In [ ]:
```
import numpy as np
from sklearn.preprocessing import StandardScaler
import matplotlib.pyplot as plt
import torch
from torch import nn
import torchvision
from PIL import Image
import itertools
from IPython.display import display
```

Main reference https://pytorch.org/

In [ ]:
```
device = (
    "cuda"
    if torch.cuda.is_available()
    else "mps"
    if torch.backends.mps.is_available()
    else "cpu"
)
print(f"Using {device} device")
```

```
Using cuda device
```

In [ ]:
```
bird_image = Image.open("D:\School\Applied ML FSU\Applied-ML-FSU\Data/bird038.png").convert("L")
tensor = torchvision.transforms.ToTensor()
bird_tensor = tensor(bird_image)
bird = bird_tensor.flatten()
bscaler = StandardScaler(with_std = False)
sbird = bscaler.fit_transform(bird.reshape(-1,1))
sbird = torch.tensor(sbird).squeeze().float().to(device)

height, width = bird_tensor.squeeze().shape
coordinates = torch.tensor(list(itertools.product(range(height), range(width))))
cscaler = StandardScaler()
scoordinates = cscaler.fit_transform(coordinates)
scoordinates = torch.tensor(scoordinates).float().to(device)

bird_coordinate = list(zip(scoordinates, sbird))
dataloader = torch.utils.data.DataLoader(bird_coordinate, batch_size = 64, shuffle = True)
```

```
<>:1: SyntaxWarning: invalid escape sequence '\S'
<>:1: SyntaxWarning: invalid escape sequence '\S'
C:\Users\evans\AppData\Local\Temp\ipykernel_44028\618277442.py:1: SyntaxWarning: invalid escape sequence '\S'
  bird_image = Image.open("D:\School\Applied ML FSU\Applied-ML-FSU\Data/bird038.png").convert("L")
```

(a)

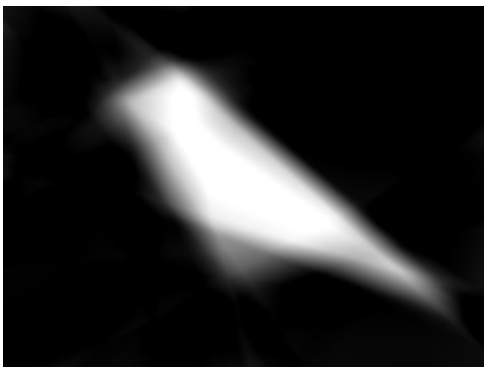
In [ ]:
```
#https://pytorch.org/tutorials/beginner/basics/buildmodel_tutorial.html

class NeuralNetwork(nn.Module):
    def __init__(self):
        super().__init__()
        self.flatten = nn.Flatten()
        self.linear_relu_stack = nn.Sequential(
            nn.Linear(2, 128),
            nn.ReLU(),
            nn.Linear(128, 1)
        )

    def forward(self, x):
        x = self.flatten(x)
        logits = self.linear_relu_stack(x)
        return logits
```

