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ФАКУЛЬТЕТ «Информатика и системы управления»

КАФЕДРА «Теоретическая информатика и компьютерные технологии»

Домашняя работа №6

по курсу «Теория искусственных нейронных сетей»

«Рекурентные нейронные сети (RNN)»

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1 Цель

Ознакомление с основными архитектурами рекурентных нейронных сетей.

2 Задание

1. Реализовать нейронную сеть архитектуры RNN и проверить её на датасете IMDB.

2. Реализовать нейронную сеть архитектуры LSTM и проверить её на датасете IMDB.

3. Реализовать нейронную сеть архитектуры GRU и проверить её на датасете IMDB.

3 Реализация

Исходный код представлен в листинге 1 - 5.

Листинг 1: Подготовка датасета

```

import numpy as np
import torch
import torch.autograd as autograd
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
from torch.autograd import Variable
from datasets import load_dataset
import pandas as pd
from sklearn.model_selection import train_test_split

from IPython.display import clear_output
import sys

import nltk
from nltk.corpus import stopwords
from nltk.stem import WordNetLemmatizer
import re
import string

from sklearn.metrics import classification_report, confusion_matrix
```

```

import matplotlib.pyplot as plt
import seaborn as sns

from torch.utils.data import DataLoader, Dataset
from tqdm import tqdm
import subprocess

try:
    nltk.data.find('wordnet.zip')
except:
    nltk.download('wordnet', download_dir='/kaggle/working/')
    command = "unzip /kaggle/working/corpora/wordnet.zip -d /kaggle/working/corpora"
    subprocess.run(command.split())
    nltk.data.path.append('/kaggle/working/')

dataset = load_dataset("imdb")

train = pd.DataFrame(dataset["train"])
test = pd.DataFrame(dataset["test"])

df = pd.concat([train, test], ignore_index=True)
df

train_text, test_text, train_labels, test_labels= train_test_split(df['text'], df['label'], test_size=0.2, random_state=1024,stratify=df['label'])

print(f"Training samples: {len(train_text)}")
print(f"Testing samples: {len(test_text)}")

lemmatizer = WordNetLemmatizer()
stop_words = set(stopwords.words('english'))

def clean_text(text):
    text = re.sub(r'<.*?>', '', text) # Remove HTML tags
    text = re.sub(r'http\S+|www.\S+', '', text) # Remove URLs
    text = re.sub(r'\d+', '', text) # Remove numbers
    text = text.translate(str.maketrans('', '', string.punctuation)) # Remove punctuation
    text = text.strip() # Remove extra whitespace
    text = text.lower() # Lowercase

    #create tokens
    tokens = nltk.word_tokenize(text)
```

```
    tokens = [lemmatizer.lemmatize(word) for word in tokens if word not in stop_words]
    return tokens

train_tokens = train_text.apply(clean_text)
test_tokens = test_text.apply(clean_text)

from collections import Counter
all_tokens = [token for tokens in train_tokens for token in tokens] # flatten the list of tokens
token_count = Counter(all_tokens) #count the frequency of each token
MAX_VOCAB_SIZE = 40000 #set the maximum vocab size to the number of tokens
vocab = ['<PAD>','<UNK>'] + [word for word, freq in token_count.most_common(MAX_VOCAB_SIZE - 2)] #create the vocab
wordtoidx = {word: idx for idx, word in enumerate(vocab)} #create the word to index mapping
unk_idx = wordtoidx['<UNK>']
pad_idx = wordtoidx['<PAD>']

def encode_tokens(tokens, wordtoidx,max_len = 200):
    encoded = [wordtoidx.get(token,unk_idx) for token in tokens]
    if len(encoded) < max_len:
        encoded += [pad_idx] * (max_len - len(encoded))
    else:
        encoded = encoded[:max_len]
    return np.array(encoded)

#encode all the datasets
train_encoded = np.array([encode_tokens(tokens, wordtoidx) for tokens in train_tokens])
test_encoded = np.array([encode_tokens(tokens, wordtoidx) for tokens in test_tokens])

#convert them to numpy array
X_train = np.array(train_encoded.tolist())
X_test = np.array(test_encoded.tolist())

def code(arr):
    result = []

    for value in arr:
        if value == 1:
            result.append([0, 1])
        elif value == 0:
            result.append([1, 0])
```

```python

    return result


y_train = np.array(code(train_labels))
y_test = np.array(code(test_labels))

print(f"X_train shape: {X_train.shape}")
print(f"X_test shape: {X_test.shape}")

class IMDBDataset(Dataset):
    def __init__(self, texts, labels):
        self.texts = torch.tensor(texts, dtype=torch.long)
        self.labels = torch.tensor(labels, dtype=torch.float)

    def __len__(self):
        return len(self.labels)

    def __getitem__(self, idx):
        return self.texts[idx], self.labels[idx]



train_dataset = IMDBDataset(X_train, y_train)
test_dataset = IMDBDataset(X_test, y_test)

train_loader = DataLoader(train_dataset, batch_size=16, shuffle=True)
test_loader = DataLoader(test_dataset, batch_size=16)

device = 'cuda' if torch.cuda.is_available() else 'cpu'
device
```

