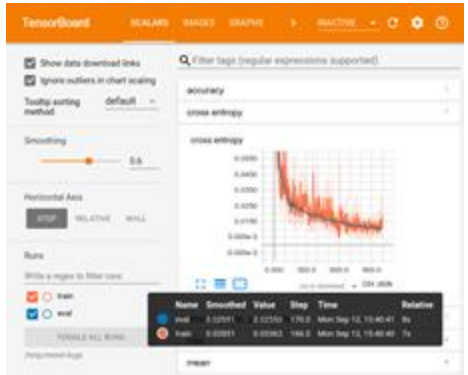
# Introduction to Deep Learning (I2DL)

## Exercise 7: Pytorch

# Today's Outline

- Exercise 6 Recap
  - Or: why are you bad?
- Pytorch
  - And other libraries
- "Optional Submission"
  - It's good for you <3
- Organization



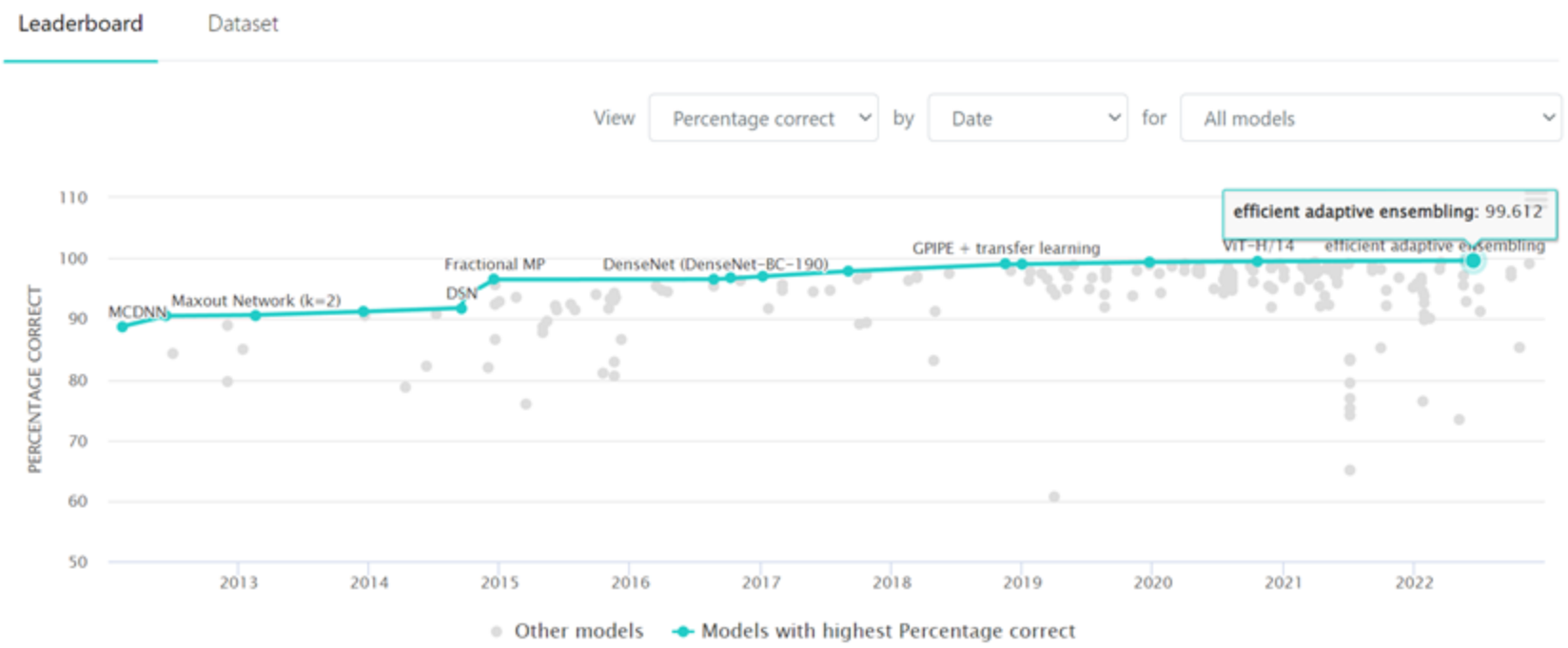

PyTorch

# Exercise 6 Recap

# Our Leaderboard

| # | User | Score |
|---|---|---|
| 1 | u0533 | 59.16 |
| 2 | a0012 | 58.19 |
| 3 | u1249 | 57.72 |
| 4 | u0736 | 56.43 |
| 5 | u1289 | 56.40 |
| 6 | u0438 | 56.29 |
| 7 | u1566 | 56.16 |
| 8 | u0871 | 56.14 |
| 9 | u0036 | 56.00 |
| 10 | u1180 | 55.93 |

