Deep Learning Toolkits II

PyTorch

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A graph is created on the fly


```
from torch.autograd import Variable

x = Variable(torch.randn(1, 10))
prev_h = Variable(torch.randn(1, 20))
W_h = Variable(torch.randn(20, 20))
W_x = Variable(torch.randn(20, 10))
```

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PYTORCH

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Tensors and Dynamic neural networks in Python with strong GPU acceleration.

PyTorch is a deep learning framework that puts Python first.

We are in an early-release Beta. Expect some adventures.

Learn More

Tensor computation (like numpy) with GPU

Deep learning with automatic differentiation

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Outlines

- Examples
  - PyTorch as a fast calculator
  - Train a CNN with PyTorch
- Basic concepts
- Write new models
- HOWTOs

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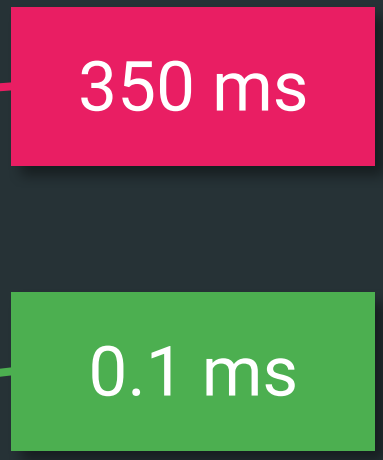
Example: A fast calculator

```python
import numpy as np
import torch

# Task: compute matrix multiplication C = AB
d = 3000

# using numpy
A = np.random.rand(d, d).astype(np.float32)
B = np.random.rand(d, d).astype(np.float32)
C = A.dot(B)

# using torch with gpu
A = torch.rand(d, d).cuda()
B = torch.rand(d, d).cuda()
C = torch.mm(A, B)
```



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Example: Auto Differentiate

```python
import torch
from torch.autograd import Variable

# Task: compute d(||x||^2)/dx
x = Variable(torch.range(1, 5), requires_grad=True)
print(x.data)  # x.data = [1, 2, 3, 4, 5]

f = x.dot(x)
print(f.data)  # f.data = 55

f.backward()
print(x.grad)  # x.grad = [2, 4, 6, 8, 10]
```

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Example: Train a CNN

- See our notebook example http://nbviewer.jupyter.org/gist/Cysu/320960298b6ccaedb778a2a4de2dd2db

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Basic Concepts

- **`torch.Tensor`** – similar to numpy.array, with GPU
- **`autograd.Variable`** – wraps a Tensor and enables auto differentiation
- **`autograd.Function`** – operate on Variables. Implement forward and backward.
- **`nn.Parameter`** – a special Variable
- **`nn.Module`** – contain Parameters and define functions on input Variables

