CORE
Control + Optimization Research Lab

Deep Learning with PyTorch

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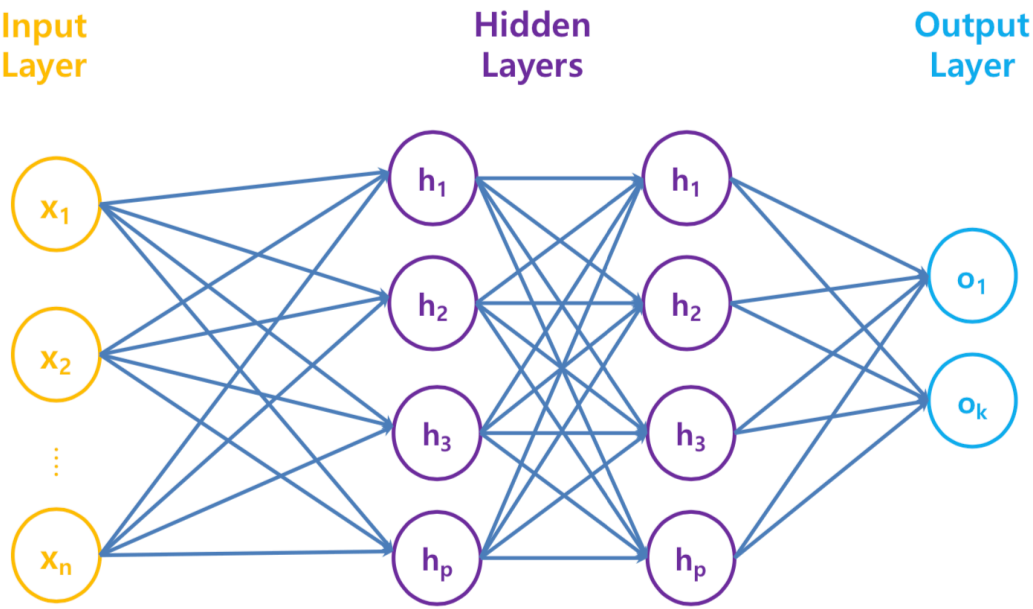
Jul 15, 2019

Outline

- Deep Learning with PyTorch
  - Tensor Manipulation
  - Deep Neural Network
  - Make Model with PyTorch

PyTorch

- Deep Neural Network도 numpy로 표현할 수 있을까?
  - Deep Neural Network (DNN)



- 신경망이 깊어질수록 numpy로 표현하는 것이 점점 더 어려워짐

  → 따라서 딥러닝 프레임워크를 통해 손쉽게 표현하고자 함

PyTorch

Facebook AI Research

Caffe2

PYTORCH

Yann LeCun

DIRECTOR OF AI RESEARCH

Facebook AI Research (FAIR)

Soumith Chintala

RESEARCH ENGINEER

Facebook AI Research (FAIR)

Tensor Manipulation

- Numpy array → Torch tensor
  - torch.Tensor - Constructs a tensor with data

```
10  ### torch.Tensor
11  array = np.array([[1,2,3,4], [5,6,7,8]])
12  tensor = torch.Tensor(array)
13  print(array)
14  print(tensor)
15  '''
16  [[1 2 3 4]
17   [5 6 7 8]]
18  tensor([[1., 2., 3., 4.],
19          [5., 6., 7., 8.]])
20  '''
21
22  array[0,0] = 10
23  print(array)
24  print(tensor)
25  '''
26  [[10  2  3  4]
27   [ 5  6  7  8]]
28  tensor([[1., 2., 3., 4.],
29          [5., 6., 7., 8.]])
30  '''
```

Tensor Manipulation

- Numpy array → Torch tensor
  - torch.from_numpy - Creates a Tensor from a numpy.ndarray

```
32  ### torch.from_numpy
33  array = np.array([[1,3,5,7], [9,11,13,15]])
34  tensor = torch.from_numpy(array)
35  print(array)
36  print(tensor)
37  '''
38  [[ 1  3  5  7]
39   [ 9 11 13 15]]
40  tensor([[ 1,  3,  5,  7],
41          [ 9, 11, 13, 15]])
42  '''
43
44  array[0][0] = 10
45  print(array)
46  print(tensor)
47  '''
48  [[10  3  5  7]
49   [ 9 11 13 15]]
50  tensor([[10,  3,  5,  7],
51          [ 9, 11, 13, 15]])
52  '''
```

