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# Pytorch Basic in Colab

Machine Intelligence Lab  
Handong Global University

# MNIST example with Pytorch

adapted from <https://github.com/pytorch/>

assuming the fields of args have proper values.

```
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torchvision import datasets, transforms
import os
```

# import torch modules

```
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('drive/My Drive/public/data', train=True,
    download=True, transform=transform),
    batch_size=batch_size, shuffle=True, **kwargs)
```

```
model = Net()
```

# model define (see the next slides)

```
optimizer = optim.SGD(model.parameters(), lr=lr, momentum=momentum)
```

# optimizer setting

```
for epoch in range(1, epochs + 1):
    train(model, device, train_loader, optimizer, epoch, log_interval)
    test(model, device, test_loader)
```

# training (see the next slide)

# MNIST example

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## # model architecture

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(784, 500)
        self.fc2 = nn.Linear(500, 300)
        self.fc3 = nn.Linear(300, 100)
        self.fc4 = nn.Linear(100, 10)

    def forward(self, x):
        batch_size, c, h, w = x.data.size()
        x = x.view(batch_size, 784)
        x = torch.tanh(self.fc1(x))
        x = torch.tanh(self.fc2(x))
        x = torch.tanh(self.fc3(x))
        x = self.fc4(x)
        return F.log_softmax(x, dim=1)
```

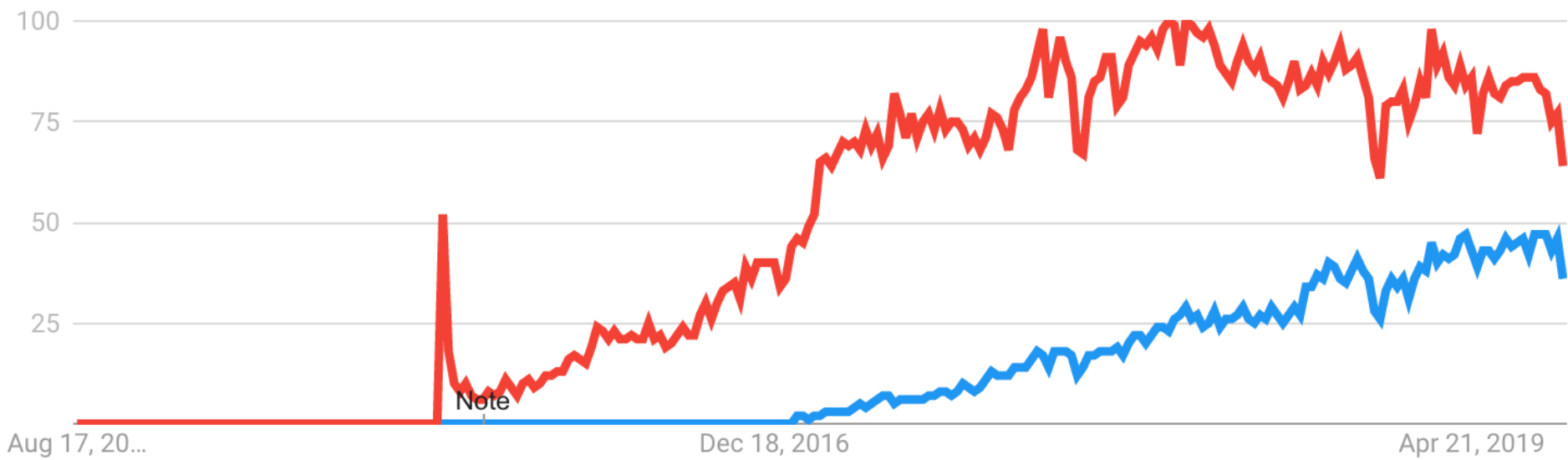
## # training step

```
def train(model, device, train_loader, optimizer, epoch, log_interval):
    model.train()
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        optimizer.zero_grad()
        output = model(data)
        loss = F.nll_loss(output, target)
        loss.backward()
        optimizer.step()