# Image Classification on CIFAR-10




https://paperswithcode.com/sota/image-classification-on-cifar-10

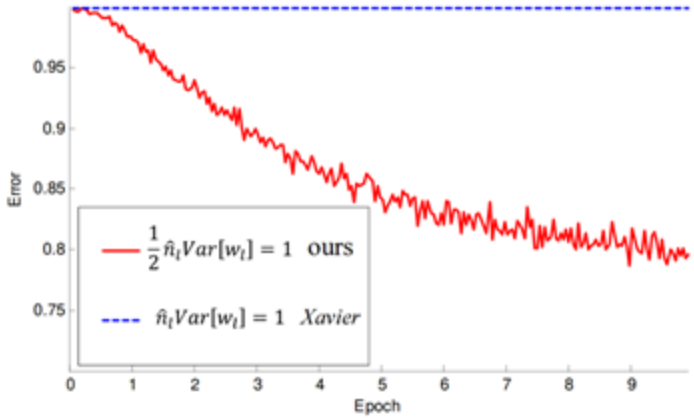
# Some Limiting Factors

- Computational power and/or time → Pytorch -> GPU support
- Specialized architectures → CNNs -> Lecture 9
- More knowledge e.g., proper initialization → Lectures ☺

# Lecture Recap: Initialization

Lecture

- Network weights shouldn't only be randomly initialized
- They should be tailored to our activation function




We in exercise 6 ^^

```
self.params = {'W1': std * np.random.randn(input_size, hidden_size),
               'b1': np.zeros(hidden_size)}
```

# Pytorch

# Exercise Overview

| | |
|---|---|
| Exercise 01: Organization<br>Exercise 02: Math Recap | Intro |
| Exercise 03: Dataset and Dataloader<br>Exercise 04: Solver and Linear Regression<br>Exercise 05: Neural Networks<br>Exercise 06: Hyperparameter Tuning | Numpy<br>(Reinvent the wheel) |
| Exercise 07: Introduction to Pytorch<br>Exercise 08: Autoencoder | Pytorch/Tensorboard |
| Exercise 09: Convolutional Neural Networks<br>Exercise 10: Semantic Segmentation<br>Exercise 11: Recurrent Neural Networks | Applications<br>(Hands-off) |

# Deep Learning Frameworks

The two big ones

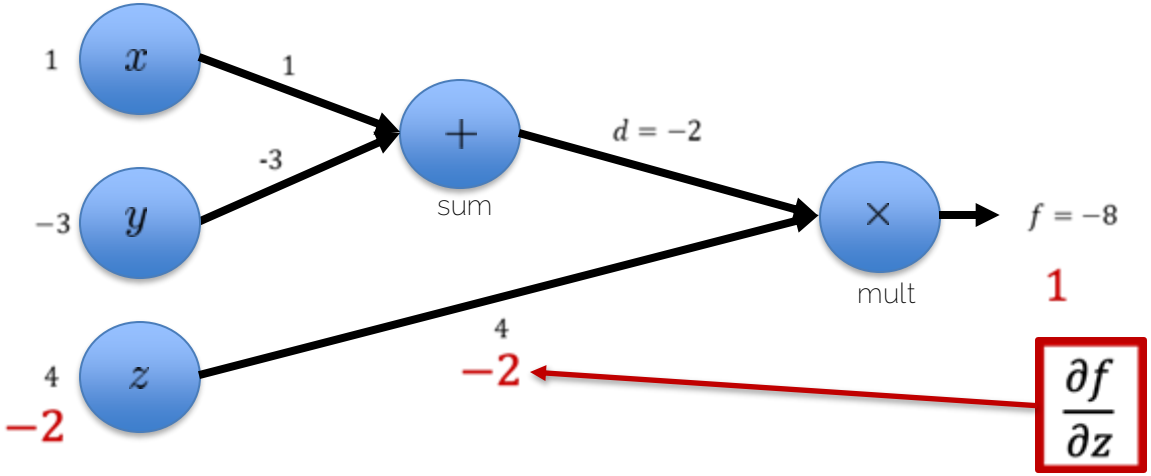
- Tensorflow - Google
  - As well as Keras
- Pytorch – Facebook