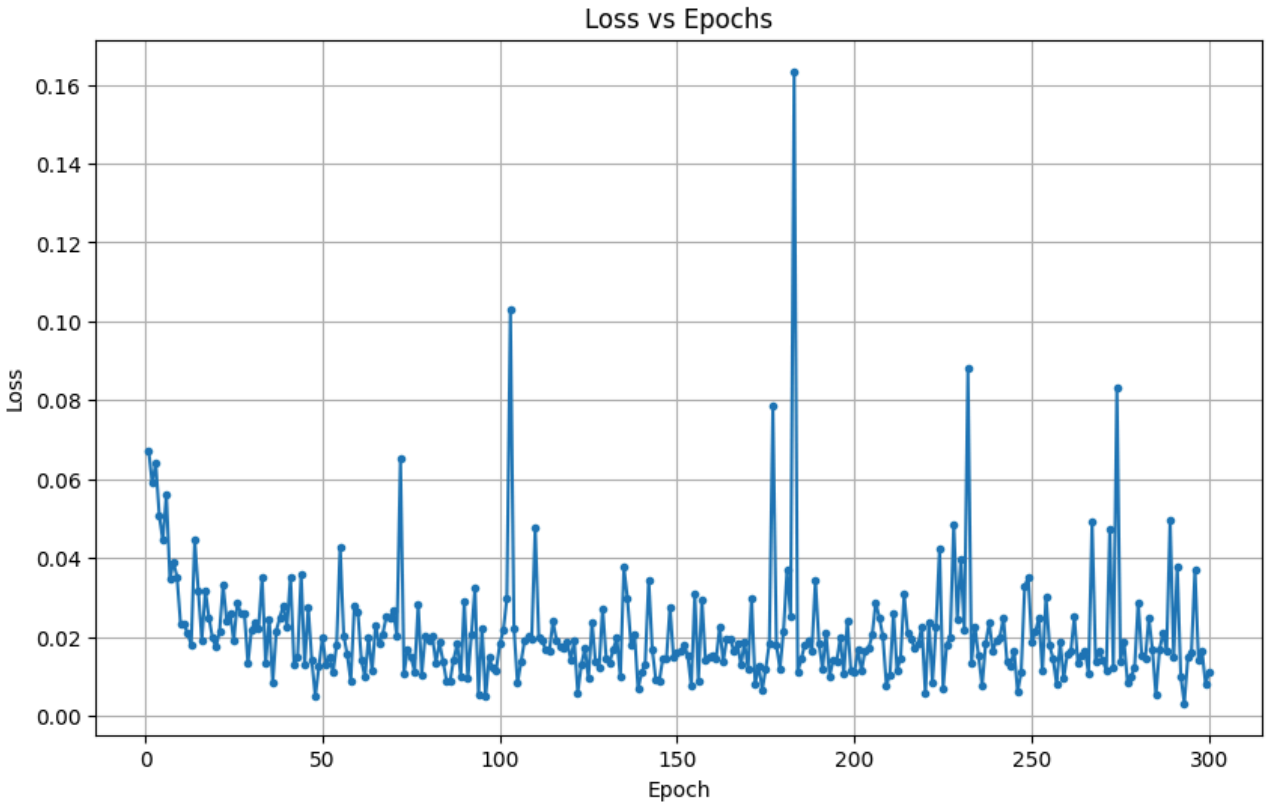
In [ ]:
```
epochs = 300
```

In [ ]:
```
neural_net = NeuralNetwork().to(device)
optimizer = torch.optim.SGD(neural_net.parameters(), lr = 0.1)
mse = nn.MSELoss()
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, step_size = 100, gamma = 0.5)
```

```
losses = []
for epoch in range(epochs):
    for _, (X,y) in enumerate(dataloader):
        optimizer.zero_grad()
        pred = neural_net(X).squeeze()
        loss = mse(pred, y)
        loss.backward()
        optimizer.step()
    losses.append(loss.item())
```

In [ ]:
```
# https://cloudxlab.com/assessment/displayslide/5658/converting-tensor-to-image
with torch.no_grad():
    L = neural_net(scoordinates).cpu()
    L =  np.clip(bscaler.inverse_transform(L), 0, 1)
    L =  (L*255).astype(np.uint8)
    reconstructed = Image.fromarray(L.reshape(height, width))
    resized = reconstructed.resize((300,225))
display(resized)
plt.figure(figsize = (10,6))
plt.plot(range(1, epochs + 1), losses, marker = '.')
plt.title('Loss vs Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.grid()
plt.show()
```