    if batch_idx % log_interval == 0:
        print('Train Epoch: {} [{}/{} ({:.0f}%)]\tLoss: {:.6f}'.format(
            epoch, batch_idx * len(data), len(train_loader.dataset),
            100. * batch_idx / len(train_loader), loss.item()))
```

# pytorch or tensorflow in google trends

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# install

<https://pytorch.org/>

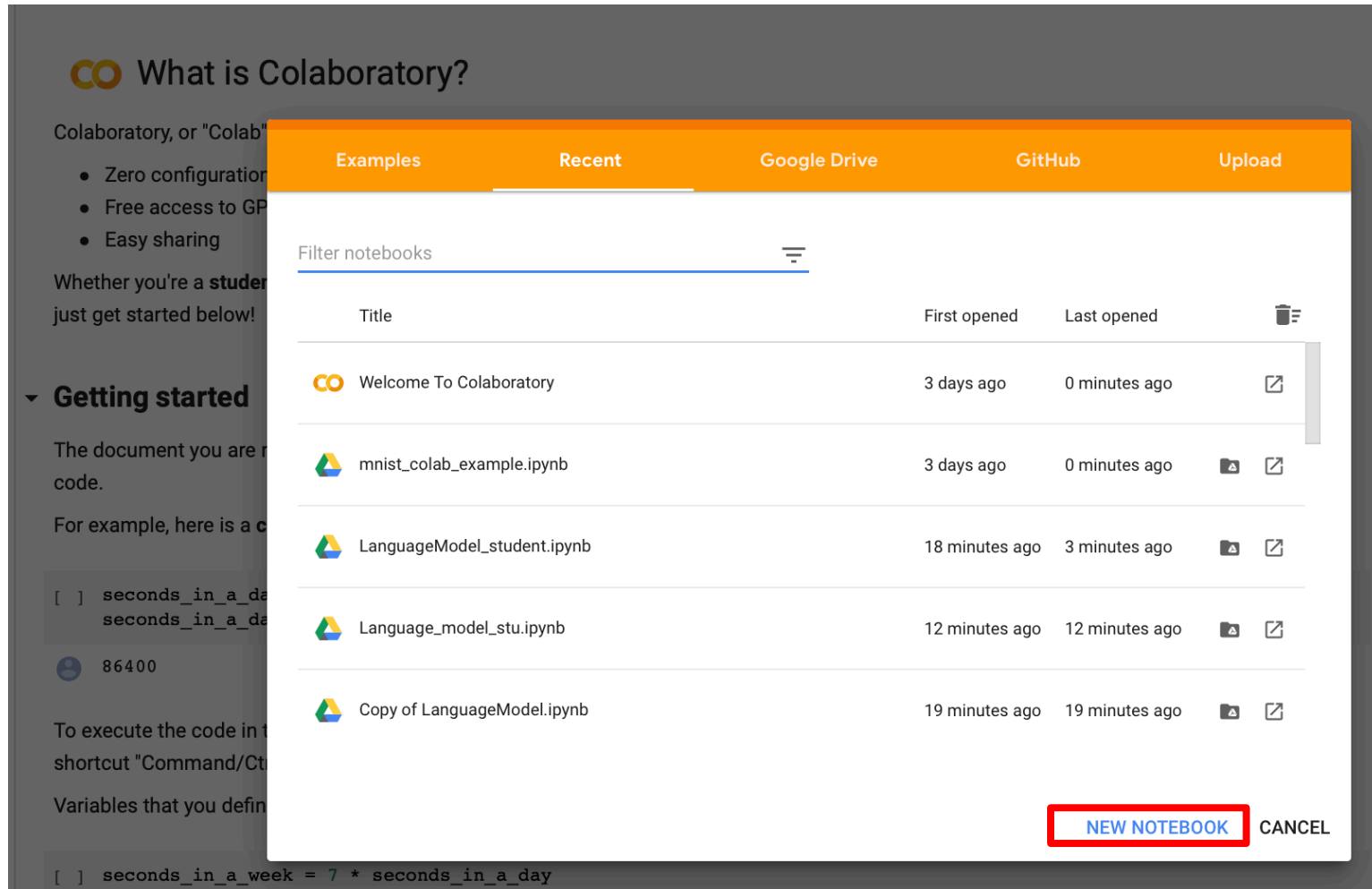
PyTorch Build	Stable (1.1)		Preview (Nightly)		
Your OS	Linux		Mac		Windows
Package	Conda	Pip		LibTorch	Source
Language	Python 2.7	Python 3.5	Python 3.6	Python 3.7	C++
CUDA	9.0		10.0		None
Run this Command:	<code>pip3 install torch torchvision</code>				

- Install Pytorch with your preference.
- Search about how to install Pytorch on your local preferences.

# everything is set in Google Colab!

<https://colab.research.google.com/>

free 12 hours at a time



**CO What is Colaboratory?**

Colaboratory, or "Colab", is a free, easy-to-use, and secure environment for running machine learning and data science code.

- Zero configuration
- Free access to GPU
- Easy sharing

Whether you're a **student** or a professional, you can just get started below!

### Getting started

The document you are viewing is a notebook. You can create a new notebook or open an existing one.

For example, here is a notebook that demonstrates how to use the `seconds_in_a_day` variable:

```
[ ] seconds_in_a_day = 24 * 60 * 60
seconds_in_a_day
```

86400











To execute the code in the notebook, click the **Run** button (a play icon) or use the keyboard shortcut "Command/Ctrl + Enter".

Variables that you define in the notebook are stored in the notebook's memory.

[ ] seconds\_in\_a\_week = 7 \* seconds\_in\_a\_day

**Examples Recent Google Drive GitHub Upload**

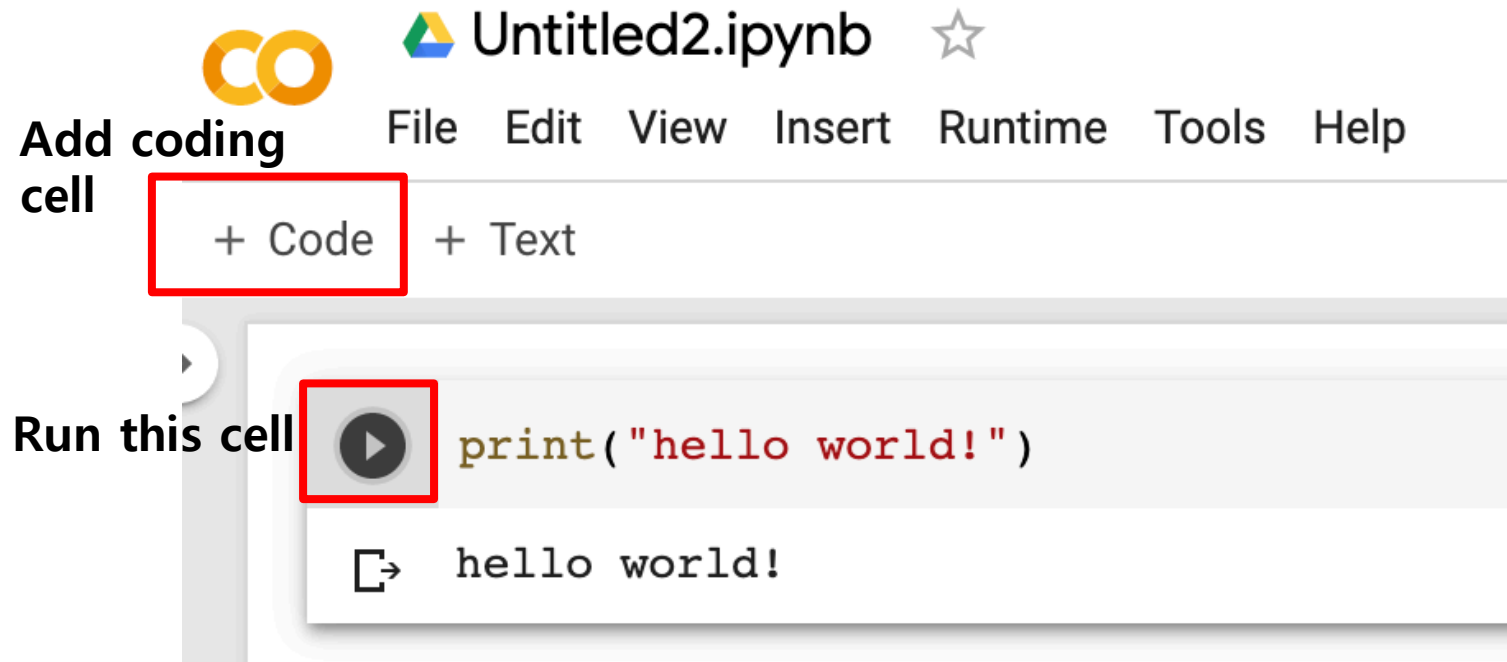
Filter notebooks

Title	First opened	Last opened	
 Welcome To Colaboratory	3 days ago	0 minutes ago	
 mnist_colab_example.ipynb	3 days ago	0 minutes ago	
 LanguageModel_student.ipynb	18 minutes ago	3 minutes ago	
 Language_model_stu.ipynb	12 minutes ago	12 minutes ago	
 Copy of LanguageModel.ipynb	19 minutes ago	19 minutes ago	

**NEW NOTEBOOK** CANCEL

# “hello world” in Google Colab

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The screenshot shows the Google Colab interface. At the top, there is a Google Drive icon, the text "Untitled2.ipynb", and a star icon. Below this is a menu bar with "File", "Edit", "View", "Insert", "Runtime", "Tools", and "Help". On the left side, there is a vertical toolbar with "Add coding cell" and a play button icon. The "Add coding cell" button is highlighted with a red box. Below it, there are two buttons: "+ Code" and "+ Text". The "+ Code" button is also highlighted with a red box. In the center, there is a code cell with a play button icon (highlighted with a red box) and the code `print("hello world!")`. Below the code cell, there is a text box showing the output: `hello world!`.

CO

Untitled2.ipynb ☆

Add coding cell

File Edit View Insert Runtime Tools Help

+ Code + Text

Run this cell