Other examples

- CNTK – Microsoft
- Mxnet – Apache
- Jax – Google
- …




# Different Paradigms

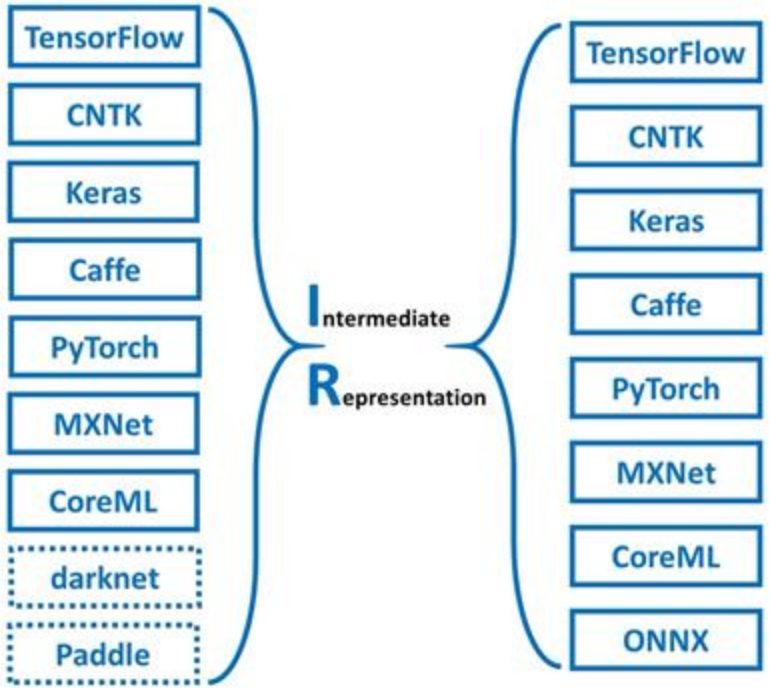



| | Tensorflow | Pytorch |
|---|---|---|
| Graph Creation | Static/Eager | Dynamic/On Runtime |
| Similar to | C | Python |

# Framework Conversion

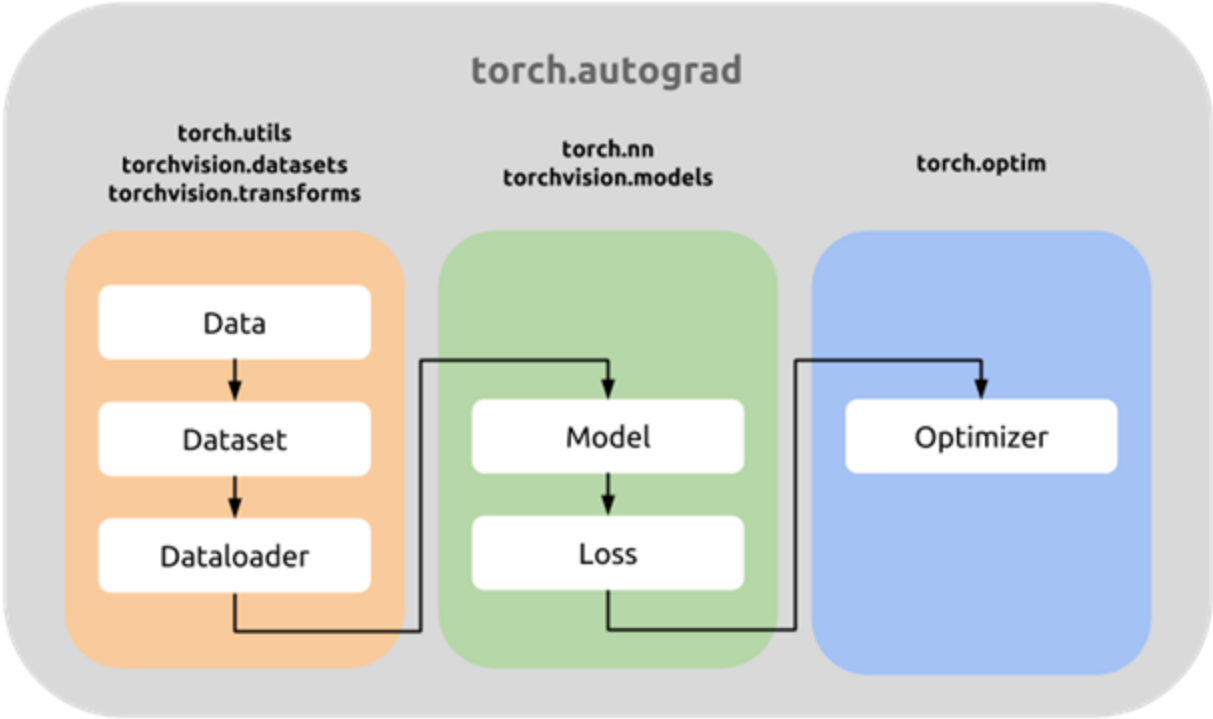
Usual workflow:

- Develop and train network in your favourite framework
- Convert and optimize in target framework for production




See: https://github.com/microsoft/MMdnn

# Pytorch: Overview



# Some key features

- Simple device management

```
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print(device)

print(f"Original device: {x.device}") # "cpu", integer

tensor = x.to(device)
print(f"Current device: {x.device}") #"cpu" or "cuda", double
```

```
cpu
Original device: cpu
Current device: cpu
```

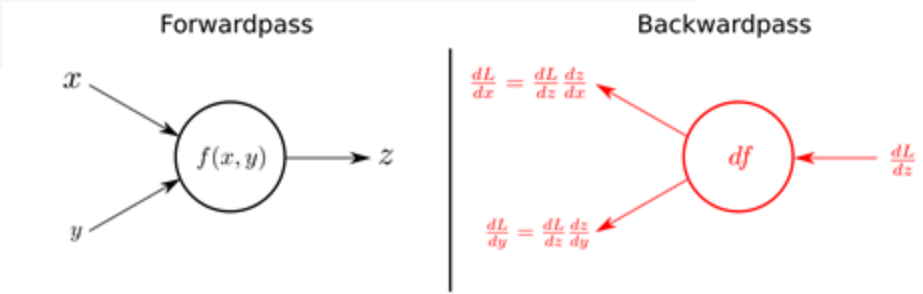
- Implementations of:
  - Optimizers, etc.
  - Datasets
  - Automatic gradients

# Easy network creation

```
import torch.nn as nn
# defining the model
class Net(nn.Module):
    def __init__(self, input_size=1*28*28, output_size=100):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(input_size, output_size)

    def forward(self, x):
        x = self.fc1(x)
        return x
net = Net()
net = net.to(device)
```

Where is the backward pass?



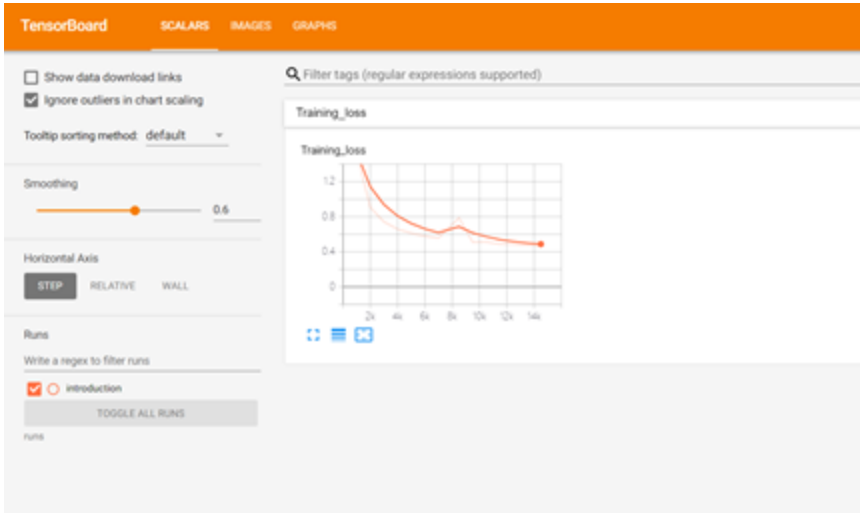
# References on Pytorch

- Repository: https://github.com/pytorch/pytorch
- Examples (recommendation): https://github.com/pytorch/examples
- PyTorch for NumPy users: https://github.com/wkentaro/pytorch-for-numpy-users
- Look up your own and share! ☺