Tensor Manipulation

- Torch tensor → Numpy array
  - numpy() - Returns self tensor as a numpy ndarray

```
58  tensor = torch.Tensor([[1,2,3,4], [5,6,7,8]])
59  array = tensor.numpy()
60  print(tensor)
61  print(array)
62  '''
63  tensor([[1., 2., 3., 4.],
64          [5., 6., 7., 8.]])
65  [[1. 2. 3. 4.]
66   [5. 6. 7. 8.]]
67  '''
```

Tensor Manipulation

- Creating functions
  - Zeros & Ones

```
73  ### Zeros & Ones
74  zeros = torch.zeros((2, 5))
75  print(zeros)
76  '''
77  tensor([[0., 0., 0., 0., 0.],
78          [0., 0., 0., 0., 0.]])
79  '''
80
81  ones = torch.ones((5, 2))
82  print(ones)
83  '''
84  tensor([[1., 1.],
85          [1., 1.],
86          [1., 1.],
87          [1., 1.],
88          [1., 1.]])
89  '''
```

Tensor Manipulation

- Creating functions
  - Something like

```
91  ### Something_like
92  tensor = torch.Tensor([[1,2,3,4], [5,6,7,8]])
93  zeros = torch.zeros_like(tensor)
94  print(zeros)
95  '''
96  tensor([[0., 0., 0., 0.],
97          [0., 0., 0., 0.]])
98  '''
```

Tensor Manipulation

- Creating functions
  - Rand - Uniform distribution over $[0, 1)$

```
100   ### Rand - Uniform distribution over [0, 1)
101   rand_sampling = torch.rand(2,5)
102   print(rand_sampling)
103   '''
104   tensor([[0.1562, 0.7464, 0.0341, 0.1269, 0.7245],
105           [0.7135, 0.6891, 0.9348, 0.4983, 0.9259]])
106   '''
```

  - Randn - Standard normal(gaussian) distribution of mean 0 and variance 1

```
108   ### Randn - Standard normal(gaussian) distribution of mean 0 and variance 1
109   randn_sampling = torch.randn(2,5)
110   print(randn_sampling)
111   '''
112   tensor([[ 0.4119, -1.1501, -0.4142,  0.9698, -0.9407],
113           [ 0.5520,  2.3532,  0.5251, -1.1743,  0.5667]])
114   '''
```

Tensor Manipulation

- Operation functions
  - Sum

```
120   ### Sum
121   tensor = torch.Tensor([[1,2,3,4], [5,6,7,8]])
122   sum_ = torch.sum(tensor)
123   sum_0 = torch.sum(tensor, dim=0)
124   sum_1 = torch.sum(tensor, dim=1)
125   print(sum_)
126   print(sum_0)
127   print(sum_1)
128   '''
129   tensor(36.)
130   tensor([ 6.,  8., 10., 12.])
131   tensor([10., 26.])
132   '''
```

Tensor Manipulation

- Operation functions
  - Max

```
134  ### Max
135  tensor = torch.Tensor([[1,2], [3,4], [5,6], [7,8]])
136
137  max_ = torch.max(tensor)
138  print(max_)
139  '''
140  tensor(8.)
141  '''
142
143  max_0 = torch.max(tensor, dim=0)
144  value, index = torch.max(tensor, dim=0)
145  max_0_0 = torch.max(tensor, dim=0)[0]
146  max_0_1 = torch.max(tensor, dim=0)[1]
147  print(max_0)
148  print(value)
149  print(index)
150  print(max_0_0)
151  print(max_0_1)
152  '''
153  (tensor([7., 8.]), tensor([3, 3]))
154  tensor([7., 8.])
155  tensor([3, 3])
156  tensor([7., 8.])
157  tensor([3, 3])
158  '''
```

```
160  max_1 = torch.max(tensor, dim=1)
161  value, index = torch.max(tensor, dim=1)
162  max_1_0 = torch.max(tensor, dim=1)[0]
163  max_1_1 = torch.max(tensor, dim=1)[1]
164  print(max_1)
165  print(value)
166  print(index)
167  print(max_1_0)
168  print(max_1_1)
169  '''
170  (tensor([2., 4., 6., 8.]), tensor([1, 1, 1, 1]))
171  tensor([2., 4., 6., 8.])
172  tensor([1, 1, 1, 1])
173  tensor([2., 4., 6., 8.])
174  tensor([1, 1, 1, 1])
175  '''
```