```
print("hello world!")
```

hello world!

# Pytorch: Basic

---

## P Y T R C H

- Python-based scientific computing package
  - to use the power of GPUs instead of Numpy
  - to provide maximum flexibility and speed for deep learning



```
import torch
x = torch.Tensor(5,3)
y = torch.Tensor(5,3)
print(x)
print(y)
```

```
↳ tensor([[9.9759e-36, 0.0000e+00, 3.7835e-44],
          [0.0000e+00,          nan, 0.0000e+00],
          [1.3733e-14, 6.4069e+02, 4.3066e+21],
          [1.1824e+22, 4.3066e+21, 6.3828e+28],
          [3.8016e-39, 1.6115e-43, 0.0000e+00]])
tensor([[9.5391e-36, 0.0000e+00, 3.9236e-44],
        [0.0000e+00,          nan, 0.0000e+00],
        [1.3733e-14, 1.2102e+25, 1.6992e-07],
        [2.9599e+21, 2.8175e+20, 1.7566e+25],
        [1.7748e+28, 0.0000e+00, 9.9884e-36]])
```



# Pytorch: Basic

---

Converting a Torch Tensor to a Numpy array and vice versa is breeze  
(Torch Tensor  $\leftrightarrow$  Numpy)



```
a = torch.ones(5) torch.ones : create n dim. tensor full of 1.  
print(a)  
b = a.numpy()  
print(b)  
c = torch.from_numpy(b)  
print(c)
```

```
☐→ tensor([1., 1., 1., 1., 1.])  
[1. 1. 1. 1. 1.]  
tensor([1., 1., 1., 1., 1.])
```

# Pytorch: cuda

---

in order to use CUDA (i.e., GPU)  
you have to set the Hardware accelerator to GPU

Edit tab -> Notebook settings

## Notebook settings

Hardware accelerator


None 

☐ Omit code cell output when saving th



## Notebook settings

Hardware accelerator

GPU 

To get the most out of Colab, avoid using  
a GPU unless you need one. [Learn more](#)

☐ Omit code cell output when saving th

**`torch.cuda.is_available()` -> True**

# Pytorch: cuda

---

## CUDA Tensors

Tensors can be moved onto any device using the `.to` method

```
[10] import torch  
     a = torch.ones(5)  
     b=a.cuda()  
     c=a.to(torch.device("cuda"))
```