# Tensorboard (also in Pytorch)

- Directly access tensorboard in your training loop

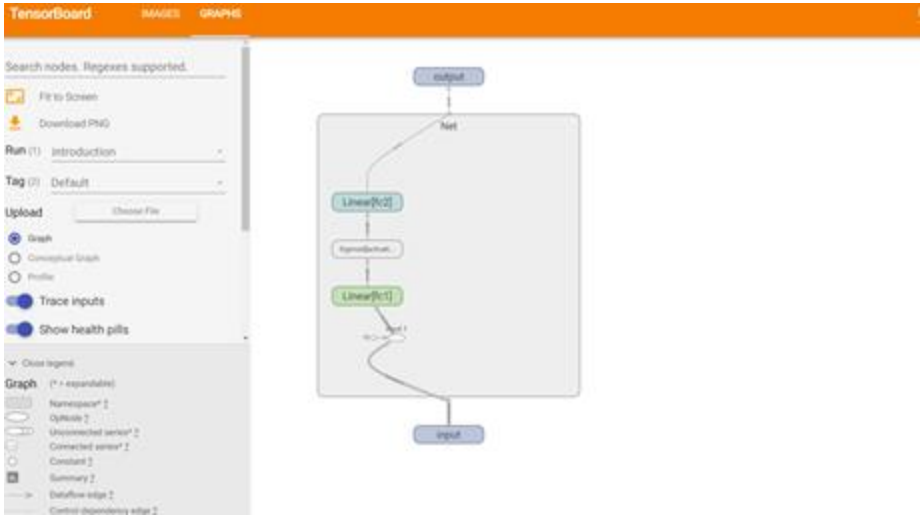
- Tensorboard generates the graph/timestamps etc. for you



