Лабораторная работа № 8

[1]:
```
import torch
import torch.nn as nn
import torch.nn.functional as F
from torch.utils.data import DataLoader
import numpy as np
import tqdm
import matplotlib.pyplot as plt
from collections import deque
```

[2]:
```
%matplotlib inline
import matplotlib_inline
matplotlib_inline.backend_inline.set_matplotlib_formats('retina', 'pdf')
plt.rcParams['figure.dpi'] = 100
```

NARX

[207]:
```
class TDL(nn.Module):
    def __init__(self, in_features, delays):
        super(TDL, self).__init__()
        self.in_features = in_features
        self.delays = delays
        self.line = deque()
        self.clear()

    def clear(self):
        self.line.clear()
        for _ in range(self.delays):
            self.line.append(torch.zeros(1, self.in_features))

    def push(self, x):
        self.line.appendleft(x)

    def forward(self):
        return self.line.pop()
```

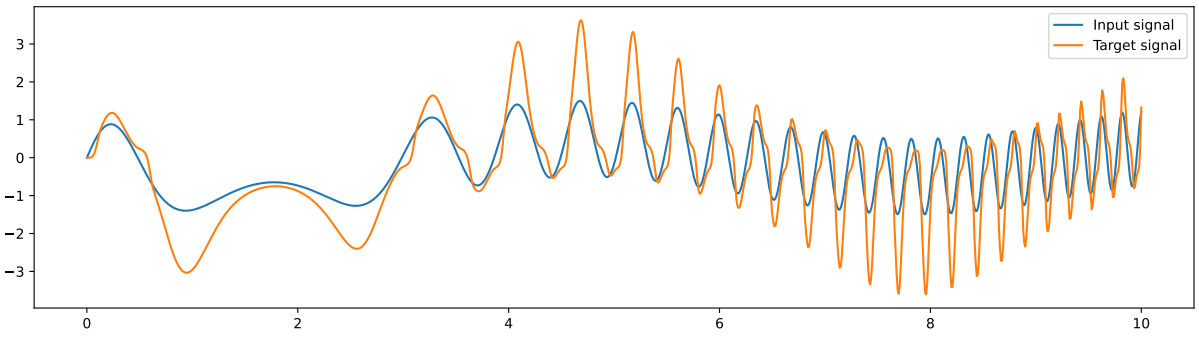
[208]:
```
class NARX(nn.Module):
    def __init__(self, in_features, hid_features, out_features, in_delay, out_delay):
        super(NARX, self).__init__()
        self.in_tdl = TDL(in_features, in_delay)
        self.out_tdl = TDL(out_features, out_delay)

        self.w1 = nn.Parameter(torch.randn(in_features, hid_features))
        self.b1 = nn.Parameter(torch.zeros(hid_features))
```

```
        self.w2 = nn.Parameter(torch.randn(out_features, hid_features))

        self.w3 = nn.Parameter(torch.randn(hid_features, out_features))
        self.b3 = nn.Parameter(torch.zeros(out_features))

    def clear(self):
        self.in_tdl.clear()
        self.out_tdl.clear()

    def forward(self, x):
        out = torch.tanh(self.in_tdl() @ self.w1 + self.b1 + self.out_tdl() @ self.
↪w2)
        out = out @ self.w3 + self.b3

        self.in_tdl.push(x.detach().clone())
        self.out_tdl.push(out.detach().clone())
        return out
```

Данные

[264]:
```
f = lambda k: np.sin(-2 * k ** 2 + 7 * k) - 0.5 * np.sin(k)
h = 0.01
k = np.arange(0, 10+h, h)

u = f(k)
y = [0]
for i in range(0, len(k)-1):
    y.append(y[-1] / (1 + y[-1] ** 2) + u[i] ** 3)
```

[265]:
```
fig = plt.figure(figsize=(15, 4))
plt.plot(k, u, label='Input signal')
plt.plot(k, y, label='Target signal')
plt.legend()
plt.show()
```