```
[11] a
```

```
↳ tensor([1., 1., 1., 1., 1.])
```

```
[12] b
```

```
↳ tensor([1., 1., 1., 1., 1.], device='cuda:0')
```

```
[13] c
```

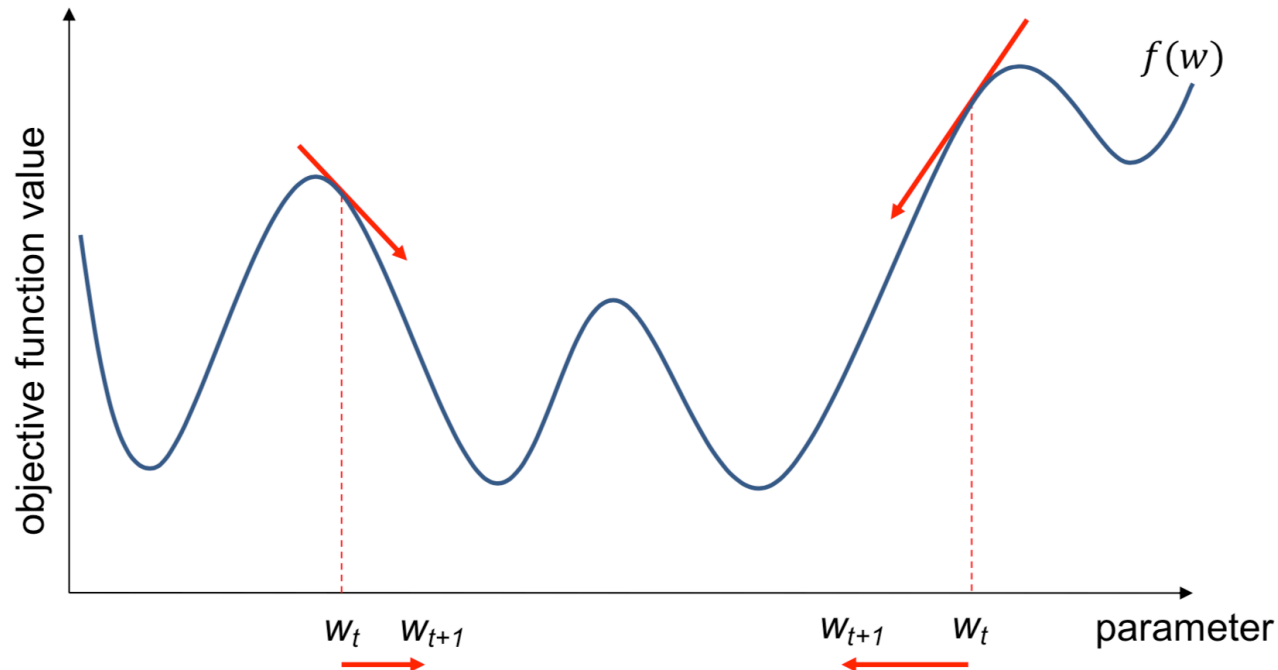
```
↳ tensor([1., 1., 1., 1., 1.], device='cuda:0')
```

## CUDA (Compute Unified Device Architecture)

a parallel computing platform and API model created by Nvidia.

# Autograd

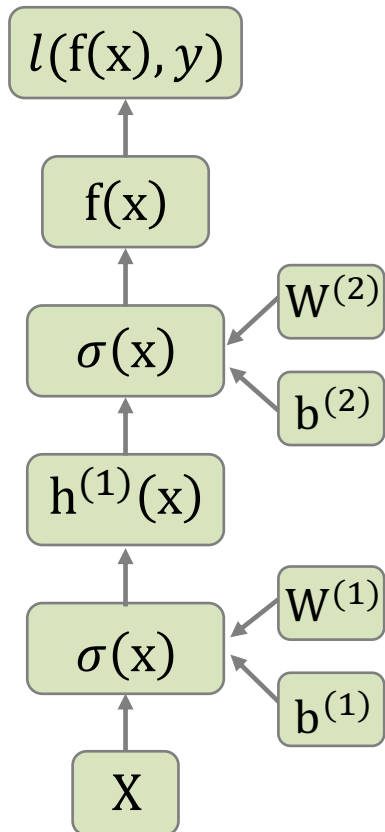
---



- The autograd provides automatic differentiation for all operations on Tensors.
- Once you finish your computation, you can call `.backward()` for autograd
- **Autograd allows you to automatically compute gradients.**

# Autograd

---



- each object has an fprop/bprop method,
- forward propagation:
  - calling fprop of each box in the right order
- backpropagation:
  - calling bprop in the reverse order
- **a large portion of deep learning research is based on Theano, PyTorch or TensorFlow**

# computational graph

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## Static vs Dynamic Graph

- We define a computational graph, and use automatic differentiation to compute **GRADIENTS**.
- Tensorflow : **Static Graph**
  - The graph is defined once and then executed over and over again.
  - Graph is optimized upfront, before the execution.
  - Loops requires specific operations(tf.scan)
- Pytorch : **Dynamic Graph**
  - Each forward pass defines a new computational graph.
  - Easy control flow
  - Easy to perform different operations for different data points.

# torch.nn

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## Torch.nn?

Neural Network Module.

Easy to make neural network  
such as **Linear**, **CNN**, **RNN**, and so on...

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(784, 500)
        self.fc2 = nn.Linear(500, 300)
        self.fc3 = nn.Linear(300, 100)
        self.fc4 = nn.Linear(100, 10)

    def forward(self, x):
        x = x.view(-1, 784)
        x = torch.tanh(self.fc1(x))
        x = torch.tanh(self.fc2(x))
        x = torch.tanh(self.fc3(x))
        x = self.fc4(x)
        return F.log_softmax(x, dim=1)
```

# loss and optimizer

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## Loss function

How to define the loss? (MSE, RMSE, CrossEntropy, L1, NLL, etc..)

