In [ ]:
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import time
import torch
import torch.nn.functional as F
import torch.optim as optim
import matplotlib.pyplot as plt
from Model import LSTM
import hashlib
import hmac
import uuid
import rsa
import numpy as np
import random
import Dataset
from matplotlib.ticker import PercentFormatter


# 初始化模型和数据
def initialize_model_data():
    INPUT_SIZE = 3
    HIDDEN_SIZE = 64
    NUM_LAYERS = 3
    PRED_OUTPUT_SIZE = 3
    CLAS_OUTPUT_SIZE = 4
    train_x, train_y = Dataset.generate_car_data(num_samples=10000, input_dim=20
    lstm = LSTM(INPUT_SIZE, HIDDEN_SIZE, NUM_LAYERS, PRED_OUTPUT_SIZE, CLAS_OUTP
    return lstm, train_x, train_y
def initialize_test_data(input_dim, per_positive):
    test_x, test_y = Dataset.generate_car_data(num_samples=1, input_dim=50, per_
    return test_x, test_y

# 训练模型
def train_model(lstm, train_x, train_y):
    optimizer = optim.Adam(lstm.parameters(), lr=1e-2, weight_decay=1e-5)

    train_y_pred = train_x[:, -1, :]  # 预测任务标签
    train_y_clas = train_y  # 分类任务标签

    train_x = train_x[:, :-1, :]

    max_epochs = 50 # 训练轮次

    # 训练轮次
    epoch_list = []
    loss_list = []
    loss_pred_list = []
    accuracy_list = []

    for epoch in range(max_epochs):
        pred_y_pred, pred_y_clas = lstm(train_x)

        loss_pred = lstm.loss_mse(pred_y_pred, train_y_pred)
        loss_ce = lstm.loss_ce(pred_y_clas, train_y_clas)

        loss = loss_pred / 1000 + loss_ce

        optimizer.zero_grad()
        loss.backward()
        optimizer.step()
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        if loss.item() < 1e-5:
            print('Epoch [{}/{}], Loss: {:.5f}'.format(epoch + 1, max_epochs, lo
            break
        elif (epoch + 1) % 10 == 0:
            # 测试模型在训练集上的预测损失与分类精度用于画图展示
            loss_pred, accuracy, _ = test_model(lstm, train_x, train_y)
            epoch_list.append(epoch + 1)
            loss_list.append(loss.item())
            loss_pred_list.append(loss_pred.detach().cpu().numpy())
            accuracy_list.append(accuracy.detach().cpu().numpy())
            print('Epoch [{}/{}], Loss: {:.5f}'.format(epoch + 1, max_epochs, lo

    return loss_pred_list, accuracy_list, loss_list, epoch_list


# 保存模型
def save_model(lstm):
    torch.save(lstm, 'Model/lstmmodel.pt')


# 加载模型
def load_model():
    return torch.load('Model/lstmmodel.pt')


# 测试模型的预测损失与分类精度
def test_model(lstm, test_x, test_y):
    test_y_pred = test_x[:, -1, :]  # 预测任务标签
    test_y_clas = test_y  # 分类任务标签

    test_x = test_x[:, :-1, :]

    pred_y_pred, pred_y_clas = lstm(test_x)

    # 预测任务的Loss
    loss_pos = lstm.loss_mse(pred_y_pred, test_y_pred)

    # 分类任务的accuracy
    pred_labels = F.one_hot(torch.argmax(pred_y_clas, dim=1), num_classes=lstm.c
    accuracy = torch.mean(torch.eq(pred_labels, test_y_clas).all(dim=1).float())

    return loss_pos, accuracy, pred_labels


# 画图
def plot_curve(loss_pred_list, accuracy_list, loss_list, epoch_list):
    plt.figure(figsize=(12, 6))

    # 绘制总损失图
    plt.subplot(1, 3, 1)
    plt.plot(epoch_list, loss_list, label='Training Loss', color='red')
    plt.title('Training Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()

    # 绘制预测任务损失图
    plt.subplot(1, 3, 2)
    plt.plot(epoch_list, loss_pred_list, label='Prediction Loss', color='blue')
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    plt.title('Training Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()