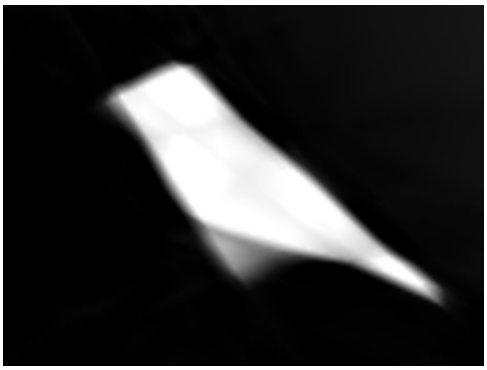


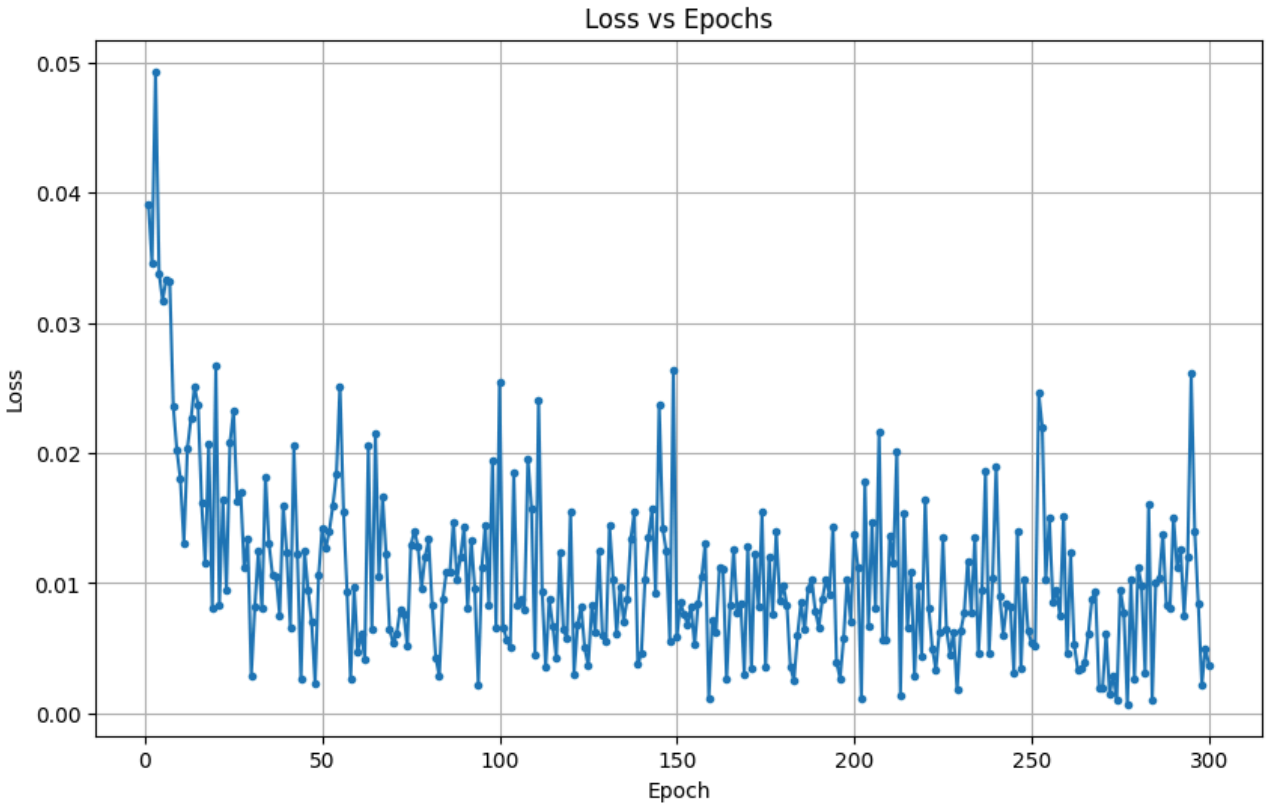
(b)

