Optimization algorithms in deep learning

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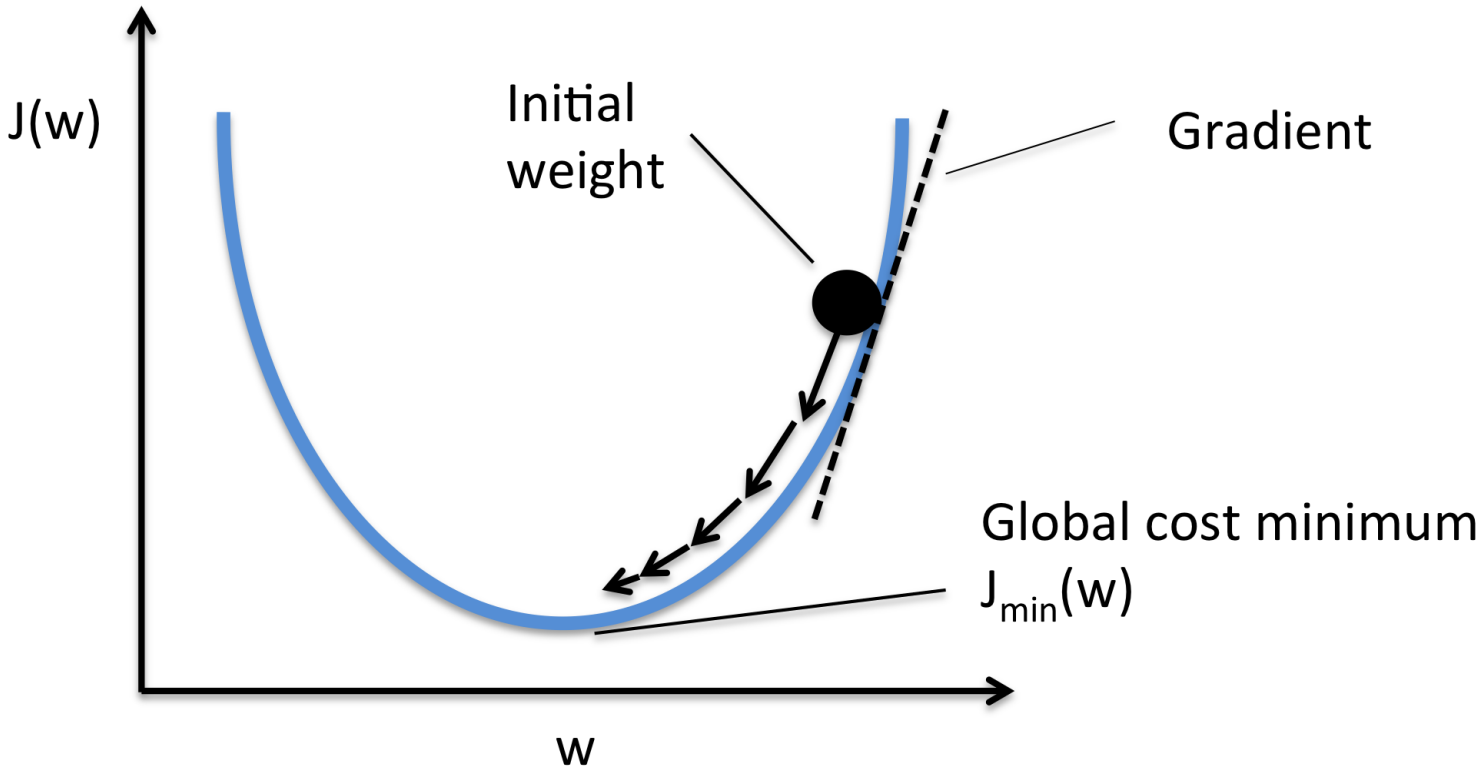
Optimization

In *context* of deep learning,
goal is to **minimize loss function**

$$w^* = \arg\min_w L(w) \tag{1}$$

What is gradient descent optimization?