    # 绘制分类任务准确率图
    plt.subplot(1, 3, 3)
    plt.plot(epoch_list, accuracy_list, label='Classification Accuracy', color='
    plt.title('Training Accuracy')
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.legend()

    plt.tight_layout()
    plt.show()


class DeviceAuthentication:
    def __init__(self, device_id, manufacturer):
        self.device_id = device_id
        self.manufacturer = manufacturer
        self.identifier = self.device_id+self.manufacturer
    def authenticate_device(self, pred_labels):
        if(pred_labels[0,0].item() == 1):
            return True
        else:
            return False
    def issue_credentials(self):
        # 生成随机的凭证和密钥对
        credential = str(uuid.uuid4())
        public_key, private_key = self.generate_key_pair()
        return credential, public_key, private_key
    def generate_key_pair(self):
        # 将字符串转换为唯一数字
        unique_number = self.string_to_unique_number(self.identifier)
        # 生成RSA公私钥对
        pubkey, privkey = rsa.newkeys(2048)  #2048
         # 将公私钥对保存到文件中
        with open('key_pair/public_key.pem', 'wb') as public_key_file:
            public_key_file.write(pubkey.save_pkcs1())
        with open('key_pair/private_key.pem', 'wb') as private_key_file:
            private_key_file.write(privkey.save_pkcs1())
        return pubkey.save_pkcs1(), privkey.save_pkcs1()
    def load_keys(self):
        # 加载已保存的公私钥对
        with open('key_pair/public_key.pem', 'rb') as public_key_file:
            pubkey = rsa.PublicKey.load_pkcs1(public_key_file.read())
        with open('key_pair/private_key.pem', 'rb') as private_key_file:
            privkey = rsa.PrivateKey.load_pkcs1(private_key_file.read())
        return pubkey, privkey
    def string_to_unique_number(self, s):
        # 使用 SHA-256 哈希函数
        hash_object = hashlib.sha256(s.encode())
        # 以 16 进制格式返回哈希值
        hex_dig = hash_object.hexdigest()
        # 分割十六进制字符串
        parts = [hex_dig[i:i+8] for i in range(0, len(hex_dig), 8)]
        # 转换每个子字符串为整数并相加
        unique_number = sum(int(part, 16) for part in parts)
        return unique_number
```

```python
# 生成小车的最后使用上次身份凭证的时间
def generate_final_time(num, low, high):
    sum = 0
    for _ in range(num):
        random_num = random.randint(low, high)
        sum += random_num
    return sum

if __name__ == "__main__":
    start_time = time.time()

    # 初始化
    lstm, train_x, train_y = initialize_model_data()

    # 加速（CPU记得注释掉）
    lstm = lstm.cuda()
    train_x = train_x.cuda()
    train_y = train_y.cuda()


    # 训练
    loss_pos_list, accuracy_list, loss_list, epoch_list = train_model(lstm, trai
    save_model(lstm)
    print("...Training Finished...")
    end_time = time.time()

    # 测试
    lstm = load_model()
    per_positive = 0.7 # 初始化小车的正样本概率
    max_num = 10 # 身份凭证最大使用次数
    use_num = 0 # 初始化使用次数
    car_num = 100 # 验证小车数量
    test_loss_sum = 0 # 小车损失值总和
    test_acc_sum = 0 # 小车acc总和
    # 进行设备身份验证，发送身份凭证
    for i in range(car_num): # 每一辆小车进行验证
        # 模拟一个小车 （后续可以随机或者导入数据集）
        device_id = "device123"
        manufacturer = "Example Inc."
        device = DeviceAuthentication(device_id, manufacturer)# 实例化设备验证类
        final_time = generate_final_time(10, 0, 3) +20 # 时间必须大于20
        test_x, test_y = initialize_test_data(final_time, per_positive)
        test_x = test_x.cuda()
        test_y = test_y.cuda()
        test_loss_list = []
        test_acc_list = []
        for i in range(20, final_time):
            test_loss, test_acc, pred_labels = test_model(lstm, test_x[:, i-20:i
            test_loss_list.append(test_loss.detach().cpu())
            test_acc_list.append(test_acc.detach().cpu())
            if device.authenticate_device(pred_labels):
                # 如果设备验证通过，下发凭证和密钥对
                print("Credential")
                # credential, public_key, private_key = device.issue_credentials
                # print("Credential:", credential)
                # print("Public Key:", public_key)
                # print("Private Key:", private_key)
            else:
                print("Device authentication failed.")
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                break
            print("Maximum usage reached, destroy authentication.")
            print("test_loss_list",type(test_loss_list))
            test_loss_sum += np.mean(test_loss_list)
            test_acc_sum += np.mean(test_acc_list)
        # 输出
        print('Test Loss: {:.5f}'.format(test_loss_sum))
        print('Test Accuracy: {:.2f}%'.format(test_acc_sum))
        print("...Test Finished...")
        execution_time = end_time - start_time
        print(f"模型运行时间: {execution_time}秒")

