```
import tensorflow as tf
from tensorflow.keras import layers, models
import numpy as np
import matplotlib.pyplot as plt

# ====== Załaduj dane MNIST ======
(x_train, y_train), (x_test, y_test) =
tf.keras.datasets.mnist.load_data()
x_train = x_train.astype("float32") / 255.
x_test = x_test.astype("float32") / 255.
x_train = x_train.reshape(-1, 28 * 28)
x_test = x_test.reshape(-1, 28 * 28)

# ====== Filtruj tylko klasy 0–4 do treningu ======
train_mask = y_train <= 4
x_train_filtered = x_train[train_mask]

# ====== Budowa autoenkodera ======
input_dim = 784
encoding_dim = 64

input_img = tf.keras.Input(shape=(input_dim,))
encoded = layers.Dense(128, activation='relu')(input_img)
encoded = layers.Dense(encoding_dim, activation='relu')(encoded)

decoded = layers.Dense(128, activation='relu')(encoded)
decoded = layers.Dense(input_dim, activation='sigmoid')(decoded)

autoencoder = models.Model(input_img, decoded)
autoencoder.compile(optimizer='adam', loss='mse')
autoencoder.summary()

# ====== Trening autoenkodera ======
autoencoder.fit(x_train_filtered, x_train_filtered,
                epochs=20,
                batch_size=256,
                shuffle=True,
                validation_split=0.2)

# ====== Ewaluacja na pełnym zbiorze testowym (klasy 0–9) ======
reconstructions = autoencoder.predict(x_test)
reconstruction_errors = np.mean(np.square(x_test - reconstructions),
axis=1)

# ====== Ustal próg detekcji na podstawie klas 0–4 ======
test_mask_0_4 = y_test <= 4
threshold = np.mean(reconstruction_errors[test_mask_0_4]) + 2 *
np.std(reconstruction_errors[test_mask_0_4])

# ====== Wykrywanie anomalii ======
```

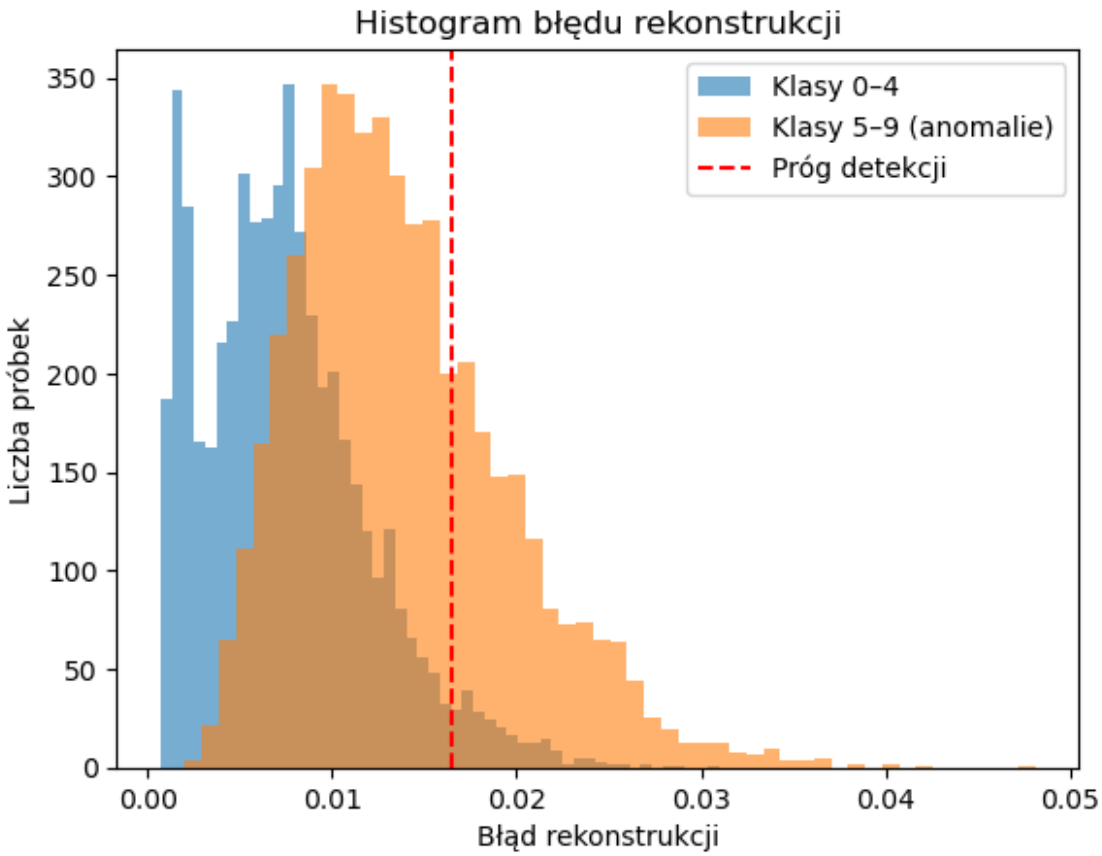
```
y_pred_anomaly = reconstruction_errors > threshold
y_true_anomaly = y_test > 4  # klasy 5–9 to anomalie

# ====== Ocena skuteczności ======
from sklearn.metrics import classification_report, confusion_matrix

print("Raport klasyfikacji (anomalia = 1):")
print(classification_report(y_true_anomaly, y_pred_anomaly))
print("Macierz pomyłek:")
print(confusion_matrix(y_true_anomaly, y_pred_anomaly))

# ====== Przykładowe błędy rekonstrukcji ======
plt.hist(reconstruction_errors[test_mask_0_4], bins=50, alpha=0.6,
label='Klasy 0–4')
plt.hist(reconstruction_errors[~test_mask_0_4], bins=50, alpha=0.6,
label='Klasy 5–9 (anomalie)')
plt.axvline(threshold, color='red', linestyle='--', label='Próg
detekcji')
plt.xlabel("Błąd rekonstrukcji")
plt.ylabel("Liczba próbek")
plt.legend()
plt.title("Histogram błędu rekonstrukcji")
plt.show()
```

```
Model: "functional"
```