Tensor Manipulation

- Operation functions
  - Dot product
    - torch.dot - Computes the dot product (inner product) of two tensors (1-Dimension)

$$\langle [x_1, \dots, x_n], [y_1, \dots, y_n] \rangle = x^T y = \sum_{i=1}^{n} x_i y_i = x_1 y_1 + \cdots + x_n y_n$$

```
177   ### Dot product
178   tensor = torch.Tensor([1,2,3,4,5])
179   dot = torch.dot(tensor, tensor)
180   print(dot)
181   '''
182   tensor(55.)
183   '''
```

Tensor Manipulation

- Operation functions
  - Mathematical functions
    - torch.sqrt : $\sqrt{x}$
    - torch.exp : e^x
    - torch.log : $\log_e x$

```
185   ### Mathematical functions
186   tensor = torch.Tensor([[1,2,3,4], [5,6,7,8]])
187
188   sqrt = torch.sqrt(tensor)
189   exp = torch.exp(tensor)
190   log = torch.log(tensor)
191   print(sqrt)
192   print(exp)
193   print(log)
194   '''
195   tensor([[1.0000, 1.4142, 1.7321, 2.0000],
196           [2.2361, 2.4495, 2.6458, 2.8284]])
197   tensor([[   2.7183,    7.3891,   20.0855,   54.5982],
198           [ 148.4132,  403.4288, 1096.6332, 2980.9580]])
199   tensor([[0.0000, 0.6931, 1.0986, 1.3863],
200           [1.6094, 1.7918, 1.9459, 2.0794]])
201   '''
```

Tensor Manipulation

- Operation functions
  - Concatenate

```
### Concatenate
tensor_a = torch.Tensor([[1,2,3,4], [5,6,7,8]])
tensor_b = torch.Tensor([[1,3,5,7], [2,4,6,8]])

cat = torch.cat([tensor_a, tensor_b]) # vstack
print(cat)
'''
tensor([[1., 2., 3., 4.],
        [5., 6., 7., 8.],
        [1., 3., 5., 7.],
        [2., 4., 6., 8.]])
'''

cat_0 = torch.cat([tensor_a, tensor_b], dim=0) # vstack
print(cat_0)
'''
tensor([[1., 2., 3., 4.],
        [5., 6., 7., 8.],
        [1., 3., 5., 7.],
        [2., 4., 6., 8.]])
'''

cat_1 = torch.cat([tensor_a, tensor_b], dim=1) # hstack
print(cat_1)
'''
tensor([[1., 2., 3., 4., 1., 3., 5., 7.],
        [5., 6., 7., 8., 2., 4., 6., 8.]])
'''
```

Tensor Manipulation

- Operation functions
  - View
    - torch.view - Returns a new tensor with the same data as the self tensor but of a different shape

```
232   ### View
233   tensor_a = torch.Tensor([[1,3,5,7], [2,4,6,8]])
234
235   tensor_b = tensor_a.view(8)
236   print(tensor_b.shape)
237   '''
238   torch.Size([8])
239   '''
240
241   tensor_c = tensor_a.view(-1, 2)
242   print(tensor_c.shape)
243   '''
244   torch.Size([4, 2])
245   '''
246
247   tensor_d = tensor_a.view(-1)
248   print(tensor_d.shape)
249   '''
250   torch.Size([8])
251   '''
```