        # 画图
        plot_curve(loss_pos_list, accuracy_list, loss_list, epoch_list) # 训练集acc,
        plt.savefig('./results/training_curve.pdf')
        error_rate = 1- per_positive # 错误率和测试准确率
        # 柱状图数据
        categories = ['Original', 'LSTM']
        # 将错误率和错误率与测试准确率的乘积转换为百分比
        values = [per_positive * 100, (test_acc_sum / 100) * 100]

        # 绘制柱状图
        plt.bar(categories, values, color=['#FFA07A', '#87CEEB'])
        plt.ylabel('Percentage')  # 纵坐标标签改为百分比
        # 设置中文字体
        # 解决中文显示问题
        plt.rcParams['font.sans-serif'] = ['SimHei']
        plt.rcParams['axes.unicode_minus'] = False
        plt.title(u'设备身份验证的准确率')
        plt.ylim(0, 100)
        plt.gca().yaxis.set_major_formatter(PercentFormatter())  # 设置纵坐标格式为百
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...generate_car_data run Finished...
Epoch [10/50], Loss: 1.66162
Epoch [20/50], Loss: 1.21489
Epoch [30/50], Loss: 1.21262
Epoch [40/50], Loss: 1.17786
Epoch [50/50], Loss: 0.99257
...Training Finished...
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Maximum usage reached, destroy authentication.
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Maximum usage reached, destroy authentication.
test_loss_list <class 'list'>
Test Loss: 4988.10674
Test Accuracy: 78.00%
...Test Finished...
模型运行时间: 4.201467037200928秒
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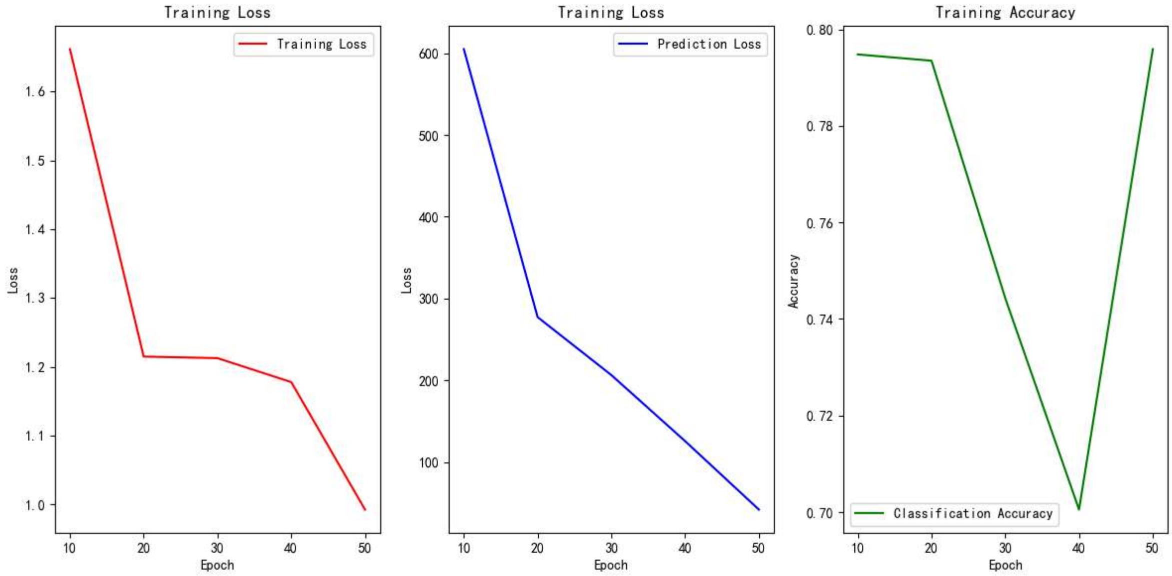

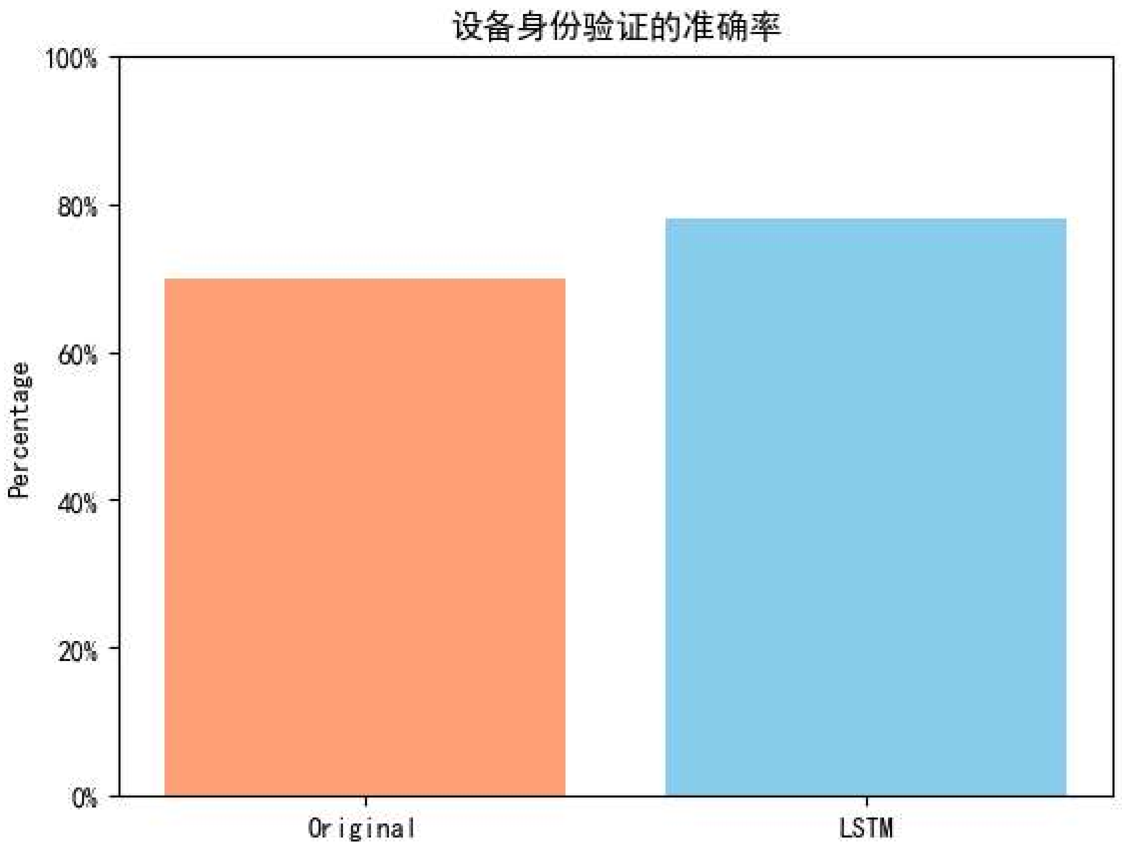

In [ ]:
```
import time
import torch
import torch.nn.functional as F
import torch.optim as optim
import matplotlib.pyplot as plt
from Model import LSTM
import hashlib
import hmac
import uuid
import rsa
import numpy as np
import random
import Dataset
from matplotlib.ticker import PercentFormatter
```

```python
# 初始化模型和数据
def initialize_model_data():
    INPUT_SIZE = 3
    HIDDEN_SIZE = 64
    NUM_LAYERS = 3
    PRED_OUTPUT_SIZE = 3
    CLAS_OUTPUT_SIZE = 4
    train_x, train_y = Dataset.generate_car_data(num_samples=10000, input_dim=20
    lstm = LSTM(INPUT_SIZE, HIDDEN_SIZE, NUM_LAYERS, PRED_OUTPUT_SIZE, CLAS_OUTP
    return lstm, train_x, train_y
def initialize_test_data(input_dim, per_positive):
    test_x, test_y = Dataset.generate_car_data(num_samples=1, input_dim=50, per_
    return test_x, test_y

# 训练模型
def train_model(lstm, train_x, train_y):
    optimizer = optim.Adam(lstm.parameters(), lr=1e-2, weight_decay=1e-5)

    train_y_pred = train_x[:, -1, :]  # 预测任务标签
    train_y_clas = train_y  # 分类任务标签

    train_x = train_x[:, :-1, :]

    max_epochs = 5000 # 训练轮次

    # 训练轮次
    epoch_list = []
    loss_list = []
    loss_pred_list = []
    accuracy_list = []

    for epoch in range(max_epochs):
        pred_y_pred, pred_y_clas = lstm(train_x)

        loss_pred = lstm.loss_mse(pred_y_pred, train_y_pred)
        loss_ce = lstm.loss_ce(pred_y_clas, train_y_clas)

        loss = loss_pred / 1000 + loss_ce

        optimizer.zero_grad()
        loss.backward()
        optimizer.step()

        if loss.item() < 1e-5:
            print('Epoch [{}/{}], Loss: {:.5f}'.format(epoch + 1, max_epochs, lo
            break
        elif (epoch + 1) % 10 == 0:
            # 测试模型在训练集上的预测损失与分类精度用于画图展示
            loss_pred, accuracy, _ = test_model(lstm, train_x, train_y)
            epoch_list.append(epoch + 1)
            loss_list.append(loss.item())
            loss_pred_list.append(loss_pred.detach().cpu().numpy())
            accuracy_list.append(accuracy.detach().cpu().numpy())
            print('Epoch [{}/{}], Loss: {:.5f}'.format(epoch + 1, max_epochs, lo

    return loss_pred_list, accuracy_list, loss_list, epoch_list


# 保存模型
def save_model(lstm):
```

```
    torch.save(lstm, 'Model/lstmmodel.pt')


# 加载模型
def load_model():
    return torch.load('Model/lstmmodel.pt')


# 测试模型的预测损失与分类精度
def test_model(lstm, test_x, test_y):
    test_y_pred = test_x[:, -1, :]  # 预测任务标签
    test_y_clas = test_y  # 分类任务标签

    test_x = test_x[:, :-1, :]

    pred_y_pred, pred_y_clas = lstm(test_x)

    # 预测任务的loss
    loss_pos = lstm.loss_mse(pred_y_pred, test_y_pred)

    # 分类任务的accuracy
    pred_labels = F.one_hot(torch.argmax(pred_y_clas, dim=1), num_classes=lstm.c
    accuracy = torch.mean(torch.eq(pred_labels, test_y_clas).all(dim=1).float())

    return loss_pos, accuracy, pred_labels


# 画图
def plot_curve(loss_pred_list, accuracy_list, loss_list, epoch_list):
    plt.figure(figsize=(12, 6))

    # 绘制总损失图
    plt.subplot(1, 3, 1)
    plt.plot(epoch_list, loss_list, label='Training Loss', color='red')
    plt.title('Training Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()

    # 绘制预测任务损失图
    plt.subplot(1, 3, 2)
    plt.plot(epoch_list, loss_pred_list, label='Prediction Loss', color='blue')
    plt.title('Training Loss')
    plt.xlabel('Epoch')
    plt.ylabel('Loss')
    plt.legend()

    # 绘制分类任务准确率图
    plt.subplot(1, 3, 3)
    plt.plot(epoch_list, accuracy_list, label='Classification Accuracy', color='
    plt.title('Training Accuracy')
    plt.xlabel('Epoch')
    plt.ylabel('Accuracy')
    plt.legend()

    plt.tight_layout()
    plt.show()


class DeviceAuthentication:
```

```
    def __init__(self, device_id, manufacturer):
        self.device_id = device_id
        self.manufacturer = manufacturer
        self.identifier = self.device_id+self.manufacturer
    def authenticate_device(self, pred_labels):
        if(pred_labels[0,0].item() == 1):
            return True
        else:
            return False
    def issue_credentials(self):
        # 生成随机的凭证和密钥对
        credential = str(uuid.uuid4())
        public_key, private_key = self.generate_key_pair()
        return credential, public_key, private_key
    def generate_key_pair(self):
        # 将字符串转换为唯一数字
        unique_number = self.string_to_unique_number(self.identifier)
        # 生成RSA公私钥对
        pubkey, privkey = rsa.newkeys(2048)  #2048
         # 将公私钥对保存到文件中
        with open('key_pair/public_key.pem', 'wb') as public_key_file:
            public_key_file.write(pubkey.save_pkcs1())
        with open('key_pair/private_key.pem', 'wb') as private_key_file:
            private_key_file.write(privkey.save_pkcs1())
        return pubkey.save_pkcs1(), privkey.save_pkcs1()
    def load_keys(self):
        # 加载已保存的公私钥对
        with open('key_pair/public_key.pem', 'rb') as public_key_file:
            pubkey = rsa.PublicKey.load_pkcs1(public_key_file.read())
        with open('key_pair/private_key.pem', 'rb') as private_key_file:
            privkey = rsa.PrivateKey.load_pkcs1(private_key_file.read())
        return pubkey, privkey
    def string_to_unique_number(self, s):
        # 使用 SHA-256 哈希函数
        hash_object = hashlib.sha256(s.encode())
        # 以 16 进制格式返回哈希值
        hex_dig = hash_object.hexdigest()
        # 分割十六进制字符串
        parts = [hex_dig[i:i+8] for i in range(0, len(hex_dig), 8)]
        # 转换每个子字符串为整数并相加
        unique_number = sum(int(part, 16) for part in parts)
        return unique_number

# 生成小车的最后使用上次身份凭证的时间
def generate_final_time(num, low, high):
    sum = 0
    for _ in range(num):
        random_num = random.randint(low, high)
        sum += random_num
    return sum

if __name__ == "__main__":
    start_time = time.time()

    # 初始化
    lstm, train_x, train_y = initialize_model_data()

    # 加速（CPU记得注释掉）
    lstm = lstm.cuda()
    train_x = train_x.cuda()
```

