COMP90051
Statistical Machine Learning

Workshop Week 7

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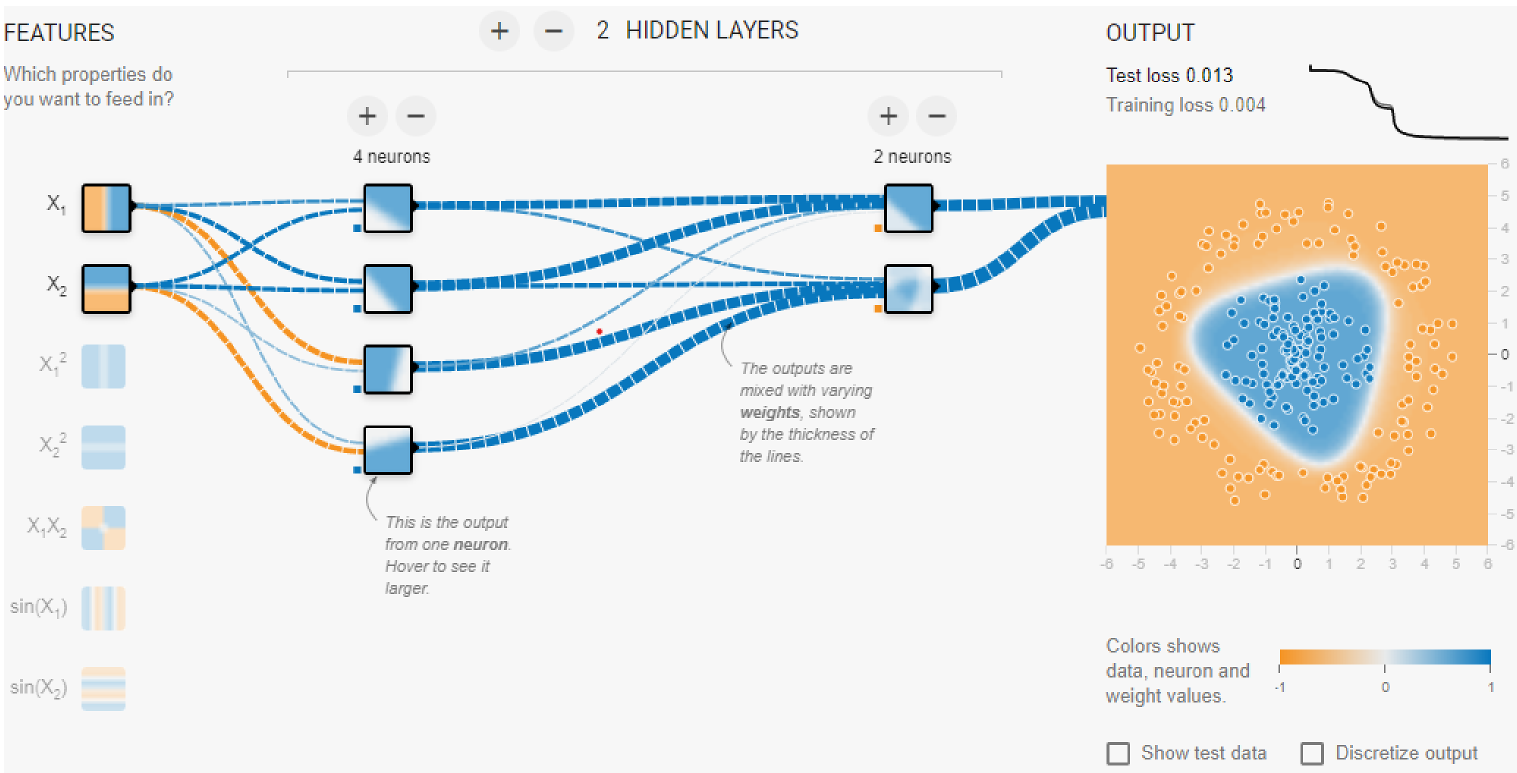
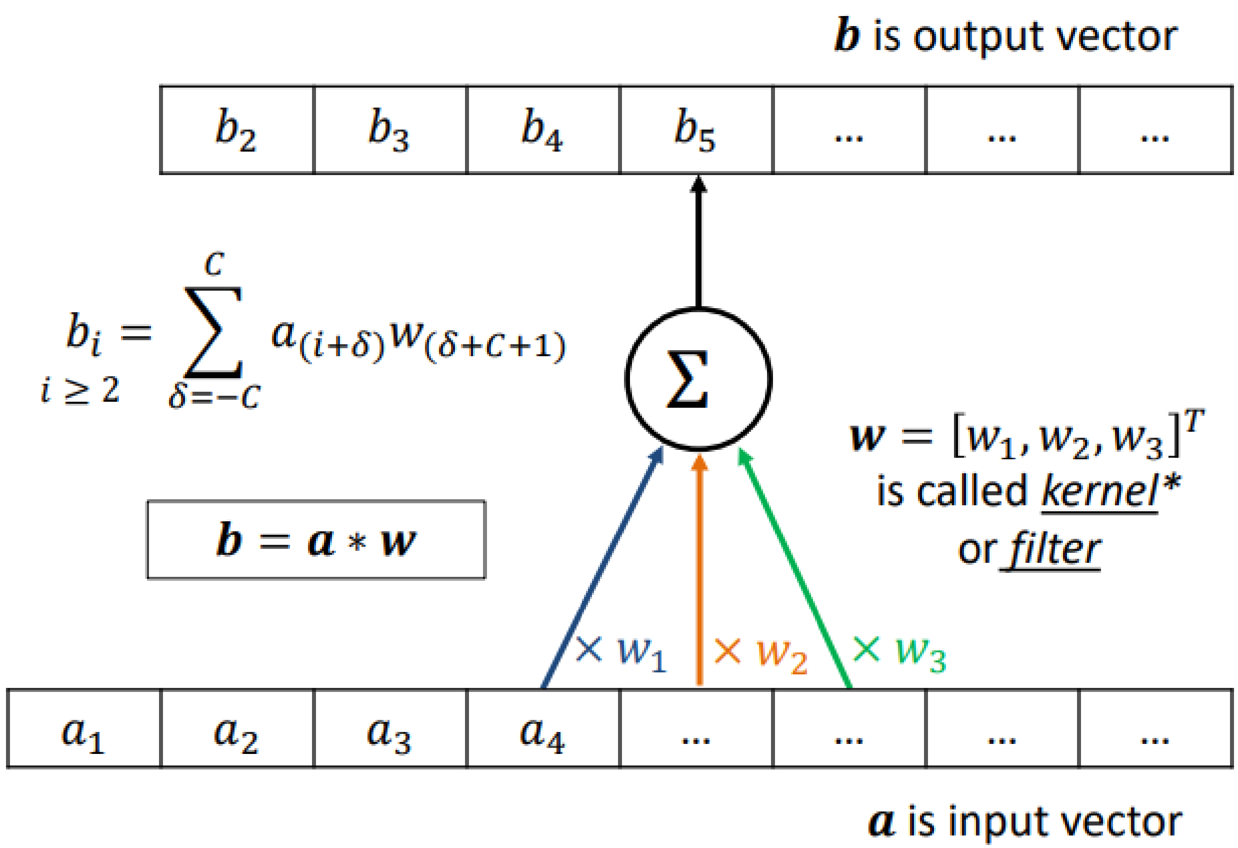
https://github.com/HanXudong/COMP90051_2020_S1