Stochastic Gradient Descent (SGD)

Algorithm

Update step:

$$\theta_{t+1} = \theta_t - \eta \cdot \nabla_\theta J(\theta_t) \tag{2}$$

where,

θ_t:	current model parameters
$\nabla_\theta J(\theta_t)$:	gradient of these model parameters
η:	learning rate (fixed)

Stochastic Gradient Descent (SGD)

How we usually call in PyTorch:

```
optimizer = optim.SGD(model.parameters(), lr=0.01)
```

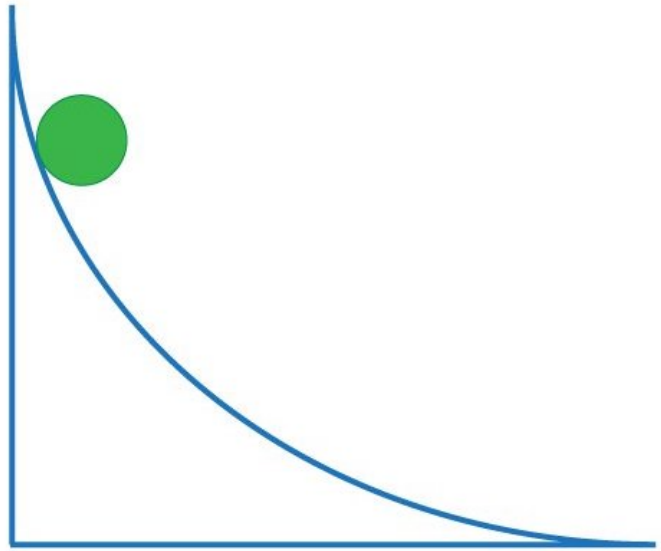
How we can create our "native" class:

```
from torch.optim.optimizer import Optimizer

class CustomSGD(Optimizer):
  def __init__(self, model_params, lr=1e-3):
      self.model_params = list(model_params)
      self.lr = lr

  def zero_grad(self):
      for param in self.model_params:
          param.grad = None

  @torch.no_grad()
  def step(self):
      for param in self.model_params:
          param.sub_(self.lr * param.grad)
```

SGD with Momentum

General idea:

- Overcome small gradients near flat areas
- Build up from previous "velocity"
- Faster learning



SGD with Momentum

Algorithm

Update step [1]:

$$v_{t,i} = \gamma \cdot v_{t-1,i} + \nabla_\theta J(\theta_{t,i}) \tag{3}$$

$$\theta_{t+1} = \theta_t - \eta \cdot v_{t,i} \tag{4}$$

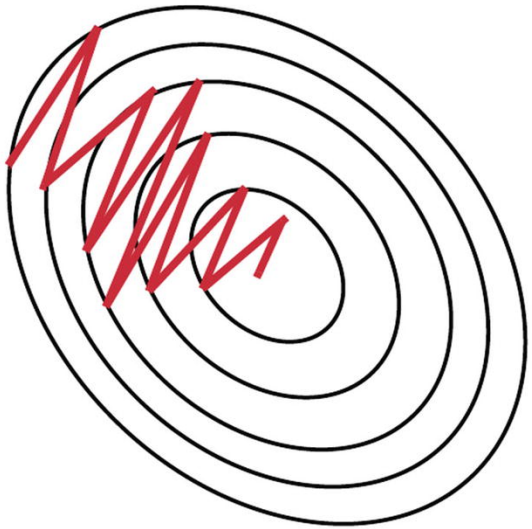
where,

γ:	friction (or momentum, fixed)
v_t:	velocity
$\nabla_\theta J(\theta_t)$:	gradient of these model parameters
η:	learning rate (fixed)