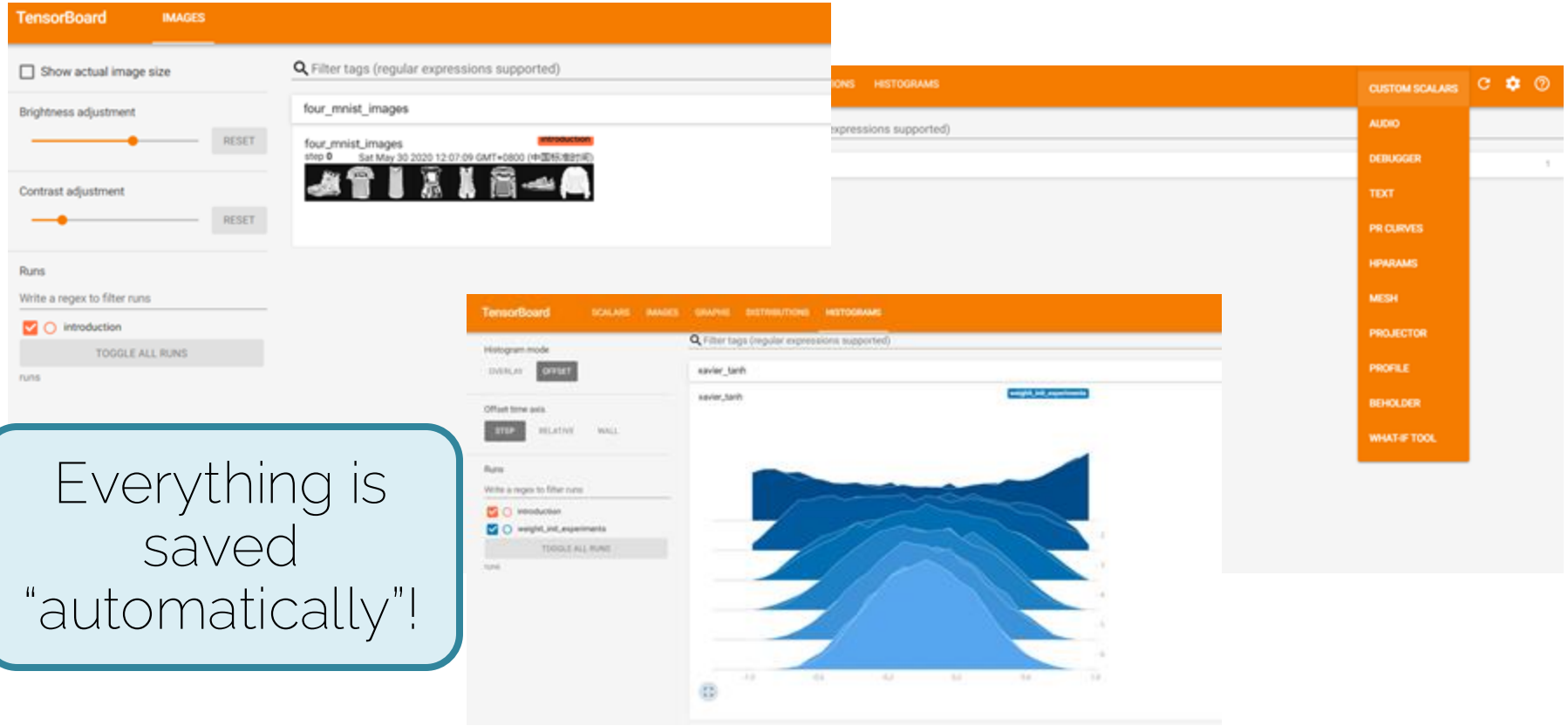
# Visualize Networks

- Using a single forward pass, tensorboard can map and display your network graph

Graph creation needs network & one batch!



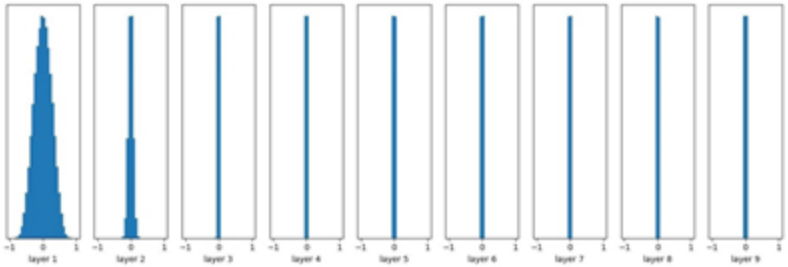
# In short: document everything!

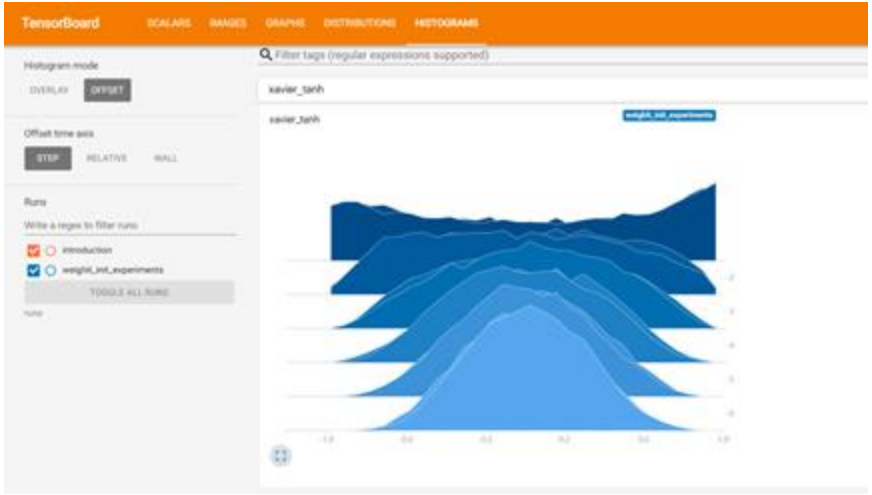



Everything is saved "automatically"!