Computational Model

- https://playground.tensorflow.org

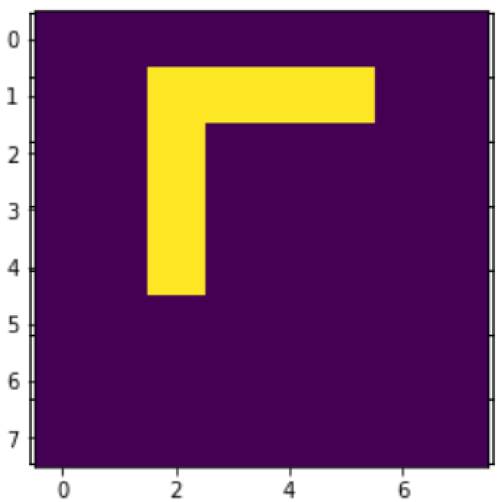


Model Design in PyTorch
Convolutional Neural Networks



Idea of filters

Filters are learned from training data!

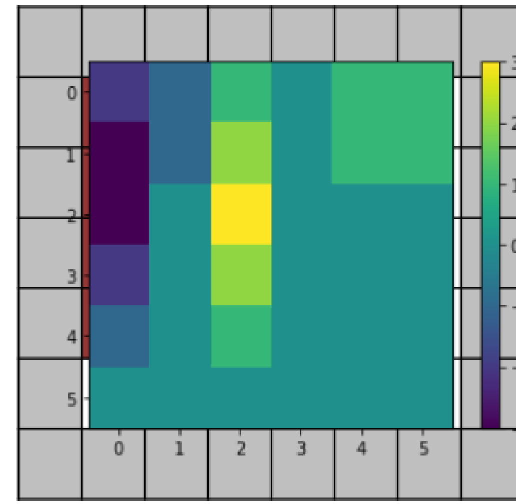


Filters/Kernels

-1	0	1
-1	0	1
-1	0	1

1	1	1
0	0	0
-1	-1	-1

Patterns/Features



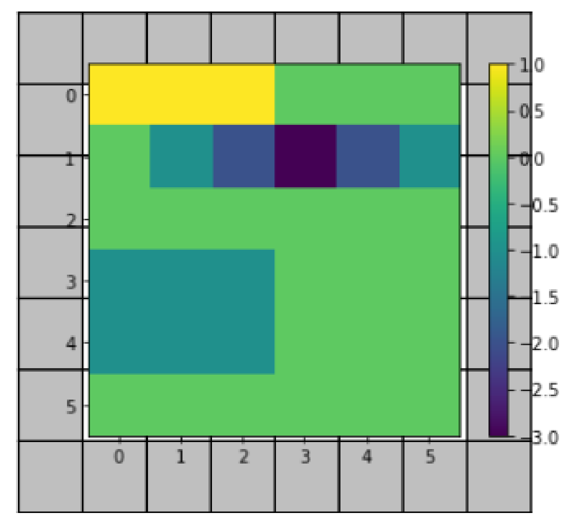
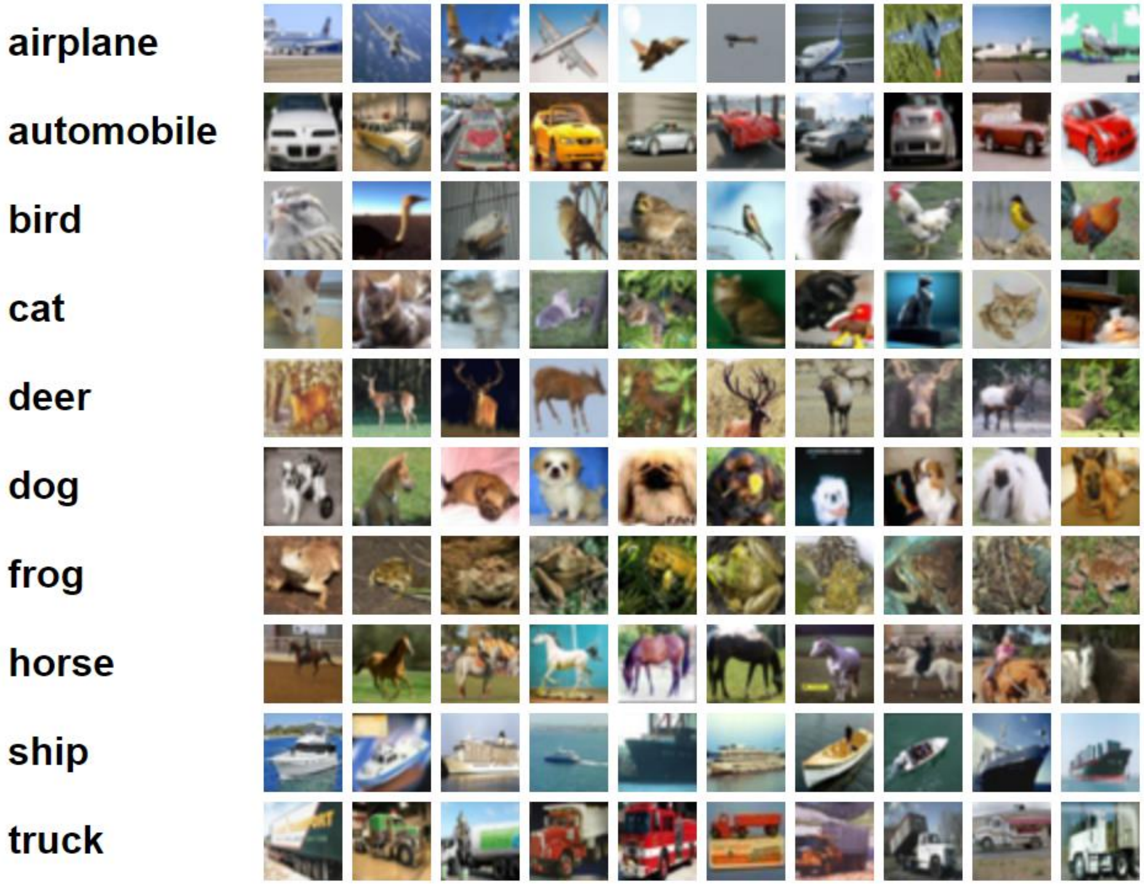