Tensor Manipulation

- Operation functions
  - Squeeze - torch.squeeze(input, dim=None)
    - Returns a tensor with all the dimensions of input of size 1 removed

```
253   ### Squeeze & Unsqueeze
254   tensor = torch.zeros(2, 1, 1, 5)
255
256   squ_0 = torch.squeeze(tensor)
257   print(squ_0.shape)
258   '''
259   torch.Size([2, 5])
260   '''
261
262   squ_1 = torch.squeeze(tensor, 1)
263   print(squ_1.shape)
264   print(tensor.squeeze(1).shape)
265   '''
266   torch.Size([2, 1, 5])
267   torch.Size([2, 1, 5])
268   '''
```

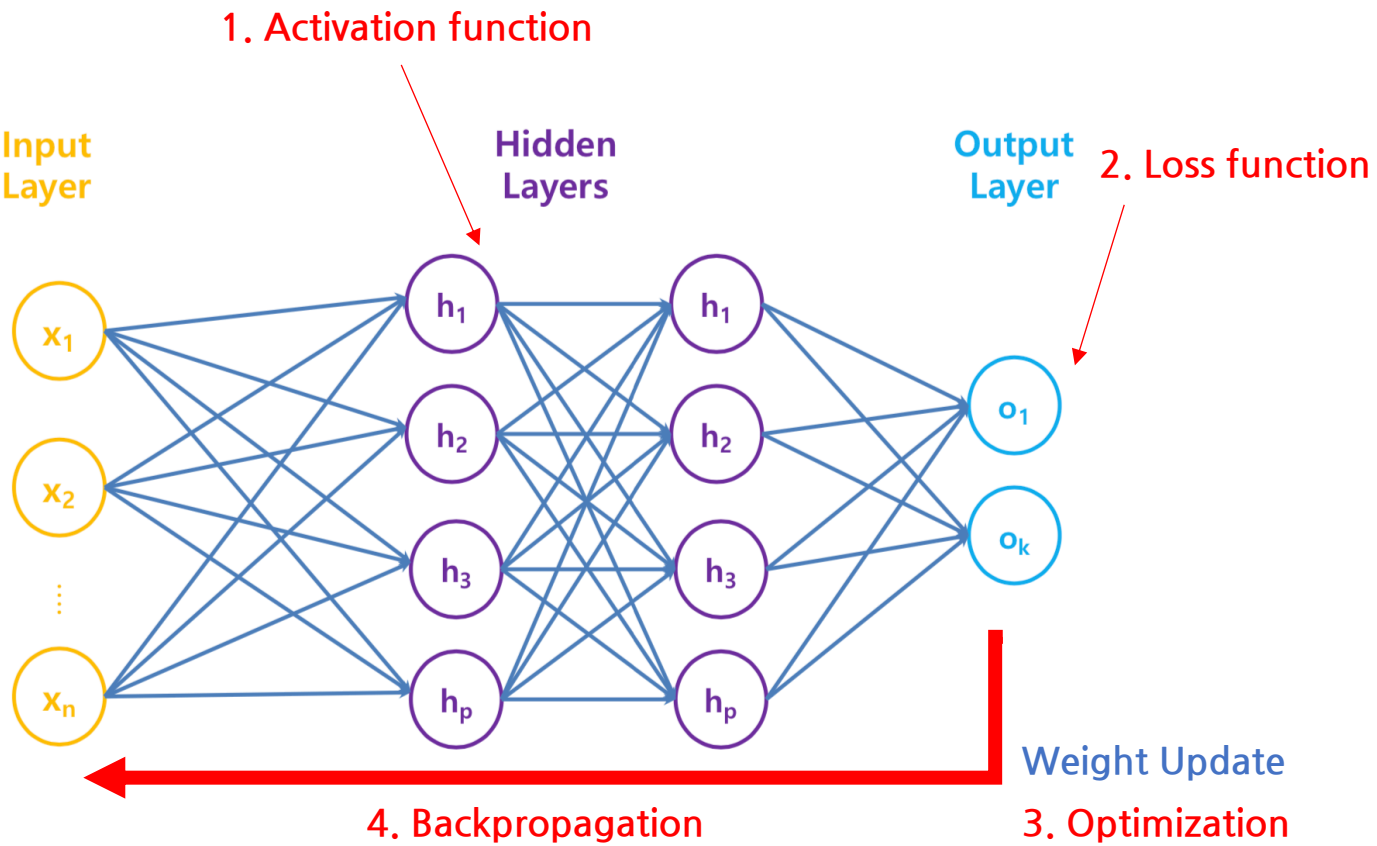
Tensor Manipulation

- Operation functions
  - Unsqueeze - torch.unsqueeze(input, dim)
    - Returns a new tensor with a dimension of size one inserted at the specified position

```
270    unsqu_0 = torch.unsqueeze(tensor, 0)
271    print(unsqu_0.shape)
272    '''
273    torch.Size([1, 2, 1, 1, 5])
274    '''
275
276    unsqu_1 = torch.unsqueeze(tensor, 1)
277    print(unsqu_1.shape)
278    print(tensor.unsqueeze(1).shape)
279    '''
280    torch.Size([2, 1, 1, 1, 5])
281    torch.Size([2, 1, 1, 1, 5])
282    '''
```

Deep Neural Network

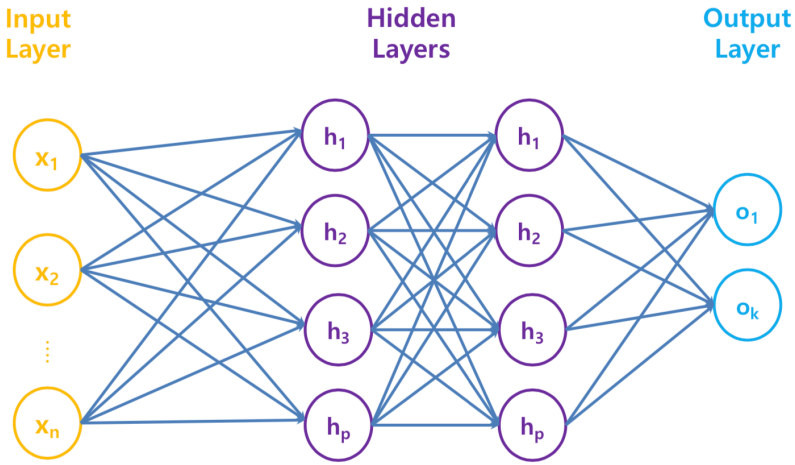
- Deep Neural Network (DNN) process



Make Model with PyTorch

- PyTorch example for Deep Neural Network (DNN)

```
294  import torch
295  import torch.nn as nn
296  import torch.optim as optim
297
298  class Net(nn.Module):
299      def __init__(self):
300          super(Net, self).__init__()
301          self.fc1 = nn.Linear(4, 64)