# Example: Weight Initialization

- Histogram visualization for layer outputs can show off effects of weight initialization as shown in the lecture



# More Abstraction: Pytorch Lightning

Classify our code into three categories

1. **Research** code (the exciting part!, changes with new tasks, models etc.)

→ LightningModule

1. **Engineering** code (the same for all projects and models)

→ Trainer

1. **Non-essential** code (logging, organizing runs)

→ Callbacks

# Lightning Module

PyTorch

```
# model
class Net(nn.Module):
  def __init__(self):
      self.layer_1 = torch.nn.Linear(28 * 28, 128)
      self.layer_2 = torch.nn.Linear(128, 10)

  def forward(self, x):
    x = x.view(x.size(0), -1)
    x = self.layer_1(x)
    x = F.relu(x)
    x = self.layer_2(x)
    return x

# train loader
mnist_train = MNIST(os.getcwd(), train=True, download=True,
                    transform=transforms.ToTensor())
mnist_train = DataLoader(mnist_train, batch_size=64)

net = Net()

# optimizer + scheduler
optimizer = torch.optim.Adam(net.parameters(), lr=1e-3)
scheduler = StepLR(optimizer, step_size=1)

# train
for epoch in range(1, 100):
    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 % args.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()))
```

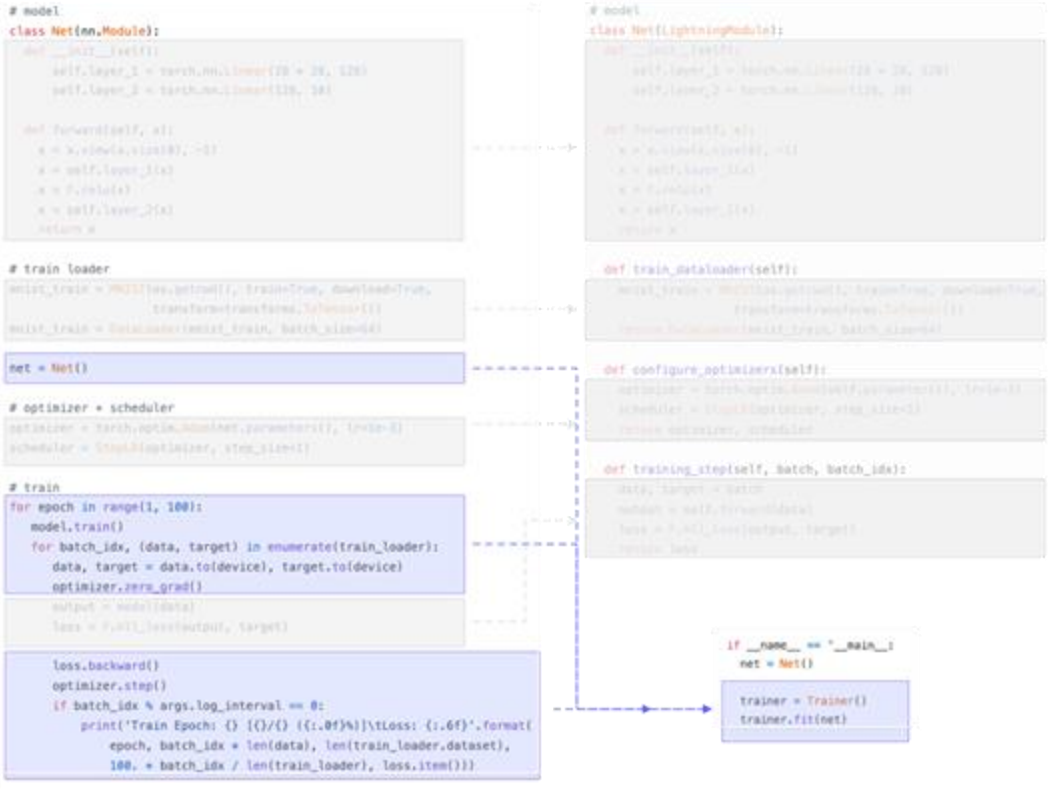
Methods that need to be implemented

- __init__
- forward
- training_step
- configure_optimizers

# Lightning Trainer

PyTorch

PyTorch Lightning



1. Initialize the model with hyperparamers for training (e.g. as a dictionary)
2. Trainer contains all code relevant for training our neural networks
3. Call the method .fit() for training the network