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━
┓
┃ Layer (type)                         ┃ Output Shape                ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━
┩
│ input_layer (InputLayer)             │ (None, 784)                 │
0 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────
┤
│ dense (Dense)                        │ (None, 128)                 │
100,480 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────
┤
│ dense_1 (Dense)                      │ (None, 64)                  │
8,256 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────
┤
│ dense_2 (Dense)                      │ (None, 128)                 │
8,320 │
├──────────────────────────────────────┼─────────────────────────────┼─────────────────
┤
│ dense_3 (Dense)                      │ (None, 784)                 │
```

```
101,136 │
└──────────────────────────────────┴──────────────────────────┴──────────
──────┘

 Total params: 218,192 (852.31 KB)

 Trainable params: 218,192 (852.31 KB)

 Non-trainable params: 0 (0.00 B)

Epoch 1/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 3s 9ms/step - loss: 0.1210 - val_loss:
0.0446
Epoch 2/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0407 - val_loss:
0.0307
Epoch 3/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0288 - val_loss:
0.0237
Epoch 4/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0226 - val_loss:
0.0190
Epoch 5/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0182 - val_loss:
0.0160
Epoch 6/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0154 - val_loss:
0.0145
Epoch 7/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0139 - val_loss:
0.0131
Epoch 8/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0129 - val_loss:
0.0123
Epoch 9/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - loss: 0.0118 - val_loss:
0.0115
Epoch 10/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0112 - val_loss:
0.0109
Epoch 11/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0106 - val_loss:
0.0103
Epoch 12/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0100 - val_loss:
0.0099
Epoch 13/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - loss: 0.0096 - val_loss:
0.0095
Epoch 14/20
```

```
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - loss: 0.0092 - val_loss:
0.0092
Epoch 15/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0089 - val_loss:
0.0089
Epoch 16/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0086 - val_loss:
0.0085
Epoch 17/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0083 - val_loss:
0.0086
Epoch 18/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0081 - val_loss:
0.0083
Epoch 19/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - loss: 0.0079 - val_loss:
0.0079
Epoch 20/20
96/96 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - loss: 0.0077 - val_loss:
0.0078
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
Raport klasyfikacji (anomalia = 1):
              precision    recall  f1-score   support

       False       0.58      0.96      0.72      5139
        True       0.86      0.28      0.42      4861

    accuracy                           0.63     10000
   macro avg       0.72      0.62      0.57     10000
weighted avg       0.72      0.63      0.58     10000

Macierz pomyłek:
[[4913  226]
 [3503 1358]]
```


Histogram błędu rekonstrukcji
Klasy 0–4
Klasy 5–9 (anomalie)
Próg detekcji
Liczba próbek
Błąd rekonstrukcji
0
50
100
150
200
250
300
350
0.00
0.01
0.02
0.03
0.04
0.05