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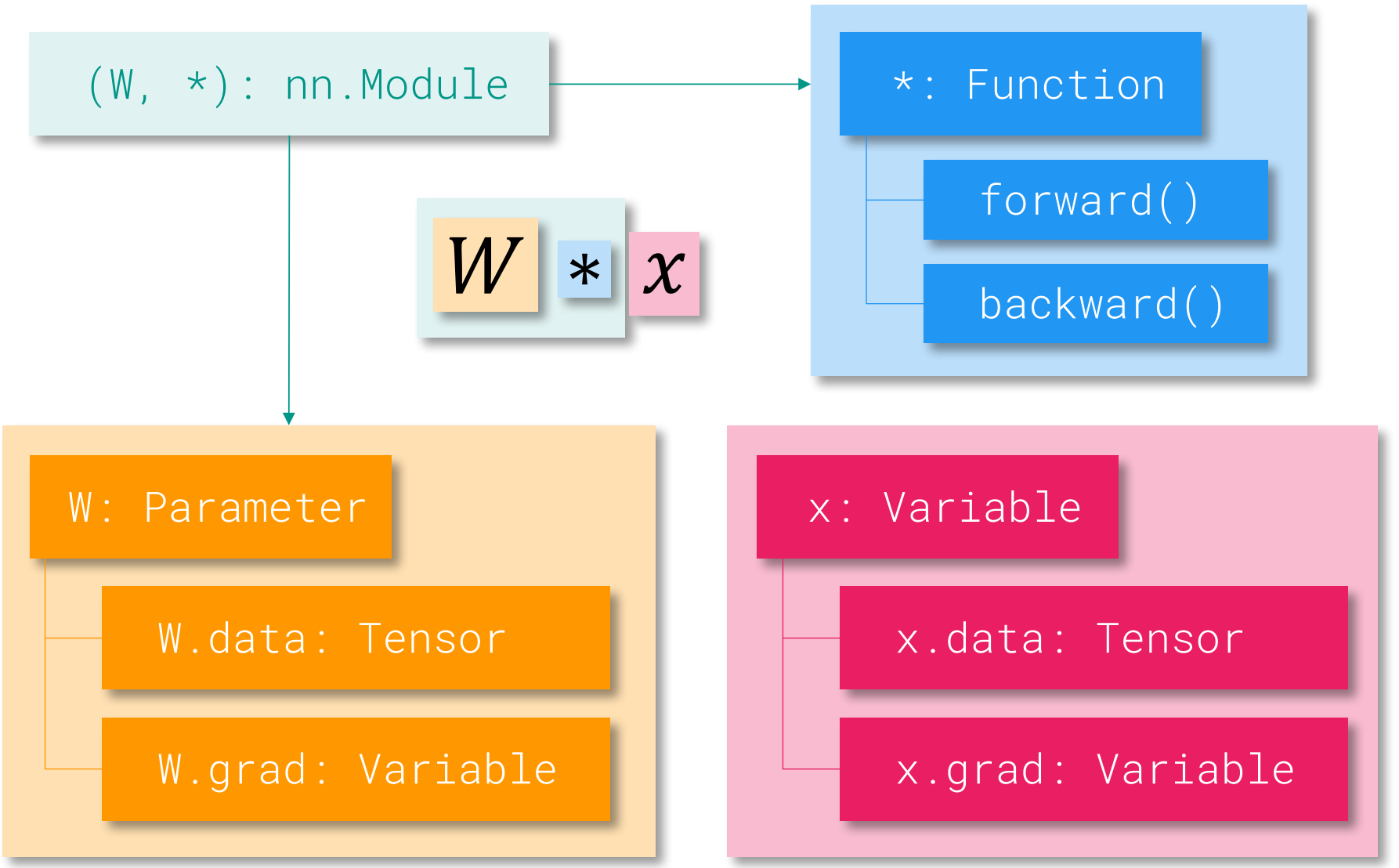
Basic Concepts



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Write New Models

```python
from torch import nn

class SimpleCNN(nn.Module):
    def __init__(self):
        super(SimpleCNN, self).__init__()

        self.block = nn.Sequential(
            nn.Conv2d(3, 16, kernel_size=3, padding=1),
            nn.BatchNorm2d(16),
            nn.ReLU(),
            nn.MaxPool2d(kernel_size=4, stride=4))
        self.fc = nn.Linear(64*16, 10)

    def forward(self, x):
        x = self.block(x)
        x = x.view(x.size(0), -1)
        x = self.fc(x)
        return x
```

Group into **nn.Sequential**

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Write New Models

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

class SimpleCNN(nn.Module):
    def __init__(self):
        super(SimpleCNN, self).__init__()
        self.conv = nn.Conv2d(3, 16, kernel_size=3, padding=1)
        self.bn = BatchNorm2d(16)
        self.fc = nn.Linear(64*16, 10)

    def forward(self, x):
        x = self.conv(x)
        x = F.relu(x)
        x = F.max_pool2d(x, 4, stride=4)
        x = x.view(x.size(0), -1)
        x = self.fc(x)
        return x
```

Functional interface

Not recommended, but sometimes useful

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Write New Models

- Combine high-level `nn.Module` and low-level math operations on `Variable`
- Use functional interfaces smartly, e.g., convolve two feature maps using `F.conv2d`
- See http://pytorch.org/docs/notes/extending.html for more details

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HOWTOs

- Initialize parameters
- Fine-tuning
- Extract features
- Two-branch modules

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Initialize Parameters