Листинг 2: Функция тренировки

```python

def train(network,train_loader, test_loader, epochs,loss_fn,optim, plot=
    True, verbose=True):
    train_loss_epochs = []
    test_loss_epochs = []
    train_accuracy_epochs = []
    test_accuracy_epochs = []

    try:
        for epoch in tqdm(range(epochs)):
            losses = []
            accuracies = []
            for X, y in train_loader:
```

```
            X,y = X.to(device), y.to(device)
            pred = model(X)
            loss_batch = loss_fn(pred, y)
            losses.append(loss_batch.item())
            optim.zero_grad()
            loss_batch.backward()
            optim.step()
            pred1 = pred.argmax(dim=1).float()
            y1 = y.argmax(dim=1).float()
            accuracies.append((torch.sum(y1 == pred1)/16).cpu())
        train_loss_epochs.append(np.mean(losses))
        train_accuracy_epochs.append(np.mean(accuracies))

        with torch.no_grad():
            losses = []
            accuracies = []
            for X, y in test_loader:
                X,y = X.to(device), y.to(device)
                pred = model(X).squeeze(1)
                loss_batch = loss_fn(pred, y)
                losses.append(loss_batch.cpu())
                pred1 = pred.argmax(dim=1).float()
                y1 = y.argmax(dim=1).float()
                accuracies.append((torch.sum(y1 == pred1)/16).cpu())
        test_loss_epochs.append(np.mean(losses))
        test_accuracy_epochs.append(np.mean(accuracies))
        clear_output(True)
        if verbose:
            sys.stdout.write('\rEpoch {0}... (Train/Test) Loss: {1:.3f}/{2:.3f}\tAccuracy: {3:.3f}/{4:.3f}'.format(
                        epoch, train_loss_epochs[-1], test_loss_epochs[-1],
                        train_accuracy_epochs[-1], test_accuracy_epochs[-1]))
        if plot:
            plt.figure(figsize=(12, 5))
            plt.subplot(1, 2, 1)
            plt.plot(train_loss_epochs, label='Train')
            plt.plot(test_loss_epochs, label='Test')
            plt.xlabel('Epochs', fontsize=16)
            plt.ylabel('Loss', fontsize=16)
            plt.legend(loc=0, fontsize=16)
            plt.grid('on')
            plt.subplot(1, 2, 2)
            plt.plot(train_accuracy_epochs, label='Train accuracy')
            plt.plot(test_accuracy_epochs, label='Test accuracy')
```

```
                plt.xlabel('Epochs', fontsize=16)
                plt.ylabel('Accuracy', fontsize=16)
                plt.legend(loc=0, fontsize=16)
                plt.grid('on')
                plt.show()
    except KeyboardInterrupt:
        pass
    return train_loss_epochs, \
           test_loss_epochs, \
           train_accuracy_epochs, \
           test_accuracy_epochs
```