Обучение и тестирование сети

[232]:
```
def fit(model, optim, crit, epochs, data):
    model.train()
    train_loss = []
    pbar = tqdm.trange(epochs, ascii=True)
    for i in pbar:
        model.clear()
        avg_loss = 0
        for X_batch, Y_batch in data:
            optim.zero_grad()

            output = model(X_batch)
            loss = crit(Y_batch, output)
            loss.backward()

            optim.step()
            avg_loss += loss.item() / len(data)
        train_loss.append(avg_loss)
        pbar.set_description(f'Epoch: {i+1}. Loss: {avg_loss:.8f}')
    return train_loss

def predict(model, data, window):
    model.eval()
    model.clear()
    with torch.no_grad():
        pred = [*model(next(iter(data))[0]).detach().numpy()[0, :window-1]]
        model.clear()
        for X, _ in data:
            pred.append(model(X).detach().numpy().item(-1))
    return pred
```

[237]:
```
def plot_history(history):
    fig = plt.figure(figsize=(6, 3))
    ax = fig.gca()
    ax.xaxis.get_major_locator().set_params(integer=True)
    ax.set_title(f'Loss: {history[-1]:.6f}')
    ax.plot(history, '-')
    plt.show()

def plot_result(model, data, window, k, y):
    pred = predict(model, data, window)
    fig = plt.figure(figsize=(15, 4))
    plt.plot(k, y, label='Actual signal')
    plt.plot(k, pred, label='Predicted signal')
    plt.legend()
```

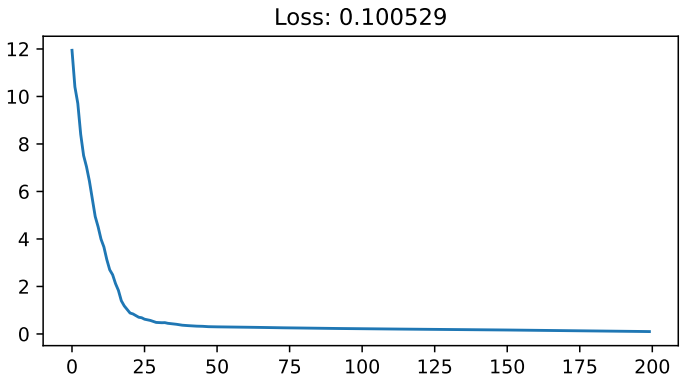
```
    plt.show()
```

[250]:
```
window = 5
train_data = [(np.array(u[i:i + window], dtype=np.float32), np.array(y[i:i +␣
 ↪window], dtype=np.float32)) for i in range(len(k) - window + 1)]
train_loader = DataLoader(train_data, batch_size=1, shuffle=False)
```

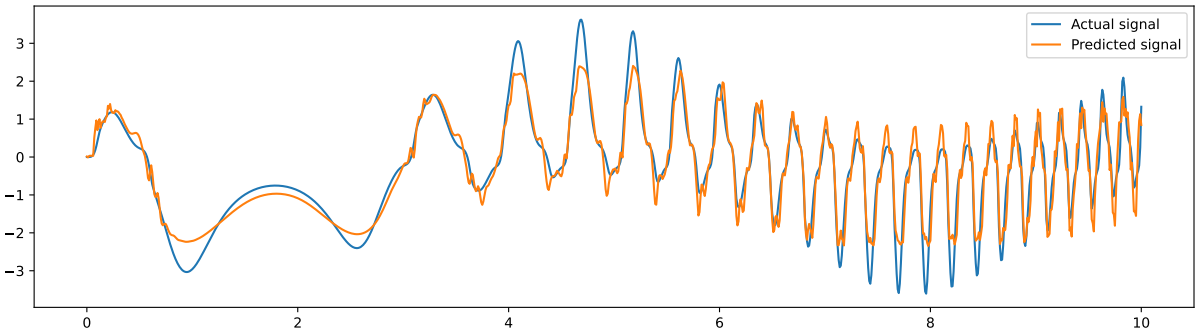
[251]:
```
model = NARX(window, 15, window, 3, 3)
hist = fit(model, torch.optim.Adam(model.parameters(), lr=1e-4), nn.MSELoss(), 200,␣
 ↪train_loader)
```

```
Epoch: 200. Loss: 0.10052883:
100%|##################################################| 200/200 [05:22<00:00,
1.61s/it]
```