Image Classification on CIFAR-10

https://www.cs.toronto.edu/~kriz/cifar.html



Model design with torch.nn.Module

- Implement the constructor __init__(self, ...). Here we define all network parameters.
- Override the forward method forward(self, x). This accepts the input tensor x and returns our desired model output.
- Provided your operations are autograd-compliant, the backward pass is implemented automatically as PyTorch walks the computational graph backward.

```python
import torch.nn as nn
import torch.nn.functional as F

class LogisticRegressionModel(nn.Module):

    def __init__(self, n_features, n_classes):
        super(LogisticRegressionModel, self).__init__()

        # Register weight matrix and bias term as model parameters - automatically tracks operations for gradient compu
        self.W = torch.nn.Parameter(torch.nn.init.xavier_uniform_(torch.empty([n_features, n_classes])))  # Weights
        self.b = torch.nn.Parameter(torch.zeros([n_classes]))  # Biases

    def forward(self, x):
        """
        Forward pass for logistic regression.
        Input: Tensor x of shape [N,C,H,W]
        Output: Logits W @ x + b
        """
        batch_size = x.shape[0]

        x = x.view(batch_size, -1)  # Flatten image into vector, retaining batch dimension
        out = torch.matmul(x,self.W) + self.b  # Compute scores
        return out
```

```python
def train(model, train_loader, test_loader, optimizer, n_epochs=10):
    """
    Generic training loop for supervised multiclass learning
    """
    LOG_INTERVAL = 250
    running_loss, running_accuracy = list(), list()
    start_time = time.time()
    criterion = torch.nn.CrossEntropyLoss()

    for epoch in range(n_epochs):  # Loop over training dataset `n_epochs` times

        epoch_loss = 0.

        for i, data in enumerate(train_loader):  # Loop over elements in training set

            x, labels = data

            logits = model(x)

            predictions = torch.argmax(logits, dim=1)
            train_acc = torch.mean(torch.eq(predictions, labels).float()).item()

            loss = criterion(input=logits, target=labels)

            loss.backward()               # Backward pass (compute parameter gradients)
            optimizer.step()              # Update weight parameter using SGD
            optimizer.zero_grad()         # Reset gradients to zero for next iteration
```