That's all you need to train you model ☺

# What to use? Your call!

- Advantages
  - Better overview of the relevant code
  - Nice debugging features
  - Many automated options, like logging

- Potential Problems
  - Can have issues like any stock library…
  - Not always straightforward to add features yourself

# "Optional" Submission

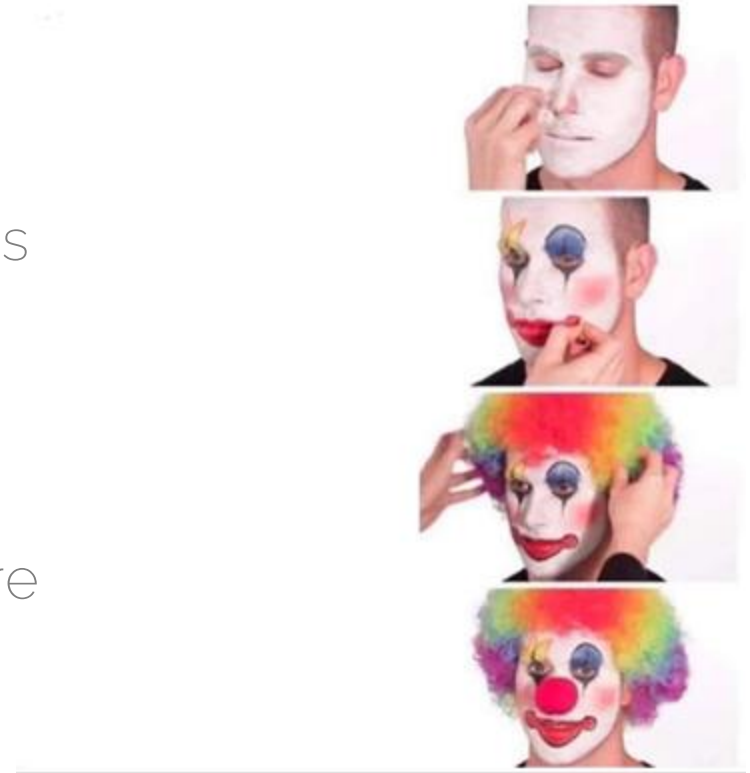
# CIFAR10… Again…

- Task: CIFAR10 classification (but now in Pytorch)


- New:
  - More knowledge from lecture 7
  - Can use everything but no: convolutional layers/transformers/ pre-trained networks
  - Filesize and parameter limit

# So… Tuning again?

- Make sure
  - To get into pytorch
    (read docs and source code!)
  - To improve upon your previous submission
  - How can you select good hyperparameters?
  - Discuss with fellow students
    -> Code sharing on campuswire allowed!



# Organization

# Post Deadline Submissions

## Post Deadline Exercises

The following entries are identical to the ones above, but allow you to submit solutions after the deadline of the respective exercise has passed.
Submitting solutions to these "Post Deadline" exercises does not count towards the bonus nor can they substitute a missed exercise!

- **Exercise 3 (Post Deadline) – Dataset and Dataloader [Optional]**
- **Exercise 4 (Post Deadline) – Solver and Linear Regression [Optional]**
- **Exercise 5 (Post Deadline) – Neural Networks [Optional]**
- **Exercise 6 (Post Deadline) – Hyperparameter Tuning [Optional]**
- **Exercise 7 (Post Deadline) – Intro to Pytorch [Optional]**
- **Exercise 8 (Post Deadline) – Autoencoder [Optional]**
- **Exercise 9 (Post Deadline) – Convolutional Neural Networks [Optional]**
- **Exercise 10 (Post Deadline) – Semantic Segmentation [Optional]**
- **Exercise 11 (Post Deadline) – Recurrent Neural Networks [Optional]**

# Solutions on Github

- Please don't upload solutions
  - You only hurt future students progression
  - We will issue take-downs!
  - No future employer cares

- What can you do else?
  - Choose an exercise of 7, 9, 10, or any other task/paper
  - Document your whole journey
  - Create: visualizations, ablations
  - Outline: key changes, maybe a story
  - Share: your documents with students

# See you next week