## Optimizer

How to update weights ? (SGD, Adam, RMSProp, AdaDelta, etc...)



# Practice

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1. Prepare the data and preprocess it
  - implement your data loader

do:

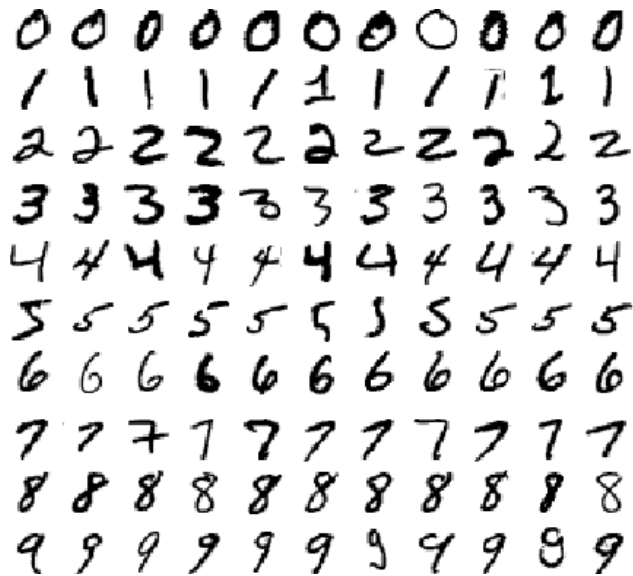
2. Set the model architecture
3. Choose and set an optimizer and an objective function
4. Train the model
5. Validate

while(!good\_performance on Validation)

6. Done

# Practice – MNIST

---



MNIST dataset [28X28] = [1 X 784]

Hand Written Digit Number from 0 to 9  
Data includes data and label.

Pytorch Dataset(torchvision) provides  
50,000 images to train,  
10,000 images to test.

# getting started

The image shows the Google Colab interface. On the left, the 'File' menu is open, displaying various options. Two options are circled in red: 'New notebook' and 'Upload notebook'. Red arrows point from these circles to the right. The 'New notebook' arrow points to a '+ Code' button in the notebook editor. The 'Upload notebook' arrow points to the text 'upload \'mnist\_colab\_example.ipynb\''.

File Edit View Insert Runtime Tools Help All c

- Locate in Drive
- Open in playground mode
- New notebook
- Open notebook ⌘/Ctrl+O
- Upload notebook
- Rename notebook
- Move to trash
- Save a copy in Drive
- Save a copy as a GitHub Gist
- Save a copy in GitHub
- Save ⌘/Ctrl+S
- Save and pin revision ⌘/Ctrl+M S
- Revision history

CO Untitled4.ipynb ☆

File Edit View Insert Runtime Tools

+ Code + Text

upload 'mnist\_colab\_example.ipynb'



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# check: mount

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```
!ls  
drive sample_data
```

+ Code + Text

Table of contents Code snippets **Files** X

⬆ Upload ↻ Refresh 🗳 Mount Drive

- ⬆ ..
- ▶ 📁 drive
- ▶ 📁 sample\_data

## code: import

---



```
from __future__ import print_function
import argparse
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torchvision import datasets, transforms
import os
```

# code: models

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(784, 500)
        self.fc2 = nn.Linear(500, 300)
        self.fc3 = nn.Linear(300, 100)
        self.fc4 = nn.Linear(100, 10)

    def forward(self, x):
        batch_size, c, h, w = x.data.size()
        x = x.view(batch_size, 784)
        x = torch.tanh(self.fc1(x))
        x = torch.tanh(self.fc2(x))
        x = torch.tanh(self.fc3(x))
        x = self.fc4(x)
        return F.log_softmax(x, dim=1)
```

```
class Net(nn.Module):
    def __init__(self):
        super(Net, self).__init__()
        self.conv = nn.Sequential(
            nn.Conv2d(1, 20, 5, 1),
            nn.ReLU(),
            nn.MaxPool2d(2,2),
            nn.Conv2d(20, 50, 5, 1),
            nn.ReLU(),
            nn.MaxPool2d(2,2)
        )
        conv_size = self.get_conv_size((1, 28, 28))
        self.fc = nn.Sequential(
            nn.Linear(conv_size, 500), # conv_size = 4*4*50
            nn.Linear(500, 10)
        )

    def get_conv_size(self, shape):
        o = self.conv(torch.zeros(1, *shape))
        return int(np.prod(o.size()))

    def forward(self, x):
        batch_size, c, h, w = x.data.size() # 32*1*28*28
        x = self.conv(x)
        x = x.view(batch_size, -1) # conv_size = 4*4*50
        x = self.fc(x)
        return F.log_softmax(x, dim=1)
```