Convolutional Networks

- Convolutional Layer #1 | 8 5×5 filters with a stride of 1, ReLU activation function.
- Max Pooling #1 | Kernel size 2 with a stride of 1.
- Convolutional Layer #2 | 16 5×5 filters with a stride of 1, ReLU activation function.
- Max Pooling #2 | Kernel size 2 with a stride of 1.
- Fully Connected Layer #1 | 400 input units (flattened convolutional output), 256 output units.
- Fully Connected Layer #2 | 256 input units, 10 output units - yields logits for classification.

```
OUT_C1 = 8
OUT_C2 = 16
DENSE_UNITS = 256

class BasicConvNet(nn.Module):
    def __init__(self, out_c1, out_c2, dense_units, n_classes=10):
        super(BasicConvNet, self).__init__()
        self.conv1 = nn.Conv2d(in_channels=3, out_channels=out_c1, kernel_size=5)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        self.conv2 = nn.Conv2d(in_channels=out_c1, out_channels=out_c2, kernel_size=5)
        self.fc1 = nn.Linear(16 * 5 * 5, dense_units)
        self.logits = nn.Linear(dense_units, n_classes)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        x = x.view(-1, 16 * 5 * 5)
        x = F.relu(self.fc1(x))
        out = self.logits(x)
        return out


conv2D_model = BasicConvNet(OUT_C1, OUT_C2, DENSE_UNITS)
```