Листинг 3: RNN

```

class MyRNNModel(nn.Module):
    def __init__(self, input_size, hidden_size):
        super(MyRNNModel, self).__init__()

        self.lin1 = nn.Linear(input_size, hidden_size)
        self.lin2 = nn.Linear(hidden_size, hidden_size)
        self.tanh = nn.Tanh()

        self.hidden_size = hidden_size

    def forward(self, x):
        batch_size, seq_len, _ = x.size()
        h_t = torch.zeros(batch_size, self.hidden_size)
        output = []
        for t in range(seq_len):
            xt = x[:, t, :]
            xt.to(device)

            h_t = self.tanh(self.lin1(xt) + self.lin2(h_t))
            output.append(h_t)
        output = torch.stack(output)

        output = output.transpose(0, 1)
        return output, h_t

class SimpleRNN(nn.Module):
    def __init__(self, vocab_size, embedding_dim, hidden_dim, output_dim
    , pad_idx):
        super(SimpleRNN, self).__init__()

        self.embedding = nn.Embedding(vocab_size, embedding_dim,
    padding_idx=pad_idx)
```

```
        self.rnn = MyRNNModel(embedding_dim, hidden_dim)
        self.fc = nn.Sequential(
            nn.Linear(hidden_dim,output_dim),
        )


    def forward(self, text):
        embedded = self.embedding(text)
        output, hidden = self.rnn(embedded)
        out = self.fc(output[:,-1,:])
        return out


VOCAB_SIZE = len(vocab)+1
EMBEDDING_DIM = 128
HIDDEN_DIM = 128
OUTPUT_DIM = 2
PAD_IDX = pad_idx
```

Листинг 4: LSTM

```

class MyLSTMModel(nn.Module):
    def __init__(self, input_size, hidden_size):
        super(MyLSTMModel, self).__init__()

        self.hidden_size = hidden_size

        self.lin_ix = nn.Linear(input_size, hidden_size)
        self.lin_ih = nn.Linear(hidden_size, hidden_size)
        self.lin_fx = nn.Linear(input_size, hidden_size)
        self.lin_fh = nn.Linear(hidden_size, hidden_size)
        self.lin_gx = nn.Linear(input_size, hidden_size)
        self.lin_gh = nn.Linear(hidden_size, hidden_size)
        self.lin_ox = nn.Linear(input_size, hidden_size)
        self.lin_oh = nn.Linear(hidden_size, hidden_size)

        self.tanh = nn.Tanh()
        self.sigmoid = nn.Sigmoid()

    def forward(self, x):
        batch_size, seq_len, _ = x.size()
        h_t = torch.zeros(batch_size, self.hidden_size).to(device)
        c_t = torch.zeros(batch_size, self.hidden_size).to(device)
        output = []
        for t in range(seq_len):
            xt = x[:, t, :]
```

```
            xt.to(device)

            i_t = self.sigmoid(self.lin_ix(xt) + self.lin_ih(h_t))
            f_t = self.sigmoid(self.lin_fx(xt) + self.lin_fh(h_t))
            g_t = self.tanh(self.lin_gx(xt) + self.lin_gh(h_t))
            o_t = self.sigmoid(self.lin_ox(xt) + self.lin_oh(h_t))

            c_t = f_t * c_t + i_t * g_t
            h_t = o_t * self.tanh(c_t)

            output.append(h_t)
        output = torch.stack(output)

        output = output.transpose(0, 1)
        return output, (h_t, c_t)

class SimpleLSTM(nn.Module):
    def __init__(self, vocab_size, embedding_dim, hidden_dim, output_dim, pad_idx):
        super(SimpleLSTM, self).__init__()

        self.embedding = nn.Embedding(vocab_size, embedding_dim, padding_idx=pad_idx)
        self.rnn = MyLSTMModel(embedding_dim, hidden_dim)
        self.fc = nn.Sequential(
            nn.Linear(hidden_dim,output_dim),
        )
        self.sigmoid = nn.Sigmoid()


    def forward(self, text):
        embedded = self.embedding(text)
        output, hidden = self.rnn(embedded)
        out = self.fc(output[:,-1,:])
        return self.sigmoid(out)
```