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    train_y = train_y.cuda()


    # 训练
    loss_pos_list, accuracy_list, loss_list, epoch_list = train_model(lstm, trai
    save_model(lstm)
    print("...Training Finished...")
    end_time = time.time()

    # 测试
    lstm = load_model()
    per_positive = 0.6 # 初始化小车的正样本概率
    max_num = 10 # 身份凭证最大使用次数
    use_num = 0 # 初始化使用次数
    car_num = 100 # 验证小车数量
    test_loss_sum = 0 # 小车损失值总和
    test_acc_sum = 0 # 小车acc总和
    # 进行设备身份验证，发送身份凭证
    for i in range(car_num): # 每一辆小车进行验证
        # 模拟一个小车 （后续可以随机或者导入数据集）
        device_id = "device123"
        manufacturer = "Example Inc."
        device = DeviceAuthentication(device_id, manufacturer)# 实例化设备验证类
        final_time = generate_final_time(10, 0, 3) +20 # 时间必须大于20
        test_x, test_y = initialize_test_data(final_time, per_positive)
        test_x = test_x.cuda()
        test_y = test_y.cuda()
        test_loss_list = []
        test_acc_list = []
        for i in range(20, final_time):
            test_loss, test_acc, pred_labels = test_model(lstm, test_x[:, i-20:i
            test_loss_list.append(test_loss.detach().cpu())
            test_acc_list.append(test_acc.detach().cpu())
            if device.authenticate_device(pred_labels):
                # 如果设备验证通过，下发凭证和密钥对
                print("Credential")
                # credential, public_key, private_key = device.issue_credentials
                # print("Credential:", credential)
                # print("Public Key:", public_key)
                # print("Private Key:", private_key)
            else:
                print("Device authentication failed.")
                break
        print("Maximum usage reached, destroy authentication.")
        print("test_loss_list",type(test_loss_list))
        test_loss_sum += np.mean(test_loss_list)
        test_acc_sum += np.mean(test_acc_list)
    # 输出
    print('Test Loss: {:.5f}'.format(test_loss_sum))
    print('Test Accuracy: {:.2f}%'.format(test_acc_sum))
    print("...Test Finished...")
    execution_time = end_time - start_time
    print(f"模型运行时间：{execution_time}秒")