In [ ]:
```
class NeuralNetwork(nn.Module):
    def __init__(self):
        super().__init__()
        self.flatten = nn.Flatten()
        self.linear_relu_stack = nn.Sequential(
            nn.Linear(2, 32),
            nn.ReLU(),
            nn.Linear(32, 128),
            nn.ReLU(),
            nn.Linear(128,1)
        )

    def forward(self, x):
        x = self.flatten(x)
        logits = self.linear_relu_stack(x)
        return logits
```

In [ ]:
```
neural_net = NeuralNetwork().to(device)
optimizer = torch.optim.SGD(neural_net.parameters(), lr = 0.1)
mse = nn.MSELoss()
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, step_size = 100, gamma = 0.5)

losses = []
for epoch in range(epochs):
    for _, (X,y) in enumerate(dataloader):
        optimizer.zero_grad()
        pred = neural_net(X).squeeze()
        loss = mse(pred, y)
        loss.backward()
        optimizer.step()
    losses.append(loss.item())
```

In [ ]:
```
with torch.no_grad():
    L = neural_net(scoordinates).cpu()
    L =  np.clip(bscaler.inverse_transform(L), 0, 1)
    L =  (L*255).astype(np.uint8)
    reconstructed = Image.fromarray(L.reshape(height, width))
    resized = reconstructed.resize((300,225))
display(resized)
plt.figure(figsize = (10,6))
plt.plot(range(1, epochs + 1), losses, marker = '.')
plt.title('Loss vs Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.grid()
plt.show()
```





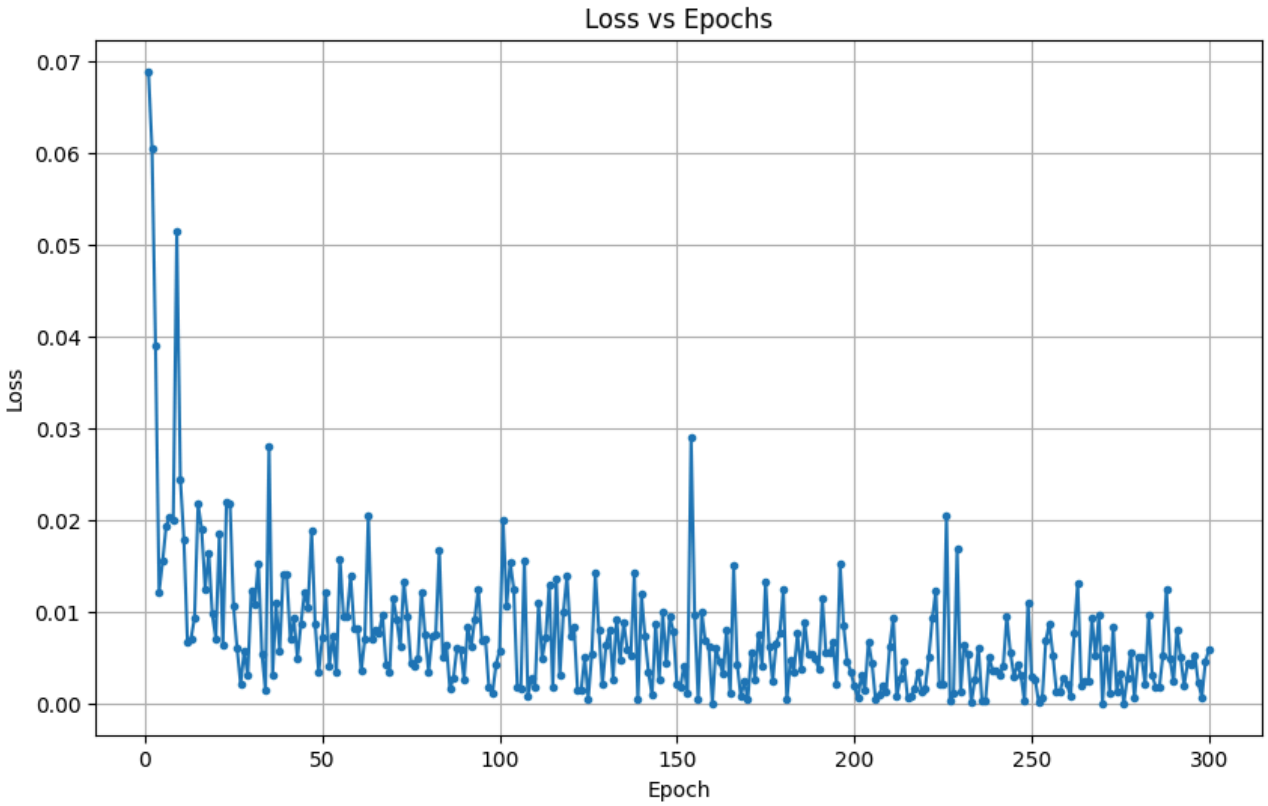
(c)