```python
class SimpleCNN(nn.Module):
    def __init__(self):
        # Create some modules here
        ...
        for m in self.modules():
            if isinstance(m, nn.Conv2d):
                n = m.kernel_size[0] * m.kernel_size[1] * m.out_channels
                m.weight.data.normal_(0, math.sqrt(2. / n))
                if m.bias is not None:
                    m.bias.data.zero_()
            elif isinstance(m, nn.BatchNorm2d):
                m.weight.data.fill_(1)
                m.bias.data.zero_()
            elif isinstance(m, nn.Linear):
                m.weight.data.normal_(0, 0.001)
                if m.bias is not None:
                    m.bias.data.zero_()
```

Any operation that changes a tensor in-place is post-fixed with an _

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Fine-tuning

```
model = torchvision.models.resnet18(pretrained=True)
model.fc = nn.Linear(512, 100)

new_param_ids = set(id(p) for p in model.fc.parameters())
base_params = [p for p in model.parameters() if id(p) not in new_param_ids]

optimizer = optim.SGD([
    {'params': base_params},
    {'params': model.fc.parameters(), 'lr': 0.1}],
    lr=0.01, momentum=0.9)
```

Replace the classifier

Different lr for pretrained layers and new layers

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Extract Features

- Make a new class FeatureExtractor that holds a pretrained model
- Redefine the forward function, call the layers in the pretrained model explicitly, save the features we want for output
- Use `model._modules`

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Extract Features – `model._modules`

```
OrderedDict([
  ('conv1', Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)),
  ('bn1', BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True)),
  ('relu', ReLU (inplace)),
  ('maxpool', MaxPool2d (size=(3, 3), stride=(2, 2), padding=(1, 1), dilation=(1, 1))),
  ('layer1', Sequential (
    (0): BasicBlock (
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True)
      (relu): ReLU (inplace)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True)
    )
    (1): BasicBlock (
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True)
      (relu): ReLU (inplace)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True)
    )
  )),
...
```

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Extract Features

```python
class FeatureExtractor(nn.Module):
    def __init__(self, model, layer_names):
        super(FeatureExtractor, self).__init__()
        self._model = model
        self._layer_names = set(layer_names)

    def forward(self, x):
        outs = {}
        for name, module in self._model._modules.iteritems():
            if isinstance(module, nn.Linear):
                x = x.view(x.size(0), -1)
            x = module(x)
            if name in self._layer_names:
                outs[name] = x
        return outs
```

Not included in the _modules.
So call it explicitly.

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Extract Features

Remember to call `model.eval()`.
Affects BN, Dropout, etc.

```
17  model = torchvision.models.resnet18(pretrained=True).cuda().eval()
18  extractor = FeatureExtractor(model, ['avgpool', 'fc'])
19
20  x = Variable(torch.randn(750, 3, 224, 224).cuda(), volatile=True)
21  outs = extractor.forward(x)
```

Don't call `extractor(x)` directly

Reduces memory cost significantly!
All non-output Tensors could be corrupted.

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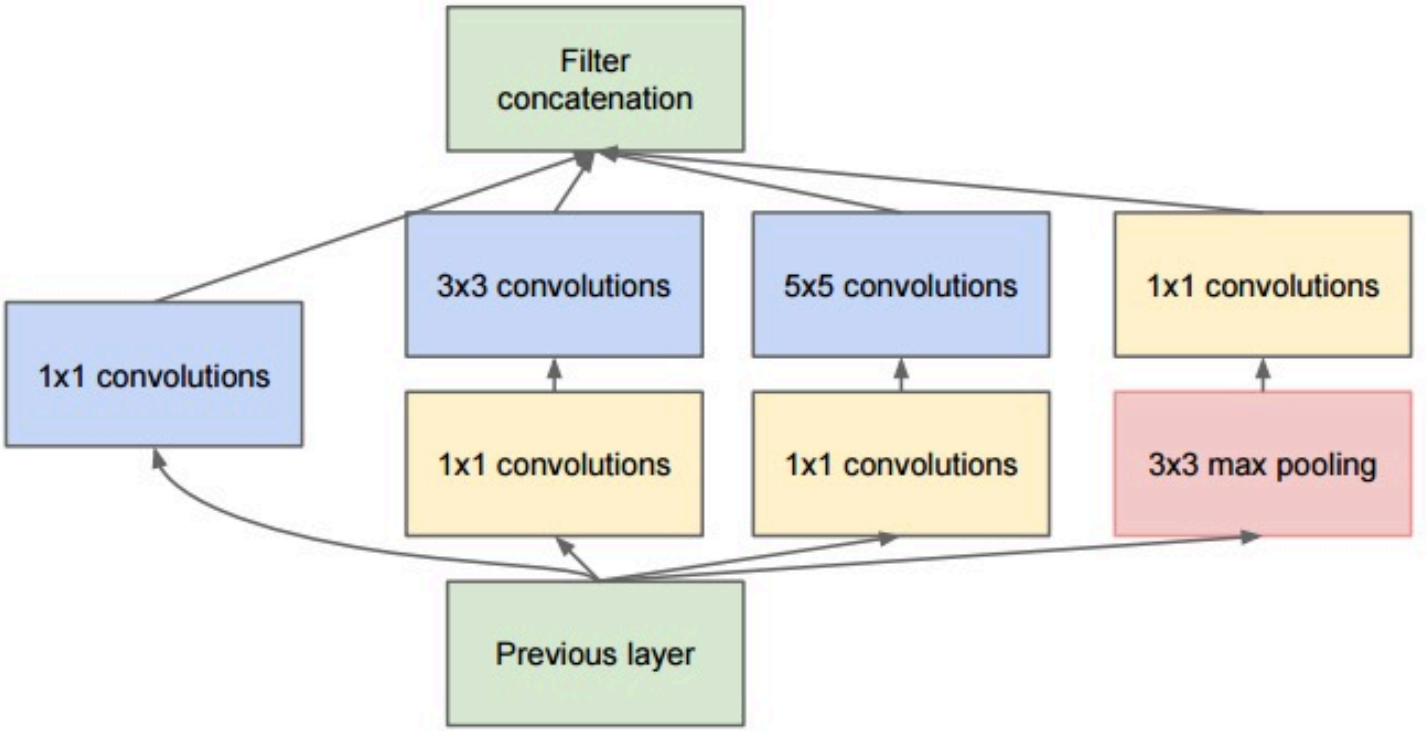
Two-branch Modules



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Two-branch Modules

```
class InceptionBlock(nn.Module):
    def __init__(self, num_in, num_out):
        super(InceptionBlock, self).__init__()
        self.branches = [
            nn.Sequential(
                nn.Conv2d(num_in, num_out, kernel_size=1),
                nn.ReLU()),
            nn.Sequential(
                nn.Conv2d(num_in, num_out, kernel_size=1),
                nn.ReLU(),
                nn.Conv2d(num_out, num_out, kernel_size=3, padding=1),
                nn.ReLU()),
            ...
        ]
        for i, branch in enumerate(self.branches):
            self.add_module(str(i), branch)

    def forward(self, x):
        # Concatenate branch results along channels
        return torch.cat([b(x) for b in self.branches], 1)
```

Need to call `add_module` to register the branches!

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Summary

- Examples
- Basic concepts
  - `torch` – Tensor
  - `autograd` – Variable, Function
  - `nn` – Module, Parameter
- Write new models
- HOWTOs

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More Adventures

- Tutorials
  - official https://github.com/pytorch/tutorials
  - jcjohnson https://github.com/jcjohnson/pytorch-examples
  - RNN and NLP https://github.com/spro/practical-pytorch
- Examples https://github.com/pytorch/examples
- Docs http://pytorch.org/docs/
- Discussions https://discuss.pytorch.org/

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Thanks to all the developers!

Tong XIAO

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And many others!