    # 画图
    plot_curve(loss_pos_list, accuracy_list, loss_list, epoch_list) # 训练集acc,
    plt.savefig('./results/training_curve.pdf')
    error_rate = 1- per_positive # 错误率和测试准确率
    # 柱状图数据
    categories = ['Original', 'LSTM']
```

```
# 将错误率和错误率与测试准确率的乘积转换为百分比
values = [per_positive * 100, (test_acc_sum / 100) * 100]

# 绘制柱状图
plt.bar(categories, values, color=['#FFA07A', '#87CEEB'])
plt.ylabel('Percentage')  # 纵坐标标签改为百分比
# 设置中文字体
# 解决中文显示问题
plt.rcParams['font.sans-serif'] = ['SimHei']
plt.rcParams['axes.unicode_minus'] = False
plt.title(u'设备身份验证的准确率')
plt.ylim(0, 100)
plt.gca().yaxis.set_major_formatter(PercentFormatter())  # 设置纵坐标格式为百
```

```
...generate_car_data run Finished...
Epoch [10/5000], Loss: 1.74666
Epoch [20/5000], Loss: 1.22534
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Epoch [40/5000], Loss: 0.99172
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Epoch [590/5000], Loss: 0.82570
```

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Epoch [4740/5000], Loss: 0.78983
Epoch [4750/5000], Loss: 0.79309
Epoch [4760/5000], Loss: 0.78764
Epoch [4770/5000], Loss: 0.79177
Epoch [4780/5000], Loss: 0.78793
Epoch [4790/5000], Loss: 0.78953
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Epoch [4800/5000], Loss: 0.78803
Epoch [4810/5000], Loss: 0.78502
Epoch [4820/5000], Loss: 0.78712
Epoch [4830/5000], Loss: 0.78352
Epoch [4840/5000], Loss: 0.78449
Epoch [4850/5000], Loss: 0.79262
Epoch [4860/5000], Loss: 0.79150
Epoch [4870/5000], Loss: 0.79288
Epoch [4880/5000], Loss: 0.79612
Epoch [4890/5000], Loss: 0.79150
Epoch [4900/5000], Loss: 0.78805
Epoch [4910/5000], Loss: 0.79207
Epoch [4920/5000], Loss: 0.78484
Epoch [4930/5000], Loss: 0.78776
Epoch [4940/5000], Loss: 0.79780
Epoch [4950/5000], Loss: 0.79863
Epoch [4960/5000], Loss: 0.79326
Epoch [4970/5000], Loss: 0.79444
Epoch [4980/5000], Loss: 0.78298
Epoch [4990/5000], Loss: 0.79742
Epoch [5000/5000], Loss: 0.79016
...Training Finished...
...generate_car_data run Finished...
Device authentication failed.
Maximum usage reached, destroy authentication.
test_loss_list <class 'list'>
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Maximum usage reached, destroy authentication.
test_loss_list <class 'list'>
Test Loss: 1106.95431
Test Accuracy: 93.11%
...Test Finished...
模型运行时间: 305.92104029655457秒
```

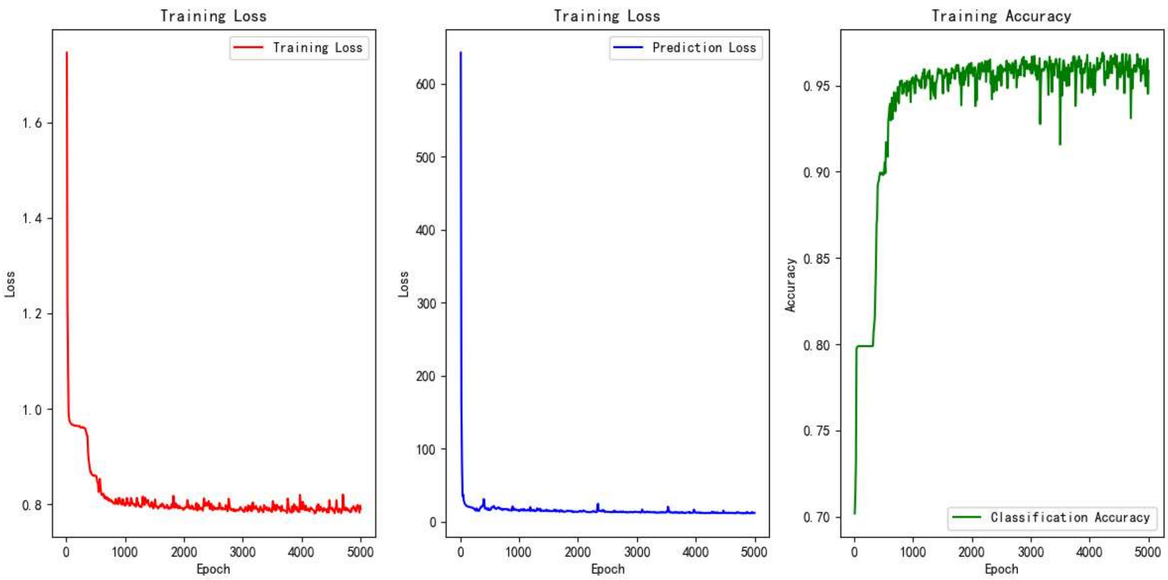

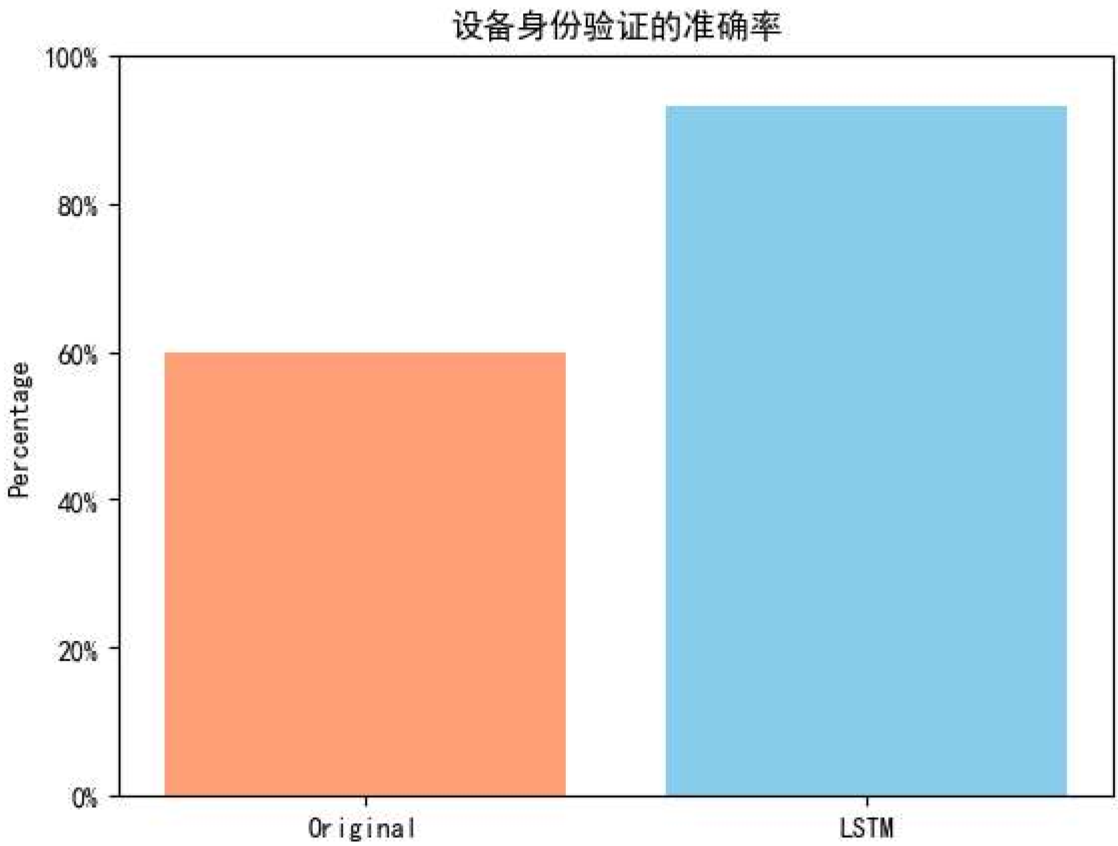
设备身份验证的准确率
100%
80%
60%
40%
20%
0%
Percentage
Original
LSTM