Other network architectures  
can be used

# code: train function

---

```
▶ def train(model, device, train_loader, optimizer, epoch, log_interval):
    model.train()
    for batch_idx, (data, target) in enumerate(train_loader):
        data, target = data.to(device), target.to(device)
        optimizer.zero_grad()
        output = model(data)
        loss = F.nll_loss(output, target)
        loss.backward()
        optimizer.step()

    if batch_idx % log_interval == 0:
        print('Train Epoch: {} [{}/{}] ({:.0f}%)\tLoss: {:.6f}'.format(
            epoch, batch_idx * len(data), len(train_loader.dataset),
            100. * batch_idx / len(train_loader), loss.item()))
```



# code: test function

---

```
def test(model, device, test_loader):
    model.eval()
    test_loss = 0
    correct = 0
    with torch.no_grad():
        for data, target in test_loader:
            data, target = data.to(device), target.to(device)
            output = model(data)

            # sum up batch loss
            test_loss += F.nll_loss(output, target, reduction='sum').item()

            # get the index of the max log-probability
            pred = output.argmax(dim=1, keepdim=True)
            correct += pred.eq(target.view_as(pred)).sum().item()

    test_loss /= len(test_loader.dataset)

    print('\nTest: Average loss: {:.4f}, Accuracy: {}/{} ({:.0f}%)\n'.format(
        test_loss, correct, len(test_loader.dataset),
        100. * correct / len(test_loader.dataset)))
```

# code: configuration

---

```
seed = 1
epochs = 2
batch_size = 32
test_batch_size = 1000
lr = 0.001
momentum = 0.9
log_interval = 100
save_model = True

torch.manual_seed(seed)

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

kwargs = {'num_workers': 1, 'pin_memory': True} if torch.cuda.is_available() else {}
```

## code: data

---

```
transform=transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.1307,), (0.3081,)) ])
train_loader = torch.utils.data.DataLoader(
    datasets.MNIST('drive/My Drive/public/data', train=True,
                  download=True, transform=transform),
    batch_size=batch_size, shuffle=True, **kwargs)
test_loader = torch.utils.data.DataLoader(
    datasets.MNIST('drive/My Drive/public/data', train=False,
                  transform=transform),
    batch_size=test_batch_size, shuffle=True, **kwargs)
```

# check: data loader

```
▶ for batch, (data, target) in enumerate(train_loader):  
    print(data)  
    print(target)  
    break
```

```
↳ tensor([[[[-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            ...,  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242]]],
```

```
        [[[-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            ...,  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242]]],
```

```
        [[[-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            ...,  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242],  
            [-0.4242, -0.4242, -0.4242, ..., -0.4242, -0.4242, -0.4242]]],
```

```
        ...,
```

```
tensor([9, 3, 0, 1, 2, 4, 6, 8, 1, 2, 3, 0, 7, 0, 0, 1, 3, 9, 4, 1, 1, 2, 9,  
        0, 0, 1, 4, 6, 2, 1, 3])
```

# code: main

---

```
▶ model = Net().to(device)
  optimizer = optim.SGD(model.parameters(), lr=lr, momentum=momentum)

  for epoch in range(1, epochs + 1):
      train(model, device, train_loader, optimizer, epoch, log_interval)
      test(model, device, test_loader)

  if (save_model):
      if not os.path.exists('drive/My Drive/public/results'):
          os.mkdir('drive/My Drive/public/results')
      torch.save(model, "drive/My Drive/public/results/mnist_nn.pth")
```

