasets.ImageNet("/archive/imagenet", augment)
loader = DataLoader(dataset, batch_size=16, shuffle=True, num_workers=4)

for input_batch, target_batch in loader:
    ...
```

PyTorch Training Loop

```
model = make_model()
model = model.cuda()

optimizer = optim.SGD(model.parameters(), lr=0.01)

for x, target in samples:
    optimizer.zero_grad()
    pred = model(x.cuda()).cpu()
    loss = F.mse_loss(target, pred)
    loss.backward()
    optimizer.step()
```

Often we wrap up this functionality into a `Trainer` class.

See the notebook for a full, running implementation.

Docker

- a full AI/DL environment contains dozens of major software libraries, all interacting
- all this can be encapsulated into a single "Docker image"
- Docker images look like virtual machines, but are actually just namespaces
- create anything from fully encapsulated to regular command line
- create standalone executables with tools like Singularity