Листинг 5: GRU

```

class MyGRUModel(nn.Module):
    def __init__(self, input_size, hidden_size):
        super(GRUModel, self).__init__()

        self.hidden_size = hidden_size

        self.lin_rx = nn.Linear(input_size, hidden_size)
        self.lin_rh = nn.Linear(hidden_size, hidden_size)
```

```
        self.lin_zx = nn.Linear(input_size, hidden_size)
        self.lin_zh = nn.Linear(hidden_size, hidden_size)
        self.lin_nx = nn.Linear(input_size, hidden_size)
        self.lin_nh = nn.Linear(hidden_size, hidden_size)

        self.tanh = nn.Tanh()
        self.sigmoid = nn.Sigmoid()

    def forward(self, x):
        batch_size, seq_len, _ = x.size()
        h_t = torch.zeros(batch_size, self.hidden_size)
        output = []
        for t in range(seq_len):
            xt = x[:, t, :]
            xt.to(device)

            r_t = self.sigmoid(self.lin_rx(xt) + self.lin_rh(h_t))
            z_t = self.sigmoid(self.lin_zx(xt) + self.lin_zh(h_t))
            n_t = self.tanh(self.lin_nx(xt) + r_t * self.lin_nh(h_t))
            h_t = (1 - z_t) * n_t + z_t * h_t

            output.append(h_t)
        output = torch.stack(output)

        output = output.transpose(0, 1)
        return output, h_t

class SimpleGRU(nn.Module):
    def __init__(self, vocab_size, embedding_dim, hidden_dim, output_dim
    , pad_idx):
        super(SimpleGRU, self).__init__()

        self.embedding = nn.Embedding(vocab_size, embedding_dim,
    padding_idx=pad_idx)
        self.rnn = nn.GRU(embedding_dim, hidden_dim, batch_first=True)
        self.fc = nn.Sequential(
            nn.Linear(hidden_dim,output_dim),
        )


    def forward(self, text):
        embedded = self.embedding(text)
        output, hidden = self.rnn(embedded)
        out = self.fc(output[:,-1,:])
        return out
```

4 Результаты

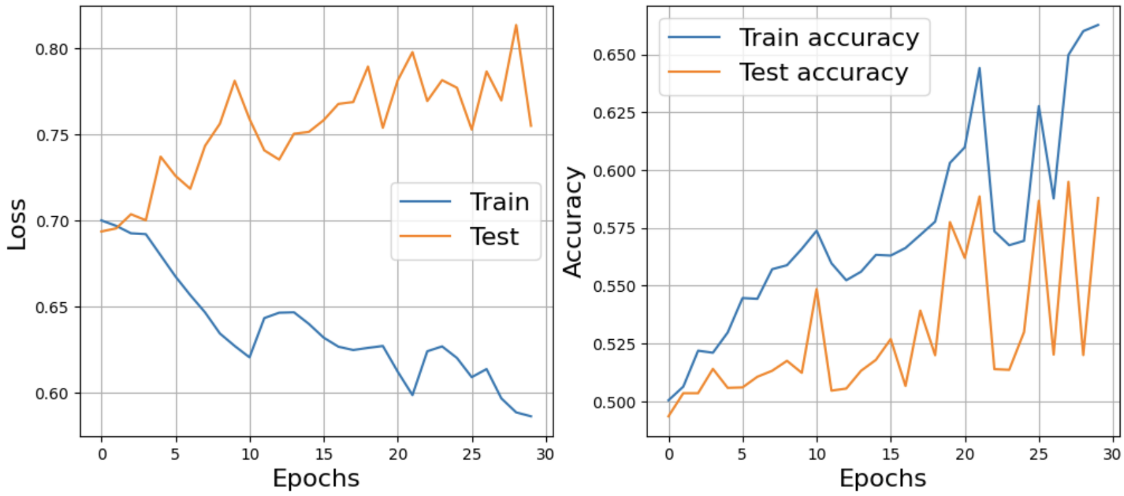
Результат представлен на рисунках 1 - 5.

```
model = SimpleRNN(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.001

loss=nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=30, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 29... (Train/Test) Loss: 0.586/0.755      Accuracy: 0.663/0.588
```




```
100%|██████████| 30/30 [05:24<00:00, 10.82s/it]
```