# results

```
☞ Train Epoch: 1 [0/60000 (0%)]    Loss: 2.301313
Train Epoch: 1 [3200/60000 (5%)]    Loss: 1.915514
Train Epoch: 1 [6400/60000 (11%)]    Loss: 1.429157
Train Epoch: 1 [9600/60000 (16%)]    Loss: 0.774661
Train Epoch: 1 [12800/60000 (21%)]   Loss: 0.816357
Train Epoch: 1 [16000/60000 (27%)]   Loss: 0.586290
Train Epoch: 1 [19200/60000 (32%)]   Loss: 0.472406
Train Epoch: 1 [22400/60000 (37%)]   Loss: 0.457613
Train Epoch: 1 [25600/60000 (43%)]   Loss: 0.525044
Train Epoch: 1 [28800/60000 (48%)]   Loss: 0.478475
Train Epoch: 1 [32000/60000 (53%)]   Loss: 0.265142
Train Epoch: 1 [35200/60000 (59%)]   Loss: 0.181658
Train Epoch: 1 [38400/60000 (64%)]   Loss: 0.292922
Train Epoch: 1 [41600/60000 (69%)]   Loss: 0.211006
Train Epoch: 1 [44800/60000 (75%)]   Loss: 0.447125
Train Epoch: 1 [48000/60000 (80%)]   Loss: 0.295472
Train Epoch: 1 [51200/60000 (85%)]   Loss: 0.416876
Train Epoch: 1 [54400/60000 (91%)]   Loss: 0.369973
Train Epoch: 1 [57600/60000 (96%)]   Loss: 0.389900
```

Test: Average loss: 0.3018, Accuracy: 9148/10000 (91%)

```
Train Epoch: 2 [0/60000 (0%)]    Loss: 0.404442
Train Epoch: 2 [3200/60000 (5%)]    Loss: 0.237755
Train Epoch: 2 [6400/60000 (11%)]    Loss: 0.178738
Train Epoch: 2 [9600/60000 (16%)]    Loss: 0.338589
Train Epoch: 2 [12800/60000 (21%)]   Loss: 0.660104
```

## check: save/load model

---

```
torch.save(model, "drive/My Drive/public/results/mnist_nn.pth")
```

```
!ls "drive/My Drive/public/results"
```

```
↳ cifar10_model.pth mnist_nn.pth ptb_trained_model_best.pth
```

```
load_model = torch.load("drive/My Drive/public/results/mnist_nn.pth")
```

# practice: with real images

---

Put image files to test in your google drive

drive/My Drive/public/data/mnist\_test\_images/



```
!ls 'drive/My Drive/public/data/mnist_test_images/'
```

```
test0.jpg  test13.jpg  test17.jpg  test20.jpg  test5.jpg  test9.jpg
test10.jpg  test14.jpg  test18.jpg  test2.jpg  test6.jpg
test11.jpg  test15.jpg  test19.jpg  test3.jpg  test7.jpg
test12.jpg  test16.jpg  test1.jpg  test4.jpg  test8.jpg
```



## practice: with one image

---

```
[7] load_model = torch.load("drive/My Drive/public/results/mnist_cnn.pth")
```



```
from skimage import io
```

```
img_name = 'drive/My Drive/public/data/mnist_test_images/test0.jpg'  
test_img = io.imread(img_name).reshape(28,28)  
test_data = transform(test_img).view(1,1,28,28).to(device)  
with torch.no_grad():  
    output=load_model(test_data)  
print(img_name, output.argmax(dim=1).cpu().numpy()[0])
```

```
↳ drive/My Drive/public/data/mnist_test_images/test0.jpg 5
```

## practice: with a directory

---

```
load_model = torch.load("drive/My Drive/public/results/mnist_cnn.pth")

from skimage import io
import glob
file_list = glob.glob("drive/My Drive/public/data/mnist_test_images/*.jpg")
for img_name in file_list:
    #img_name = 'drive/My Drive/public/data/mnist_test_images/test0.jpg'
    test_img = io.imread(img_name).reshape(28,28)
    test_data = transform(test_img).view(1,1,28,28).to(device)
    with torch.no_grad():
        output=load_model(test_data)
    print(img_name, output.argmax(dim=1).cpu().numpy()[0])
```

```
↳ drive/My Drive/public/data/mnist_test_images/test3.jpg 1
drive/My Drive/public/data/mnist_test_images/test8.jpg 1
drive/My Drive/public/data/mnist_test_images/test9.jpg 4
drive/My Drive/public/data/mnist_test_images/test2.jpg 4
drive/My Drive/public/data/mnist_test_images/test0.jpg 5
drive/My Drive/public/data/mnist_test_images/test6.jpg 1
drive/My Drive/public/data/mnist_test_images/test4.jpg 9
drive/My Drive/public/data/mnist_test_images/test7.jpg 3
drive/My Drive/public/data/mnist_test_images/test5.jpg 2
drive/My Drive/public/data/mnist_test_images/test1.jpg 0
drive/My Drive/public/data/mnist_test_images/test10.jpg 3
```

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Machine Intelligence Lab  
<https://milab.handong.edu/>

Handong Global University