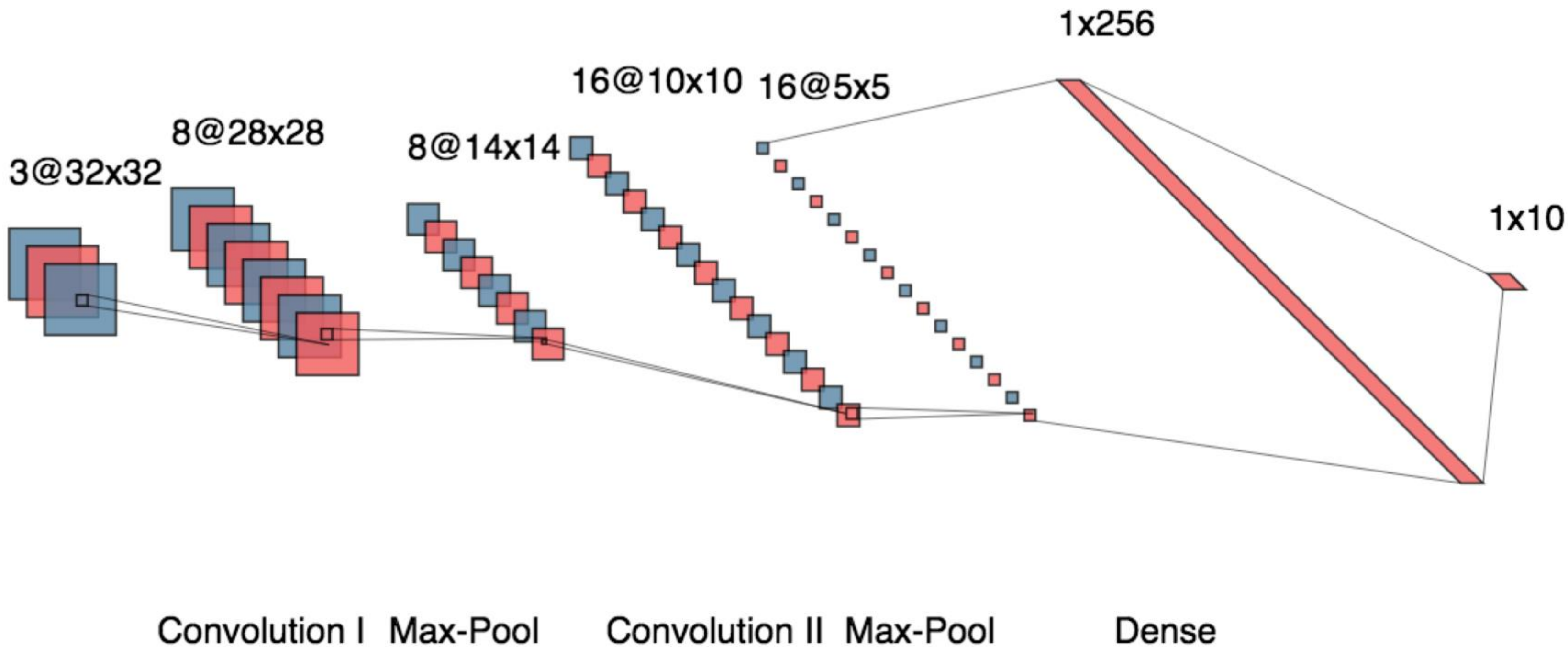
Downsampling   Max-Pool

kernel_size=2, stride=2

1	2	3	4
1	3	2	5
3	2	1	5
2	4	5	3

3	5
4	5

Calculate the number of parameters



Convolution I: $3 \times 8 \times 5 \times 5 + 8$

https://pytorch.org/docs/stable/nn.html#torch.nn.Conv2d

Dense I: $16 \times 5 \times 5 \times 256 + 256$

$$\text{out}(N_i, C_{\text{out}_j}) = \text{bias}(C_{\text{out}_j}) + \sum_{k=0}^{C_{\text{in}}-1} \text{weight}(C_{\text{out}_j}, k) \star \text{input}(N_i, k)$$

where $\star$ is the valid 2D cross-correlation operator, N is a batch size, C denotes a number of channels, H is a height of input planes in pixels, and W is width in pixels.

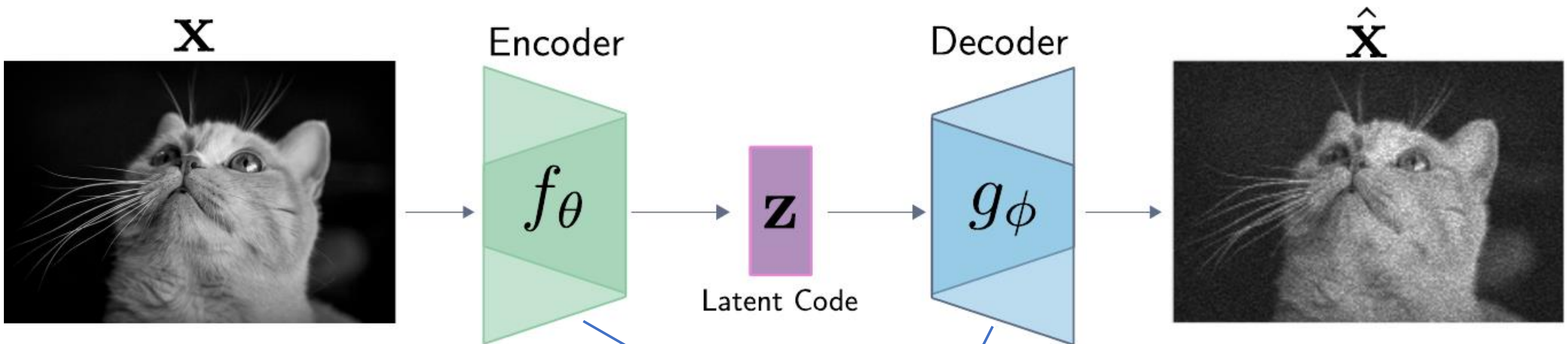
For a certain output channel

- 1 bias term
- 1 kernel for each input channel
- Kernels (aka filters) are learned from data (have parameters).

Our example

- Input channel 3, kernel size 5x5, for each output channel, there are $3 \times 5 \times 5 + 1$ parameters.

Autoencoders



$$\min_{f,g} \sum_k \|\mathbf{x}_k - g \circ f(\mathbf{x}_k)\|^2$$