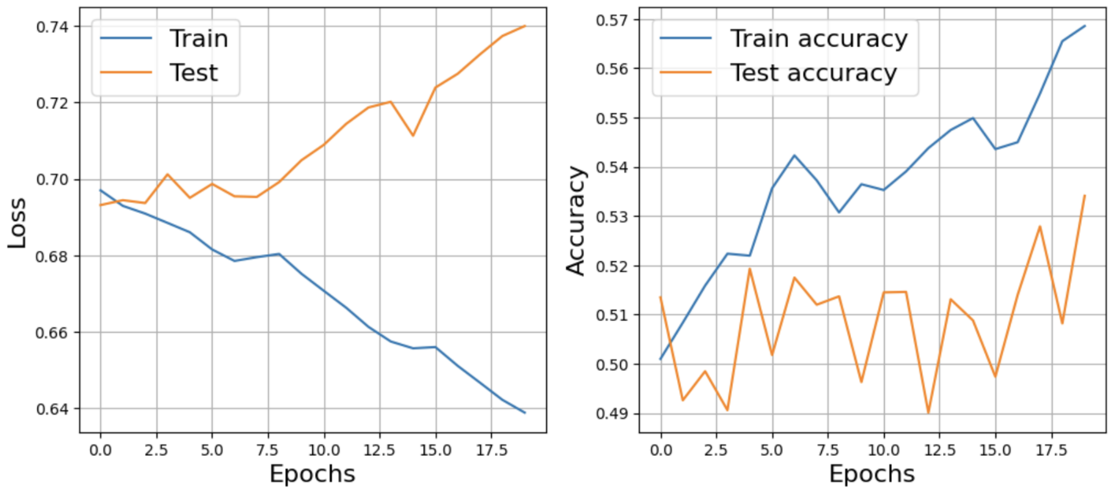
Рис. 1 — RNN Adam

```python
model = SimpleRNN(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.01

loss=nn.CrossEntropyLoss()
optimizer = optim.Adagrad(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=20, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 19... (Train/Test) Loss: 0.639/0.740      Accuracy: 0.569/0.534
```




```
100%|██████████| 20/20 [03:13<00:00,  9.66s/it]
```

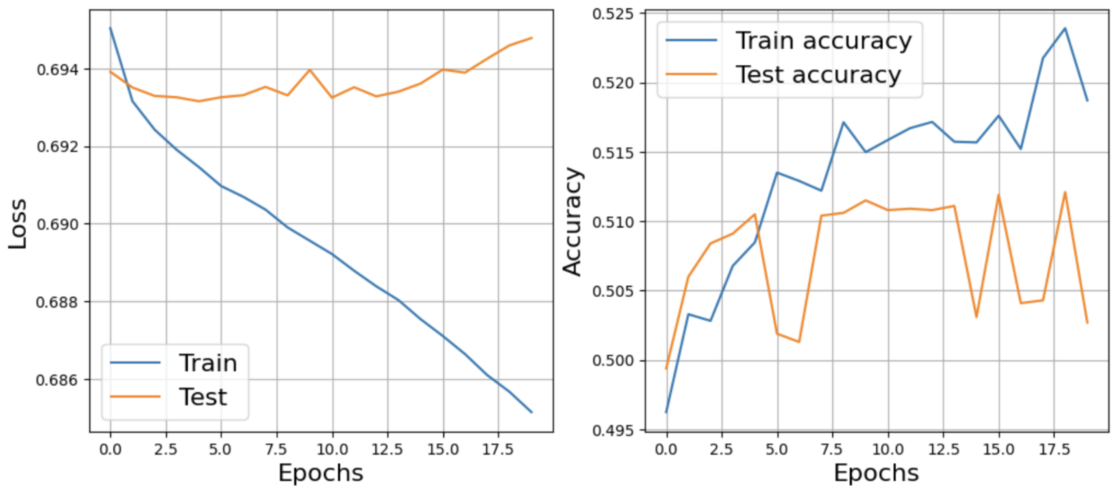
Рис. 2 — RNN Adagrad

```python
model = SimpleRNN(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.001

loss=nn.CrossEntropyLoss()
optimizer = optim.SGD(model.parameters(), lr=lr, momentum=0.8, nesterov=True)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=20, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 19... (Train/Test) Loss: 0.685/0.695      Accuracy: 0.519/0.503
```




```
100%|██████████| 20/20 [02:59<00:00,  9.00s/it]
```