In [ ]:
```
class NeuralNetwork(nn.Module):
    def __init__(self):
        super().__init__()
        self.flatten = nn.Flatten()
        self.linear_relu_stack = nn.Sequential(
            nn.Linear(2,32),
            nn.ReLU(),
            nn.Linear(32,64),
            nn.ReLU(),
            nn.Linear(64,128),
            nn.ReLU(),
            nn.Linear(128,1)
        )

    def forward(self, x):
        x = self.flatten(x)
        logits = self.linear_relu_stack(x)
        return logits
```

In [ ]:
```
neural_net = NeuralNetwork().to(device)
optimizer = torch.optim.SGD(neural_net.parameters(), lr = 0.1)
mse = nn.MSELoss()
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, step_size = 100, gamma = 0.5)

losses = []
for epoch in range(epochs):
    for _, (X,y) in enumerate(dataloader):
        optimizer.zero_grad()
        pred = neural_net(X).squeeze()
        loss = mse(pred, y)
        loss.backward()
        optimizer.step()
    losses.append(loss.item())
```

In [ ]:
```
with torch.no_grad():
    L = neural_net(scoordinates).cpu()
    L = np.clip(bscaler.inverse_transform(L), 0, 1)
```

```
    L =  (L*255).astype(np.uint8)
    reconstructed = Image.fromarray(L.reshape(height, width))
    resized = reconstructed.resize((300,225))
display(resized)
plt.figure(figsize = (10,6))
plt.plot(range(1, epochs + 1), losses, marker = '.')
plt.title('Loss vs Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.grid()
plt.show()
```