302          self.fc2 = nn.Linear(64, 64)
303          self.fc3 = nn.Linear(64, 2)
304
305      def forward(self, x):
306          x = torch.tanh(self.fc1(x))
307          x = torch.tanh(self.fc2(x))
308          x = self.fc3(x)
309          return x
```



$$o_1 = \sum_{i=1}^{p} w_i \phi\left(\sum_{j=1}^{p} w_j' \phi\left(\sum_{k=1}^{n} w_k'' x_k\right)\right)$$

Make Model with PyTorch

- PyTorch example for Deep Neural Network (DNN)

```
294  import torch
295  import torch.nn as nn
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298  class Net(nn.Module):
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303          self.fc3 = nn.Linear(64, 2)
304
305      def forward(self, x):
306          x = torch.tanh(self.fc1(x))
307          x = torch.tanh(self.fc2(x))
308          x = self.fc3(x)
309          return x
```

```
311  net = Net()
312
313  # Define loss and optimizer
314  criterion = torch.nn.MSELoss()
315  optimizer = optim.Adam(net.parameters(), lr=0.001)
316
317
318  net.train()
319
320  hypothesis = net(inputs)
321  loss = criterion(hypothesis, labels)
322
323  optimizer.zero_grad() # initialize gradient
324  loss.backward()       # compute gradient
325  optimizer.step()      # improve step
```

Make Model with PyTorch

- Save & Load

```
331    ### save
332    torch.save(net.state_dict(), './save_model/model.pth')
333
334    ### load
335    net.load_state_dict(torch.load('./save_model/model.pth'))
```

Make Model with PyTorch

- MNIST example

Thank you