[252]:
```
plot_history(hist)
```



[253]:
```
plot_result(model, train_loader, window, k, y)
```

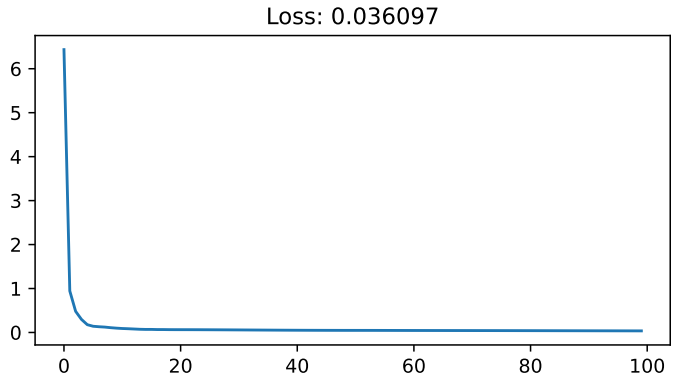


[242]:
```
window = 3
train_data = [(np.array(u[i:i + window], dtype=np.float32), np.array(y[i:i +␣
↪window], dtype=np.float32)) for i in range(len(k) - window + 1)]
train_loader = DataLoader(train_data, batch_size=1, shuffle=False)
```

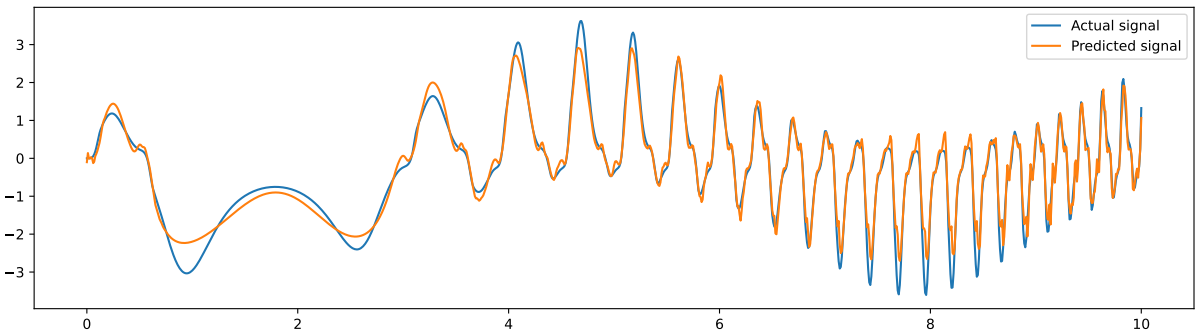
[243]:
```
model = NARX(window, 20, window, 2, 2)
hist = fit(model, torch.optim.Adam(model.parameters(), lr=1e-3), nn.MSELoss(), 100,␣
↪train_loader)
```

```
Epoch: 100. Loss: 0.03609701:
100%|##################################################| 100/100 [03:36<00:00,
2.17s/it]
```

[244]:
```
plot_history(hist)
```



[245]:
```
plot_result(model, train_loader, window, k, y)
```

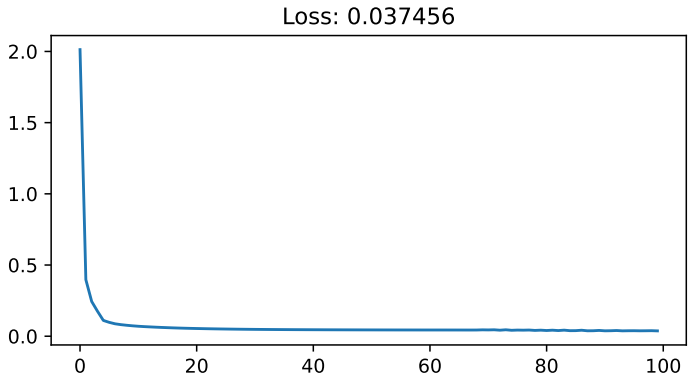


[266]:
```
window = 2
train_data = [(np.array(u[i:i + window], dtype=np.float32), np.array(y[i:i +␣
↪window], dtype=np.float32)) for i in range(len(k) - window + 1)]
train_loader = DataLoader(train_data, batch_size=1, shuffle=False)
```

[267]:
```
model = NARX(window, 20, window, 2, 2)
hist = fit(model, torch.optim.Adam(model.parameters(), lr=1e-3), nn.MSELoss(), 100,␣
↪train_loader)
```

```
Epoch: 100. Loss: 0.03745640:
100%|##################################################| 100/100 [02:43<00:00,
1.63s/it]
```

[268]:
```
plot_history(hist)
```



[269]:
```
plot_result(model, train_loader, window, k, y)
```