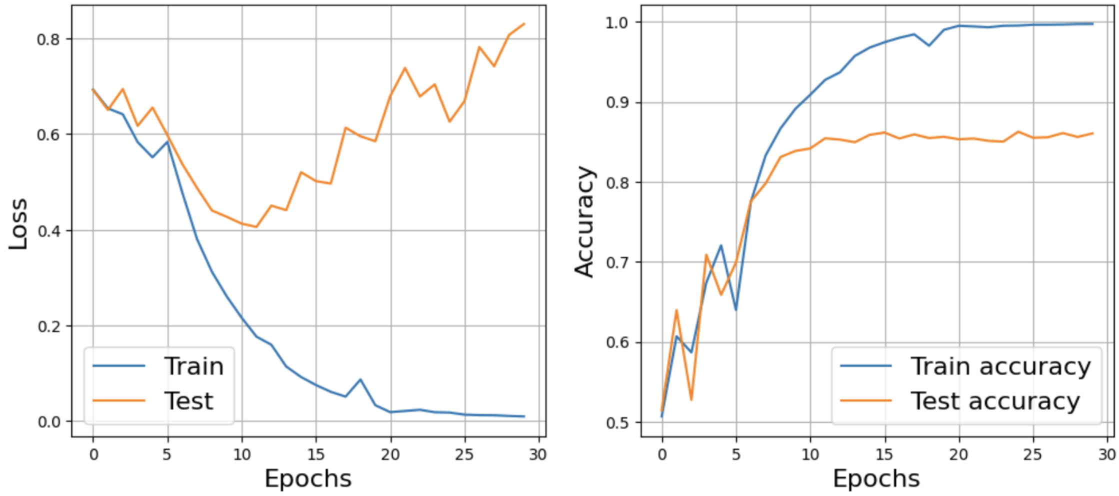
Рис. 3 — RNN Momentum

```
model = SimpleLSTM(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.001

loss=nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=30, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 29... (Train/Test) Loss: 0.010/0.830      Accuracy: 0.997/0.860
```




```
100%|██████████| 30/30 [06:47<00:00, 13.58s/it]
```

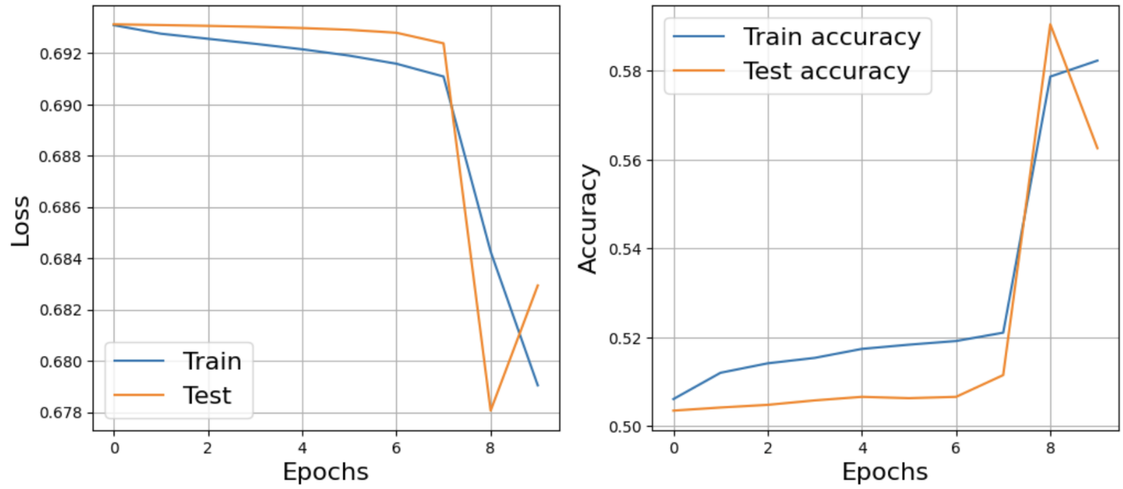
Рис. 4 — LSTM Adam

```
model = SimpleLSTM(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.001

loss=nn.CrossEntropyLoss()
optimizer = optim.Adagrad(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=10, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 9... (Train/Test) Loss: 0.679/0.683      Accuracy: 0.582/0.563
```




```
100%|██████████| 10/10 [02:05<00:00, 12.57s/it]
```

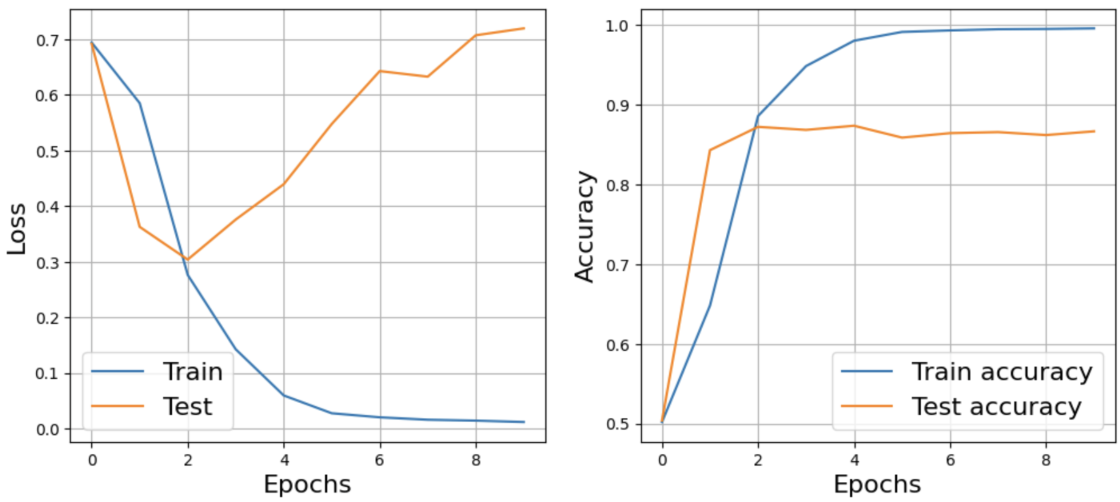
Рис. 5 — LSTM Adagrad

```
model = SimpleGRU(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.001

loss=nn.CrossEntropyLoss()
optimizer = optim.Adam(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=10, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 9... (Train/Test) Loss: 0.012/0.720       Accuracy: 0.996/0.867
```




```
100%|██████████| 10/10 [01:55<00:00, 11.58s/it]
```

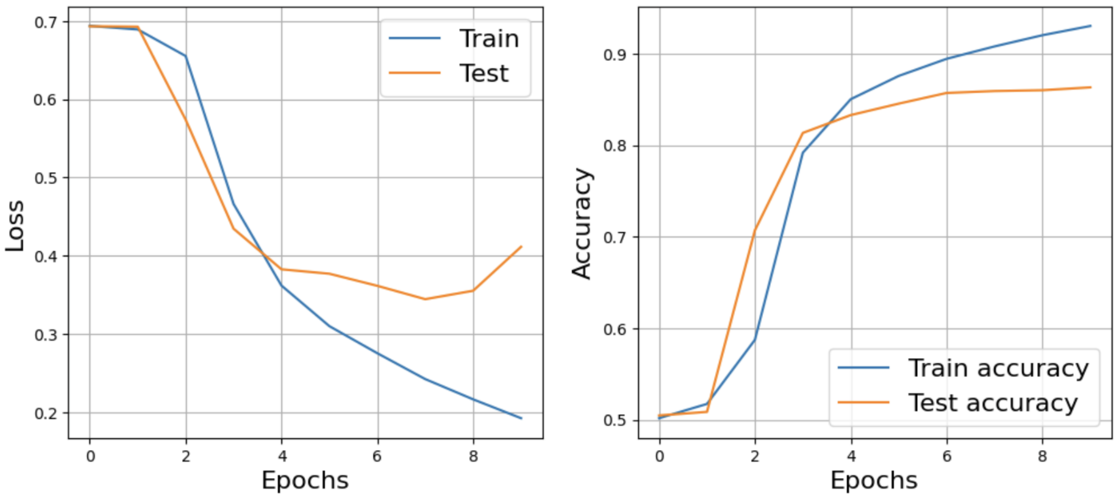
Рис. 6 — GRU Adam

```python
model = SimpleGRU(VOCAB_SIZE, EMBEDDING_DIM, HIDDEN_DIM, OUTPUT_DIM, PAD_IDX)
model.to(device)
lr = 0.0001

loss=nn.CrossEntropyLoss()
optimizer = optim.Adagrad(model.parameters(),lr = lr)

tr_lenet_sgd, ts_lenet_sgd, tr_ac_lenet_sgd, ts_ac_lenet_sgd = train(
    model,train_loader,test_loader, epochs=10, plot=True, verbose=True, loss_fn=loss, optim=optimizer
```

```
Epoch 9... (Train/Test) Loss: 0.193/0.412       Accuracy: 0.930/0.863
```




```
100%|██████████| 10/10 [01:55<00:00, 11.56s/it]
```

Рис. 7 — GRU Adagrad

5 Выводы

В результе выполнения данной лабораторной работы были реализованы различные архитектуры рекурентных нейронных сетей с помощью библиотеки pytorch. Реализованные архитектуры были протестированы на различных открытых датасетах с использованием различных оптимизаторов.