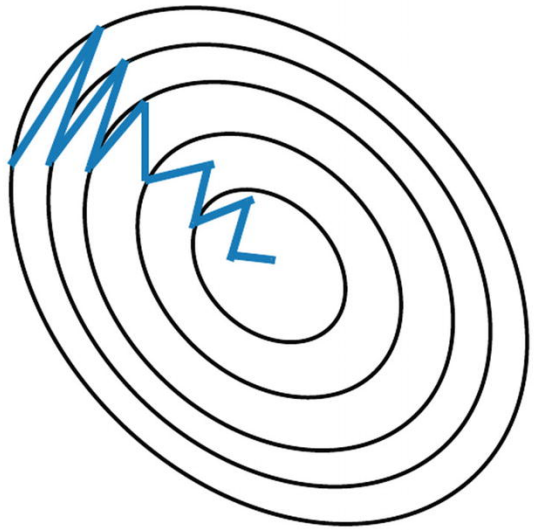
SGD with Momentum

```python
from torch.optim.optimizer import Optimizer

class CustomSGDMomentum(Optimizer):
  def __init__(self, model_params, lr=1e-3, momentum=0.9):
      self.model_params = list(model_params)
      self.lr = lr
      self.momentum = momentum
      self.v = [torch.zeros_like(p) for p in self.model_params]

  def zero_grad(self):
      for param in self.model_params:
          param.grad = None

  @torch.no_grad()
  def step(self):
      for param, v in zip(self.model_params, self.v):
          v.mul_(self.momentum).add_(param.grad)
          param.sub_(self.lr * v)
```

SGD with Momentum [1]



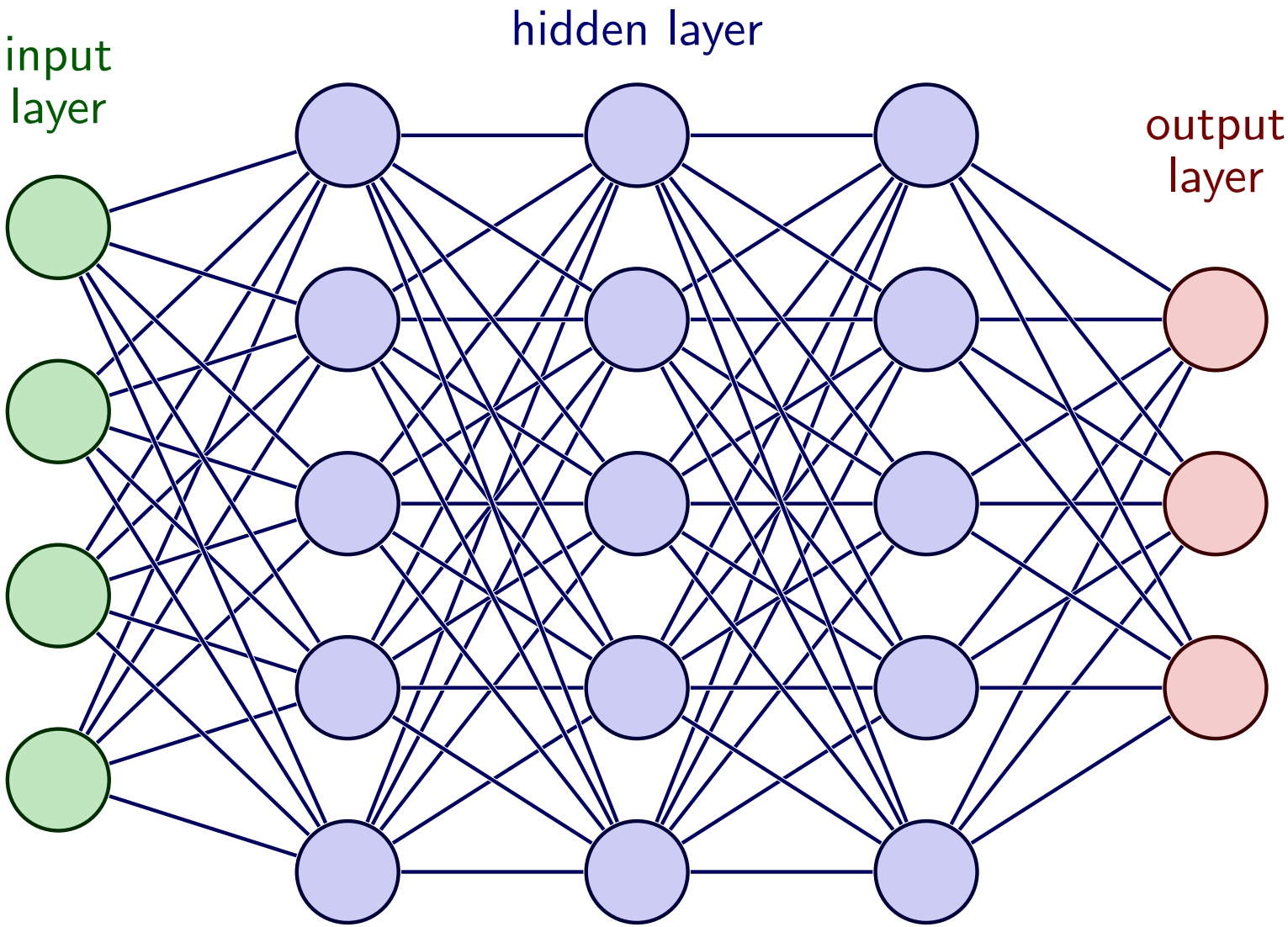
Stochastic Gradient Descent **withhout** Momentum



Stochastic Gradient Descent **with** Momentum

Experiment

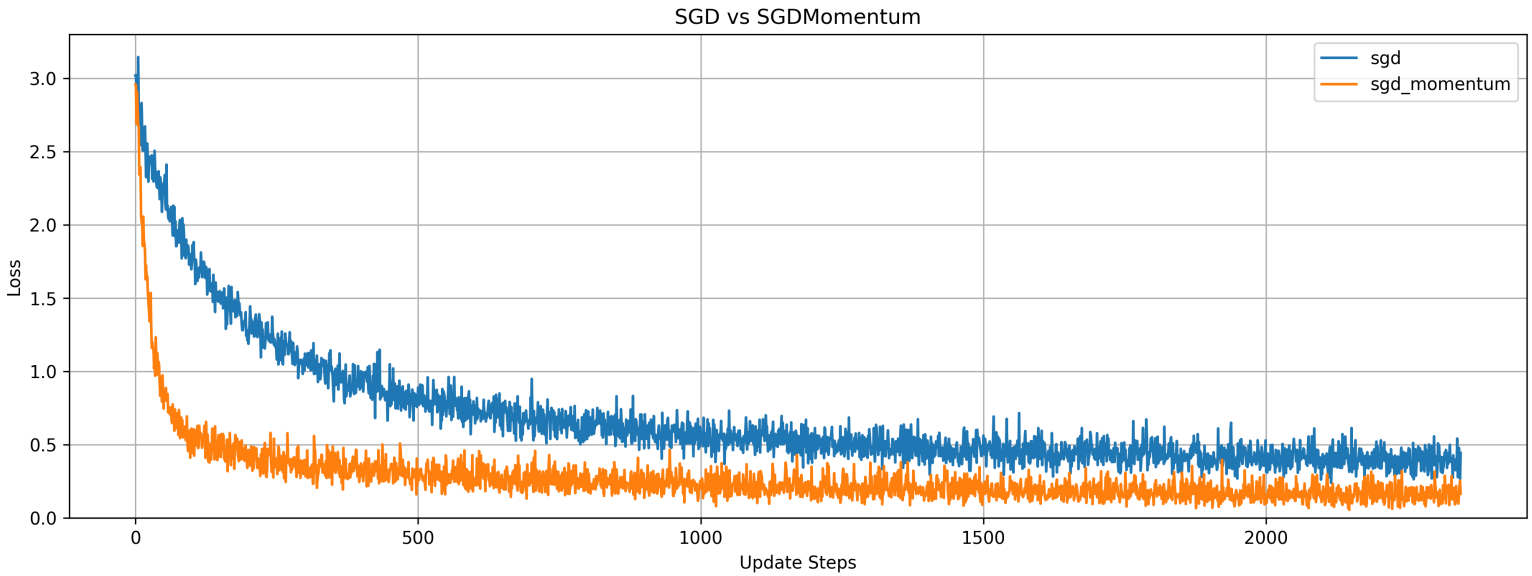
A vanilla MLP (Multilayer Perceptron)



Experiment

MNIST dataset

Experiment


SGD vs SGDMomentum
sgd
sgd_momentum
Loss
Update Steps
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
2000

 Ning Qian. “On the momentum term in gradient descent learning algorithms”. In: *Neural networks* 12.1 (1999), pp. 145–151.