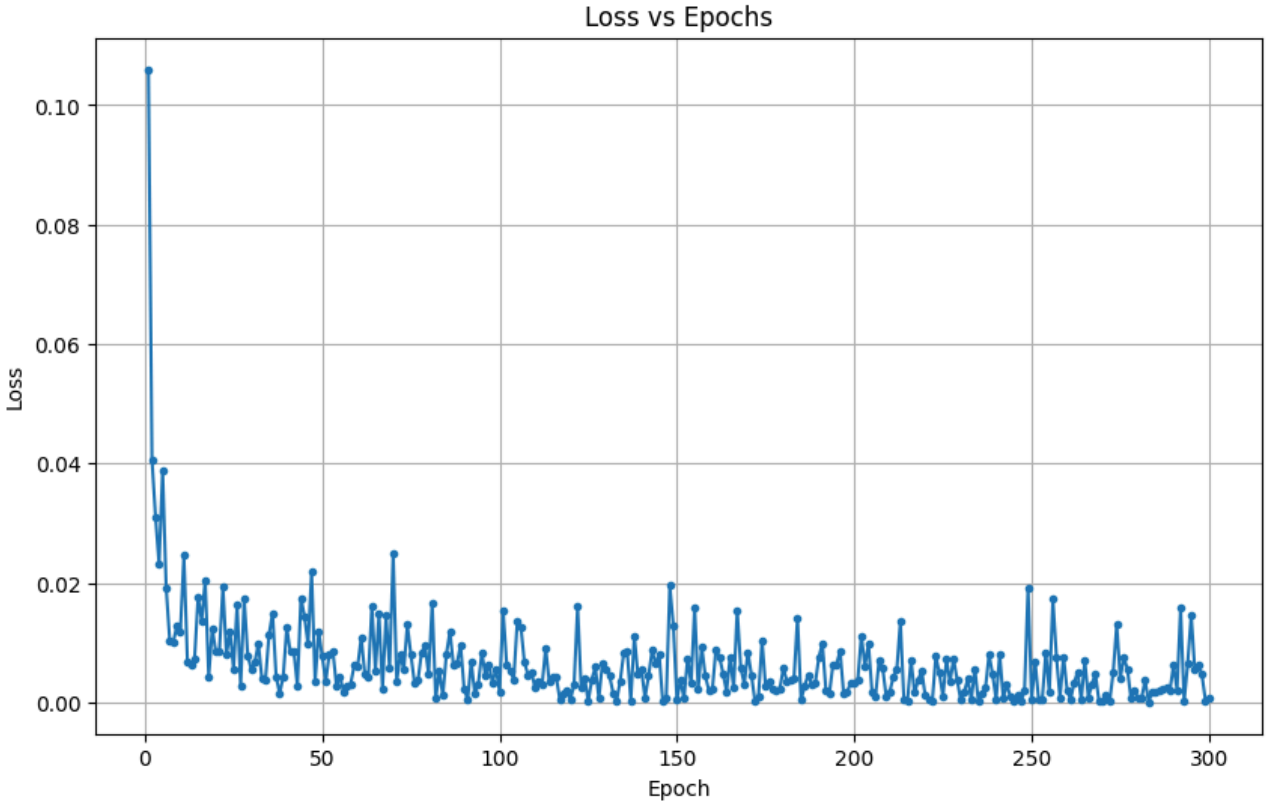
(d)

In [ ]:
```
class NeuralNetwork(nn.Module):
    def __init__(self):
        super().__init__()
        self.flatten = nn.Flatten()
        self.linear_relu_stack = nn.Sequential(
            nn.Linear(2,32),
            nn.ReLU(),
            nn.Linear(32,64),
            nn.ReLU(),
            nn.Linear(64,128),
            nn.ReLU(),
            nn.Linear(128,128),
```

```
            nn.ReLU(),
            nn.Linear(128,1)
        )

    def forward(self, x):
        x = self.flatten(x)
        logits = self.linear_relu_stack(x)
        return logits
```

In [ ]:
```
neural_net = NeuralNetwork().to(device)
optimizer = torch.optim.SGD(neural_net.parameters(), lr = 0.1)
mse = nn.MSELoss()
scheduler = torch.optim.lr_scheduler.StepLR(optimizer, step_size = 100, gamma = 0.5)

losses = []
for epoch in range(epochs):
    for _, (X,y) in enumerate(dataloader):
        optimizer.zero_grad()
        pred = neural_net(X).squeeze()
        loss = mse(pred, y)
        loss.backward()
        optimizer.step()
    losses.append(loss.item())
```

In [ ]:
```
with torch.no_grad():
    L = neural_net(scoordinates).cpu()
    L =  np.clip(bscaler.inverse_transform(L), 0, 1)
    L =  (L*255).astype(np.uint8)
    reconstructed = Image.fromarray(L.reshape(height, width))
    resized = reconstructed.resize((300,225))
display(resized)

plt.figure(figsize = (10,6))
plt.plot(range(1, epochs + 1), losses, marker = '.')
plt.title('Loss vs Epochs')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.grid()
plt.show()
```


Loss vs Epochs
Loss
Epoch
0.10
0.08
0.06
0.04
0.02
0.00
0
50
100
150
200
250
300

In [ ]: