In [1]:

```
!pip install optuna
```

```
Requirement already satisfied: optuna in /usr/local/lib/python3.11/dist-packages (4.3.0)
Requirement already satisfied: alembic>=1.5.0 in /usr/local/lib/python3.11/dist-packages
(from optuna) (1.16.1)
Requirement already satisfied: colorlog in /usr/local/lib/python3.11/dist-packages (from
optuna) (6.9.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from opt
una) (2.0.2)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.11/dist-packages
(from optuna) (24.2)
Requirement already satisfied: sqlalchemy>=1.4.2 in /usr/local/lib/python3.11/dist-packag
es (from optuna) (2.0.41)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packages (from optu
na) (4.67.1)
Requirement already satisfied: PyYAML in /usr/local/lib/python3.11/dist-packages (from op
tuna) (6.0.2)
Requirement already satisfied: Mako in /usr/lib/python3/dist-packages (from alembic>=1.5.
0->optuna) (1.1.3)
Requirement already satisfied: typing-extensions>=4.12 in /usr/local/lib/python3.11/dist-
packages (from alembic>=1.5.0->optuna) (4.14.0)
Requirement already satisfied: greenlet>=1 in /usr/local/lib/python3.11/dist-packages (fr
om sqlalchemy>=1.4.2->optuna) (3.2.2)
```

In [2]:

```
import pandas as pd
import numpy as np
import optuna
from sklearn.model_selection import StratifiedKFold
from sklearn.preprocessing import LabelEncoder, StandardScaler
from sklearn.impute import SimpleImputer
from sklearn.metrics import accuracy_score, f1_score, precision_score, recall_score, roc_
auc_score
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping
```

In [3]:

```
df = pd.read_csv("heart_disease_uci.csv")
df.drop(columns=["id", "dataset"], inplace=True)
df["target"] = df["num"].apply(lambda x: 1 if x > 0 else 0)
df.drop(columns=["num"], inplace=True)
```

In [4]:

```
numerical = ['age', 'trestbps', 'chol', 'thalch', 'oldpeak', 'ca']
categorical = ['sex', 'cp', 'fbs', 'restecg', 'exang', 'slope', 'thal']
```

In [5]:

```
df[numerical] = SimpleImputer(strategy="median").fit_transform(df[numerical])
for col in categorical:
    df[col] = LabelEncoder().fit_transform(df[col].astype(str))
df[numerical] = StandardScaler().fit_transform(df[numerical])

X = df[numerical + categorical].astype(np.float32).values
y = df["target"].values
```

In [6]:

```
def rnn_objective(trial):
    n_layers = trial.suggest_int('n_layers', 1, 3)
    n_units = trial.suggest_int('n_units', 16, 128)
```

```
    activation = trial.suggest_categorical('activation', ['relu', 'tanh'])
    dropout_rate = trial.suggest_float('dropout_rate', 0.0, 0.5)
    learning_rate = trial.suggest_float('learning_rate', 1e-4, 5e-3, log=True)
    batch_size = trial.suggest_categorical('batch_size', [16, 32])
    epochs = trial.suggest_int('epochs', 50, 150)

    cv = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
    aucs = []

    for train_idx, val_idx in cv.split(X, y):
        X_train, X_val = X[train_idx], X[val_idx]
        y_train, y_val = y[train_idx], y[val_idx]

        if len(X_train) < batch_size:
            batch_size = len(X_train)

        model = Sequential()
        model.add(Dense(n_units, activation=activation, input_shape=(X.shape[1],)))
        for _ in range(n_layers - 1):
            model.add(Dense(n_units, activation=activation))
            if dropout_rate > 0:
                model.add(Dropout(dropout_rate))
        model.add(Dense(1, activation='sigmoid'))

        optimizer = Adam(learning_rate=learning_rate)
        model.compile(optimizer=optimizer, loss='binary_crossentropy', metrics=['AUC'])

        early_stop = EarlyStopping(monitor='val_loss', patience=10, restore_best_weights
=True)

        model.fit(X_train, y_train,
                  validation_data=(X_val, y_val),
                  epochs=epochs,
                  batch_size=batch_size,
                  verbose=0,
                  callbacks=[early_stop])

        y_proba = model.predict(X_val).ravel()

        if np.isnan(y_proba).any() or y_proba.shape[0] != y_val.shape[0]:
            return 0.0  # Invalid trial

        auc = roc_auc_score(y_val, y_proba)
        aucs.append(auc)

    return np.mean(aucs)
```

In [7]:

```
# running optuna
study = optuna.create_study(direction="maximize")
study.optimize(rnn_objective, n_trials=30)

best_params = study.best_params
print("\n Best Hyperparameters Found:")
for k, v in best_params.items():
    print(f"{k}: {v}")
```

```
[I 2025-06-09 06:01:49,273] A new study created in memory with name: no-name-361c65ab-cd5
6-4bf9-9986-83eb57038975
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
WARNING:tensorflow:5 out of the last 13 calls to <function TensorFlowTrainer.make_predict
_function.<locals>.one_step_on_data_distributed at 0x7f3de0c21c60> triggered tf.function
retracing. Tracing is expensive and the excessive number of tracings could be due to (1)
creating @tf.function repeatedly in a loop, (2) passing tensors with different shapes, (3
) passing Python objects instead of tensors. For (1), please define your @tf.function out
side of the loop. For (2), @tf.function has reduce_retracing=True option that can avoid u
nnecessary retracing. For (3), please refer to https://www.tensorflow.org/guide/function#
controlling_retracing and https://www.tensorflow.org/api_docs/python/tf/function for  mor
e details.
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
WARNING:tensorflow:5 out of the last 13 calls to <function TensorFlowTrainer.make_predict
_function.<locals>.one_step_on_data_distributed at 0x7f3de1b45d00> triggered tf.function
retracing. Tracing is expensive and the excessive number of tracings could be due to (1)
creating @tf.function repeatedly in a loop, (2) passing tensors with different shapes, (3
) passing Python objects instead of tensors. For (1), please define your @tf.function out
side of the loop. For (2), @tf.function has reduce_retracing=True option that can avoid u
nnecessary retracing. For (3), please refer to https://www.tensorflow.org/guide/function#
controlling_retracing and https://www.tensorflow.org/api_docs/python/tf/function for  mor
e details.
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
[I 2025-06-09 06:02:30,191] Trial 0 finished with value: 0.8901442752700361 and parameter
s: {'n_layers': 3, 'n_units': 57, 'activation': 'relu', 'dropout_rate': 0.329746303350685
94, 'learning_rate': 0.0009538529104641583, 'batch_size': 16, 'epochs': 60}. Best is tria
l 0 with value: 0.8901442752700361.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
```

```
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
[I 2025-06-09 06:03:03,482] Trial 1 finished with value: 0.8900025375305504 and parameter
s: {'n_layers': 3, 'n_units': 58, 'activation': 'relu', 'dropout_rate': 0.053907270514781
45, 'learning_rate': 0.0008106064753593207, 'batch_size': 16, 'epochs': 137}. Best is tri
al 0 with value: 0.8901442752700361.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
[I 2025-06-09 06:04:02,889] Trial 2 finished with value: 0.8943758870018478 and parameter
s: {'n_layers': 3, 'n_units': 29, 'activation': 'tanh', 'dropout_rate': 0.306522607519542
74, 'learning_rate': 0.0008876130700599473, 'batch_size': 16, 'epochs': 121}. Best is tri
al 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
```

```
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
[I 2025-06-09 06:05:11,919] Trial 3 finished with value: 0.8917958294247775 and parameter
s: {'n_layers': 3, 'n_units': 46, 'activation': 'relu', 'dropout_rate': 0.099403671269953
36, 'learning_rate': 0.0001689407454731478 8, 'batch_size': 16, 'epochs': 56}. Best is tri
al 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
[I 2025-06-09 06:05:52,482] Trial 4 finished with value: 0.8940374335959118 and parameter
s: {'n_layers': 3, 'n_units': 36, 'activation': 'relu', 'dropout_rate': 0.069490023424356
4, 'learning_rate': 0.0009458214635885713, 'batch_size': 16, 'epochs': 64}. Best is trial
2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step

```
[I 2025-06-09 06:06:47,288] Trial 5 finished with value: 0.8935166266558509 and parameters
: {'n_layers': 3, 'n_units': 22, 'activation': 'tanh', 'dropout_rate': 0.2349200417895708
8, 'learning_rate': 0.0008521125312832888, 'batch_size': 32, 'epochs': 85}. Best is trial
2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
[I 2025-06-09 06:07:22,896] Trial 6 finished with value: 0.8920789797255987 and parameter
s: {'n_layers': 3, 'n_units': 58, 'activation': 'tanh', 'dropout_rate': 0.145307457468313
97, 'learning_rate': 0.0036428136072926016, 'batch_size': 16, 'epochs': 102}. Best is tri
al 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
```

```
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
[I 2025-06-09 06:08:16,783] Trial 7 finished with value: 0.8721491588753697 and parameter
s: {'n_layers': 1, 'n_units': 20, 'activation': 'relu', 'dropout_rate': 0.313303684920329
84, 'learning_rate': 0.00015042895798854537, 'batch_size': 32, 'epochs': 57}. Best is tri
al 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
[I 2025-06-09 06:08:59,789] Trial 8 finished with value: 0.8943035548304273 and parameter
s: {'n_layers': 2, 'n_units': 126, 'activation': 'tanh', 'dropout_rate': 0.38452816781543
914, 'learning_rate': 0.0010535949945702074, 'batch_size': 32, 'epochs': 105}. Best is tr
ial 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
```

```
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
[I 2025-06-09 06:09:34,863] Trial 9 finished with value: 0.8917450246174121 and parameter
s: {'n_layers': 2, 'n_units': 88, 'activation': 'tanh', 'dropout_rate': 0.300738916668475
35, 'learning_rate': 0.0004334392226610813, 'batch_size': 32, 'epochs': 146}. Best is tri
al 2 with value: 0.8943758870018478.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 13ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
[I 2025-06-09 06:10:18,281] Trial 10 finished with value: 0.8982494690325715 and paramete
rs: {'n_layers': 2, 'n_units': 102, 'activation': 'tanh', 'dropout_rate': 0.4911755424801
0364, 'learning_rate': 0.0029510105477201375, 'batch_size': 16, 'epochs': 122}. Best is t
rial 10 with value: 0.8982494690325715.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
[I 2025-06-09 06:11:05,476] Trial 11 finished with value: 0.8968601881708974 and paramete
rs: {'n_layers': 2, 'n_units': 93, 'activation': 'tanh', 'dropout_rate': 0.48338483566862
73, 'learning_rate': 0.003512411294796149, 'batch_size': 16, 'epochs': 122}. Best is tria
l 10 with value: 0.8982494690325715.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step

```
[I 2025-06-09 06:11:47,296] Trial 12 finished with value: 0.8999217918023501 and paramete
rs: {'n_layers': 1, 'n_units': 95, 'activation': 'tanh', 'dropout_rate': 0.49832650587202
32, 'learning_rate': 0.0038961378808007475, 'batch_size': 16, 'epochs': 122}. Best is tri
al 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
[I 2025-06-09 06:12:32,735] Trial 13 finished with value: 0.8949480950065587 and paramete
rs: {'n_layers': 1, 'n_units': 114, 'activation': 'tanh', 'dropout_rate': 0.4897350883188
6375, 'learning_rate': 0.0022183965056060497, 'batch_size': 16, 'epochs': 121}. Best is t
rial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
[I 2025-06-09 06:13:08,700] Trial 14 finished with value: 0.8966003537139594 and paramete
rs: {'n_layers': 1, 'n_units': 87, 'activation': 'tanh', 'dropout_rate': 0.42823790547566
66, 'learning_rate': 0.004999925077264876, 'batch_size': 16, 'epochs': 132}. Best is tria
l 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
```

```
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
[I 2025-06-09 06:14:08,060] Trial 15 finished with value: 0.8946137063275048 and parameters: {'n_layers': 1, 'n_units': 104, 'activation': 'tanh', 'dropout_rate': 0.420892481596014, 'learning_rate': 0.001892524000408981, 'batch_size': 16, 'epochs': 88}. Best is trial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
[I 2025-06-09 06:14:52,572] Trial 16 finished with value: 0.89573594461657 and parameters: {'n_layers': 2, 'n_units': 80, 'activation': 'tanh', 'dropout_rate': 0.19623111218124123, 'learning_rate': 0.0018818380133275182, 'batch_size': 16, 'epochs': 115}. Best is trial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
[I 2025-06-09 06:16:25,997] Trial 17 finished with value: 0.8912675432899118 and paramete
rs: {'n_layers': 1, 'n_units': 105, 'activation': 'tanh', 'dropout_rate': 0.3946829249667
088, 'learning_rate': 0.00038466077859439923, 'batch_size': 16, 'epochs': 149}. Best is t
rial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
```

```
[I 2025-06-09 06:17:01,725] Trial 18 finished with value: 0.8948310280199167 and paramete
rs: {'n_layers': 2, 'n_units': 74, 'activation': 'tanh', 'dropout_rate': 0.49490779806565
044, 'learning_rate': 0.002628832174219858, 'batch_size': 32, 'epochs': 86}. Best is tria
l 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
[I 2025-06-09 06:17:51,221] Trial 19 finished with value: 0.8913629203234233 and paramete
rs: {'n_layers': 1, 'n_units': 127, 'activation': 'tanh', 'dropout_rate': 0.4457834783255
711, 'learning_rate': 0.0013673152418825095, 'batch_size': 16, 'epochs': 134}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
[I 2025-06-09 06:18:57,301] Trial 20 finished with value: 0.8982946374186606 and paramete
rs: {'n_layers': 2, 'n_units': 101, 'activation': 'tanh', 'dropout_rate': 0.0016250102695
229973, 'learning_rate': 0.0004796329857182179, 'batch_size': 16, 'epochs': 110}. Best is
trial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
```

```
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
[I 2025-06-09 06:19:43,385] Trial 21 finished with value: 0.890479151716316 and parameter
s: {'n_layers': 2, 'n_units': 100, 'activation': 'tanh', 'dropout_rate': 0.15950871794708
177, 'learning_rate': 0.0004314507923056113, 'batch_size': 16, 'epochs': 110}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 13ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 13ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
[I 2025-06-09 06:20:16,489] Trial 22 finished with value: 0.8986528297088237 and paramete
rs: {'n_layers': 2, 'n_units': 118, 'activation': 'tanh', 'dropout_rate': 0.3648493098591
915, 'learning_rate': 0.0046387956230907502, 'batch_size': 16, 'epochs': 94}. Best is tria
l 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
[I 2025-06-09 06:21:43,082] Trial 23 finished with value: 0.8939687867768644 and paramete
rs: {'n_layers': 2, 'n_units': 113, 'activation': 'tanh', 'dropout_rate': 0.3575179584364
6705, 'learning_rate': 0.000242650121716741, 'batch_size': 16, 'epochs': 93}. Best is tri
al 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
[I 2025-06-09 06:22:18,454] Trial 24 finished with value: 0.8943042593830868 and paramete
rs: {'n_layers': 2, 'n_units': 115, 'activation': 'tanh', 'dropout_rate': 0.0139356116976
02691, 'learning_rate': 0.004782932937564674, 'batch_size': 16, 'epochs': 75}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
[I 2025-06-09 06:23:32,023] Trial 25 finished with value: 0.8895707123563646 and paramete
rs: {'n_layers': 1, 'n_units': 120, 'activation': 'tanh', 'dropout_rate': 0.2663697256427
454, 'learning_rate': 0.0002742217118270734, 'batch_size': 16, 'epochs': 97}. Best is tri
al 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
```

```
[I 2025-06-09 06:24:41,407] Trial 26 finished with value: 0.8877557847053655 and paramete
rs: {'n_layers': 1, 'n_units': 93, 'activation': 'relu', 'dropout_rate': 0.23234544034519
672, 'learning_rate': 0.00010037231636296617, 'batch_size': 32, 'epochs': 76}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
```

```
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step

```
[I 2025-06-09 06:25:40,554] Trial 27 finished with value: 0.8924604878596447 and paramete
rs: {'n_layers': 2, 'n_units': 70, 'activation': 'tanh', 'dropout_rate': 0.37350111648651
124, 'learning_rate': 0.0005409531934507921, 'batch_size': 16, 'epochs': 111}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step

```
[I 2025-06-09 06:26:26,503] Trial 28 finished with value: 0.896527262793521 and parameter
s: {'n_layers': 2, 'n_units': 109, 'activation': 'tanh', 'dropout_rate': 0.26710980815280
677, 'learning_rate': 0.0013659067009906965, 'batch_size': 16, 'epochs': 129}. Best is tr
ial 12 with value: 0.8999217918023501.
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
```

```
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step
```

```
[I 2025-06-09 06:27:21,617] Trial 29 finished with value: 0.8925578159620597 and paramete
rs: {'n_layers': 1, 'n_units': 96, 'activation': 'relu', 'dropout_rate': 0.34970732507462
79, 'learning_rate': 0.0005762725225235987, 'batch_size': 16, 'epochs': 105}. Best is tri
al 12 with value: 0.8999217918023501.
```

```
 Best Hyperparameters Found:
n_layers: 1
n_units: 95
activation: tanh
dropout_rate: 0.4983265058720232
learning_rate: 0.0038961378808007475
batch_size: 16
epochs: 122
```

In [8]:

```
# Training
final_model = Sequential()
final_model.add(Dense(best_params['n_units'], activation=best_params['activation'], inpu
t_shape=(X.shape[1],)))
for _ in range(best_params['n_layers'] - 1):
    final_model.add(Dense(best_params['n_units'], activation=best_params['activation']))
    if best_params['dropout_rate'] > 0:
        final_model.add(Dropout(best_params['dropout_rate']))
final_model.add(Dense(1, activation='sigmoid'))

optimizer = Adam(learning_rate=best_params['learning_rate'])
final_model.compile(optimizer=optimizer, loss='binary_crossentropy', metrics=['AUC'])

early_stop = EarlyStopping(monitor='loss', patience=10, restore_best_weights=True)
final_model.fit(X, y, epochs=best_params['epochs'], batch_size=best_params['batch_size']
, verbose=1, callbacks=[early_stop])
```

```
Epoch 1/122
```

```
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
58/58 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step - AUC: 0.8243 - loss: 0.5195
```

```
Epoch 2/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8829 - loss: 0.4304
Epoch 3/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8882 - loss: 0.4206
Epoch 4/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9029 - loss: 0.3992
Epoch 5/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8996 - loss: 0.3950
Epoch 6/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8988 - loss: 0.3992
Epoch 7/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8980 - loss: 0.4025
Epoch 8/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8931 - loss: 0.4058
Epoch 9/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8984 - loss: 0.4019
Epoch 10/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.8895 - loss: 0.4241
Epoch 11/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9248 - loss: 0.3465
Epoch 12/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9040 - loss: 0.3889
Epoch 13/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9073 - loss: 0.3853
Epoch 14/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9165 - loss: 0.3643
Epoch 15/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9150 - loss: 0.3679
Epoch 16/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9191 - loss: 0.3700
Epoch 17/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9170 - loss: 0.3688
Epoch 18/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9108 - loss: 0.3763
Epoch 19/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9245 - loss: 0.3510
Epoch 20/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9303 - loss: 0.3357
Epoch 21/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9219 - loss: 0.3465
Epoch 22/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9199 - loss: 0.3569
Epoch 23/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9274 - loss: 0.3428
Epoch 24/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9355 - loss: 0.3216
Epoch 25/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9416 - loss: 0.3083
Epoch 26/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9322 - loss: 0.3308
Epoch 27/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9469 - loss: 0.2967
Epoch 28/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9313 - loss: 0.3330
Epoch 29/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9473 - loss: 0.2879
Epoch 30/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9356 - loss: 0.3238
Epoch 31/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9263 - loss: 0.3328
Epoch 32/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9451 - loss: 0.3125
Epoch 33/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9494 - loss: 0.2928
Epoch 34/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9414 - loss: 0.3075
Epoch 35/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9545 - loss: 0.2761
Epoch 36/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9440 - loss: 0.3061
Epoch 37/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9579 - loss: 0.2696
```

Epoch 38/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9607 - loss: 0.2598
Epoch 39/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9383 - loss: 0.3141
Epoch 40/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9570 - loss: 0.2694
Epoch 41/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9590 - loss: 0.2629
Epoch 42/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9546 - loss: 0.2698
Epoch 43/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9664 - loss: 0.2488
Epoch 44/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9679 - loss: 0.2388
Epoch 45/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9560 - loss: 0.2699
Epoch 46/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9686 - loss: 0.2335
Epoch 47/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9583 - loss: 0.2643
Epoch 48/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9611 - loss: 0.2564
Epoch 49/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9672 - loss: 0.2361
Epoch 50/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9575 - loss: 0.2633
Epoch 51/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9693 - loss: 0.2281
Epoch 52/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9604 - loss: 0.2602
Epoch 53/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9705 - loss: 0.2291
Epoch 54/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9725 - loss: 0.2154
Epoch 55/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9706 - loss: 0.2260
Epoch 56/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9789 - loss: 0.2028
Epoch 57/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9726 - loss: 0.2178
Epoch 58/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9767 - loss: 0.2025
Epoch 59/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9746 - loss: 0.2164
Epoch 60/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9758 - loss: 0.2055
Epoch 61/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9768 - loss: 0.2050
Epoch 62/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9740 - loss: 0.2116
Epoch 63/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9796 - loss: 0.1958
Epoch 64/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9765 - loss: 0.1988
Epoch 65/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9832 - loss: 0.1826
Epoch 66/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9838 - loss: 0.1735
Epoch 67/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9843 - loss: 0.1862
Epoch 68/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9795 - loss: 0.1877
Epoch 69/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9836 - loss: 0.1762
Epoch 70/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9786 - loss: 0.1893
Epoch 71/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9869 - loss: 0.1623
Epoch 72/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9863 - loss: 0.1659
Epoch 73/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9859 - loss: 0.1647

```
Epoch 74/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9886 - loss: 0.1535
Epoch 75/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9856 - loss: 0.1663
Epoch 76/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9908 - loss: 0.1485
Epoch 77/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9907 - loss: 0.1467
Epoch 78/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9904 - loss: 0.1471
Epoch 79/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9893 - loss: 0.1521
Epoch 80/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9892 - loss: 0.1537
Epoch 81/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9922 - loss: 0.1336
Epoch 82/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9887 - loss: 0.1545
Epoch 83/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9894 - loss: 0.1414
Epoch 84/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9868 - loss: 0.1529
Epoch 85/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9922 - loss: 0.1332
Epoch 86/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9931 - loss: 0.1285
Epoch 87/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9919 - loss: 0.1269
Epoch 88/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9930 - loss: 0.1290
Epoch 89/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9893 - loss: 0.1473
Epoch 90/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9950 - loss: 0.1102
Epoch 91/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9919 - loss: 0.1261
Epoch 92/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9945 - loss: 0.1213
Epoch 93/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step - AUC: 0.9924 - loss: 0.1254
Epoch 94/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9962 - loss: 0.1051
Epoch 95/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9956 - loss: 0.1054
Epoch 96/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9954 - loss: 0.1049
Epoch 97/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9956 - loss: 0.1076
Epoch 98/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9951 - loss: 0.1088
Epoch 99/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9961 - loss: 0.1034
Epoch 100/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9939 - loss: 0.1164
Epoch 101/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9953 - loss: 0.0995
Epoch 102/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9949 - loss: 0.1062
Epoch 103/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9962 - loss: 0.1007
Epoch 104/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9965 - loss: 0.1028
Epoch 105/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9983 - loss: 0.0808
Epoch 106/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9966 - loss: 0.1016
Epoch 107/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9958 - loss: 0.1008
Epoch 108/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9960 - loss: 0.0960
Epoch 109/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9951 - loss: 0.0981
```

```
Epoch 110/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9949 - loss: 0.0976
Epoch 111/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9974 - loss: 0.0757
Epoch 112/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9977 - loss: 0.0836
Epoch 113/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9985 - loss: 0.0755
Epoch 114/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9984 - loss: 0.0675
Epoch 115/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9981 - loss: 0.0752
Epoch 116/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9993 - loss: 0.0649
Epoch 117/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9990 - loss: 0.0676
Epoch 118/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9994 - loss: 0.0628
Epoch 119/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9992 - loss: 0.0655
Epoch 120/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9990 - loss: 0.0705
Epoch 121/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9983 - loss: 0.0745
Epoch 122/122
58/58 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - AUC: 0.9993 - loss: 0.0551
```

Out[8]:

```
<keras.src.callbacks.history.History at 0x7f3dc572db90>
```

In [9]:

```
# Evaluating
y_pred_proba = final_model.predict(X).ravel()
y_pred = (y_pred_proba > 0.5).astype(int)
```

```
29/29 ━━━━━━━━━━━━━━━━━━━━ 0s 3ms/step
```

In [10]:

```
results = {
    'Model': "RNN (Optuna Tuned)",
    'Accuracy': accuracy_score(y, y_pred),
    'F1 Score': f1_score(y, y_pred),
    'Precision': precision_score(y, y_pred),
    'Recall': recall_score(y, y_pred),
    'ROC AUC': roc_auc_score(y, y_pred_proba)
}
```

In [11]:

```
print("\n Final Evaluation Metrics:")
for k, v in results.items():
    print(f"{k}: {v:.4f}" if isinstance(v, float) else f"{k}: {v}")
```

```
 Final Evaluation Metrics:
Model: RNN (Optuna Tuned)
Accuracy: 0.9913
F1 Score: 0.9921
Precision: 0.9960
Recall: 0.9882
ROC AUC: 0.9996
```

In [12]:

```
import matplotlib.pyplot as plt
```

In [13]:

```
results = {
```

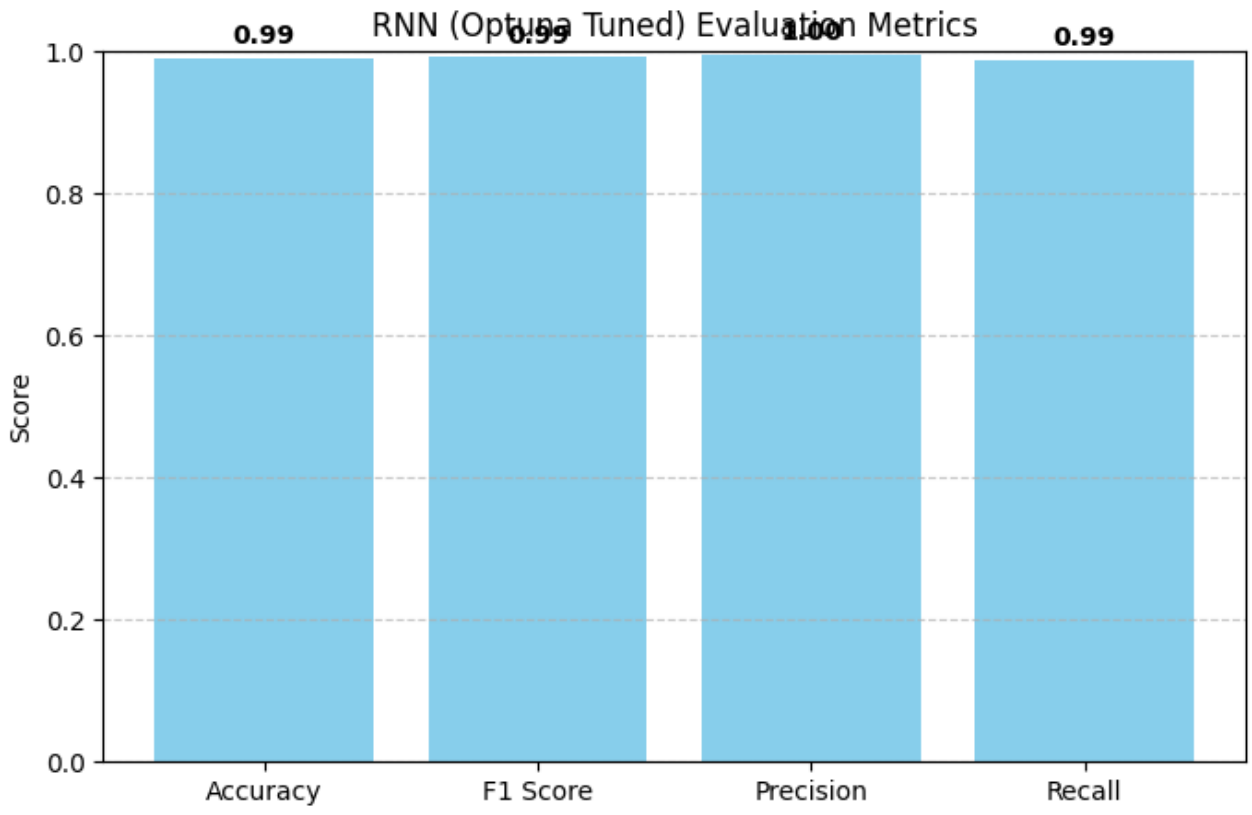
```
    'Model': "RNN (Optuna Tuned)",
    'Accuracy': accuracy_score(y, y_pred),
    'F1 Score': f1_score(y, y_pred),
    'Precision': precision_score(y, y_pred),
    'Recall': recall_score(y, y_pred),
    'ROC AUC': roc_auc_score(y, y_pred_proba)
}
```

In [14]:

```
# Selecting metrics
metrics_to_plot = {k: v for k, v in results.items() if k in ['Accuracy', 'F1 Score', 'Precision', 'Recall']}
```

In [29]:

```
# Plot
plt.figure(figsize=(8, 5))
plt.bar(metrics_to_plot.keys(), metrics_to_plot.values(), color='skyblue')
plt.title(f"{results['Model']} Evaluation Metrics")
plt.ylabel("Score")
plt.ylim(0, 1)
plt.grid(True, axis='y', linestyle='--', alpha=0.7)

# Adding values above bars
for i, (metric, value) in enumerate(metrics_to_plot.items()):
    plt.text(i, value + 0.02, f"{value:.2f}", ha='center', fontweight='bold')

plt.show()
```



Regularization

In [17]:

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import StratifiedKFold
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score, roc_curve, auc
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, BatchNormalization, Activation
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping
```

```
from tensorflow.keras import regularizers
```

In [18]:

```
cv_results = {'Accuracy': [], 'Precision': [], 'Recall': [], 'F1 Score': [], 'ROC AUC': [
]}
train_acc_histories = []
val_acc_histories = []
```

In [19]:

```
# ROC for allfolds
all_y_true = []
all_y_pred_proba = []

skf = StratifiedKFold(n_splits=5, shuffle=True, random_state=42)
```

In [20]:

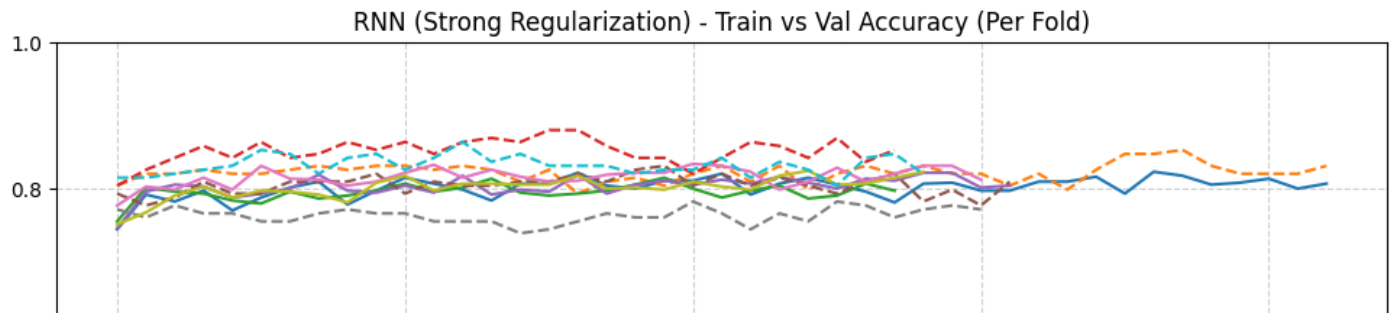
```
for fold, (train_idx, val_idx) in enumerate(skf.split(X, y)):
    print(f"\n Fold {fold+1}")
    X_train, X_val = X[train_idx], X[val_idx]
    y_train, y_val = y[train_idx], y[val_idx]

    model = Sequential()
    model.add(Dense(best_params['n_units'],
                    input_shape=(X.shape[1],),
                    kernel_regularizer=regularizers.l2(0.005),
                    use_bias=False))
    model.add(BatchNormalization())
    model.add(Activation(best_params['activation']))
    model.add(Dropout(min(best_params['dropout_rate'] + 0.1, 0.5)))

    for _ in range(best_params['n_layers'] - 1):
        model.add(Dense(best_params['n_units'],
                        kernel_regularizer=regularizers.l2(0.005),
                        use_bias=False))
        model.add(BatchNormalization())
        model.add(Activation(best_params['activation']))
        model.add(Dropout(min(best_params['dropout_rate'] + 0.1, 0.5)))

    model.add(Dense(1, activation='sigmoid'))

    model.compile(optimizer=Adam(learning_rate=best_params['learning_rate']),
                  loss='binary_crossentropy',
                  metrics=['accuracy', 'AUC'])

    early_stop = EarlyStopping(monitor='val_loss', patience=10, restore_best_weights=Tru
e)

    history = model.fit(X_train, y_train,
                        validation_data=(X_val, y_val),
                        epochs=best_params['epochs'],
                        batch_size=best_params['batch_size'],
                        verbose=0,
                        callbacks=[early_stop])

    train_acc_histories.append(history.history['accuracy'])
    val_acc_histories.append(history.history['val_accuracy'])

    y_pred_proba = model.predict(X_val).ravel()
    y_pred = (y_pred_proba > 0.5).astype(int)

    # Collect for global ROC
    all_y_true.extend(y_val)
    all_y_pred_proba.extend(y_pred_proba)

    cv_results['Accuracy'].append(accuracy_score(y_val, y_pred))
    cv_results['Precision'].append(precision_score(y_val, y_pred))
    cv_results['Recall'].append(recall_score(y_val, y_pred))
    cv_results['F1 Score'].append(f1_score(y_val, y_pred))
```

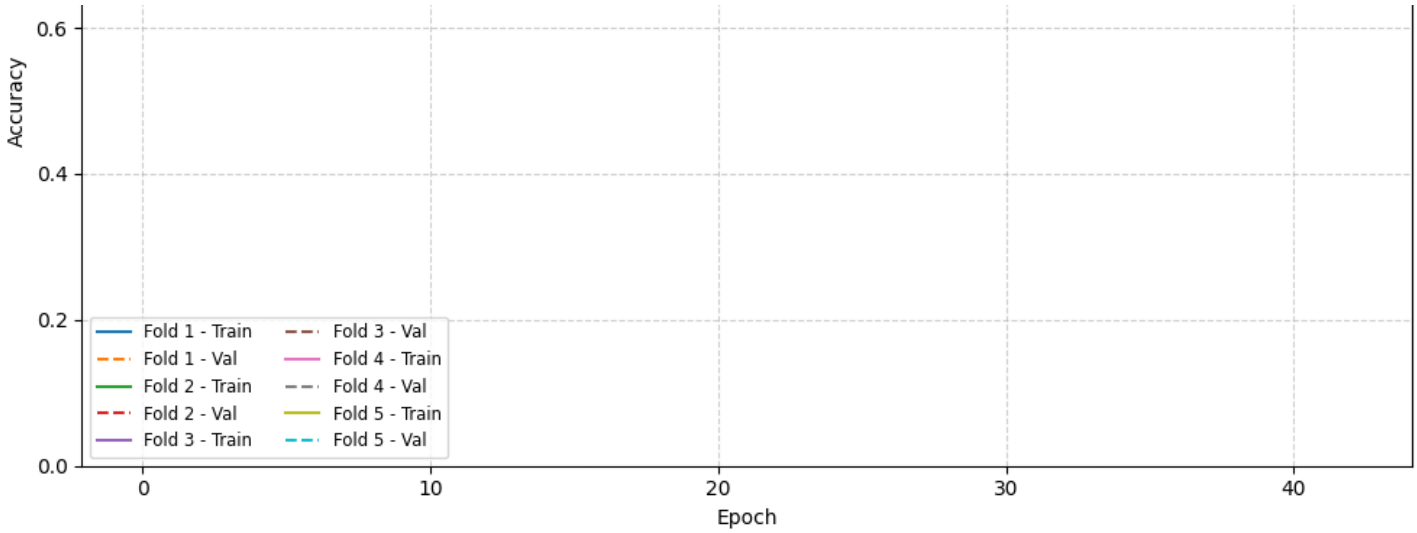
```
    cv_results['ROC AUC'].append(roc_auc_score(y_val, y_pred_proba))
```

```
 Fold 1
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
 Fold 2
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
 Fold 3
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step
 Fold 4
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step
 Fold 5
/usr/local/lib/python3.11/dist-packages/keras/src/layers/core/dense.py:87: UserWarning: D
o not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models
, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
6/6 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step
```

In [21]:

```
# Plot 1: Train vs Validation Accuracy for every fold
plt.figure(figsize=(10, 6))
for i in range(len(train_acc_histories)):
    plt.plot(train_acc_histories[i], label=f"Fold {i+1} - Train", linestyle='-')
    plt.plot(val_acc_histories[i], label=f"Fold {i+1} - Val", linestyle='--')

plt.title("RNN (Strong Regularization) - Train vs Val Accuracy (Per Fold)")
plt.xlabel("Epoch")
plt.ylabel("Accuracy")
plt.ylim(0, 1)
plt.grid(True, linestyle='--', alpha=0.6)
plt.legend(ncol=2, fontsize='small')
plt.tight_layout()
plt.show()
```



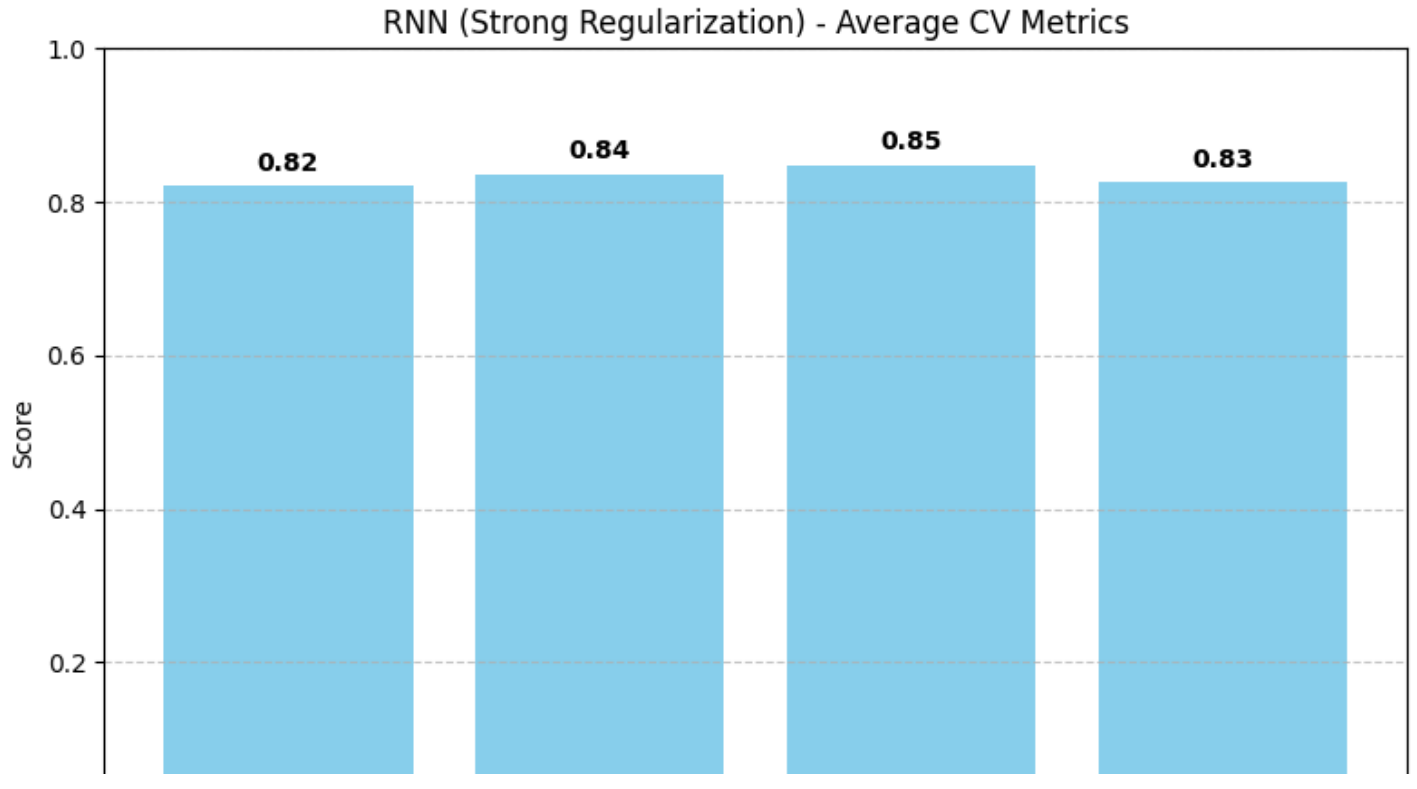


In [22]:

```
# Plot 2: Bar Plot for Final CV Metrics
# Computing averages
avg_metrics = {
    'Accuracy': np.mean(cv_results['Accuracy']),
    'F1 Score': np.mean(cv_results['F1 Score']),
    'Precision': np.mean(cv_results['Precision']),
    'Recall': np.mean(cv_results['Recall'])
}
```

In [30]:

```
# Plot bar chart
plt.figure(figsize=(8, 5))
bars = plt.bar(avg_metrics.keys(), avg_metrics.values(), color='skyblue')
plt.title("RNN (Strong Regularization) - Average CV Metrics")
plt.ylabel("Score")
plt.ylim(0, 1)
plt.grid(True, axis='y', linestyle='--', alpha=0.7)

for bar, value in zip(bars, avg_metrics.values()):
    plt.text(bar.get_x() + bar.get_width() / 2, value + 0.02, f"{value:.2f}", ha='center
', fontweight='bold')

plt.tight_layout()
plt.show()
```

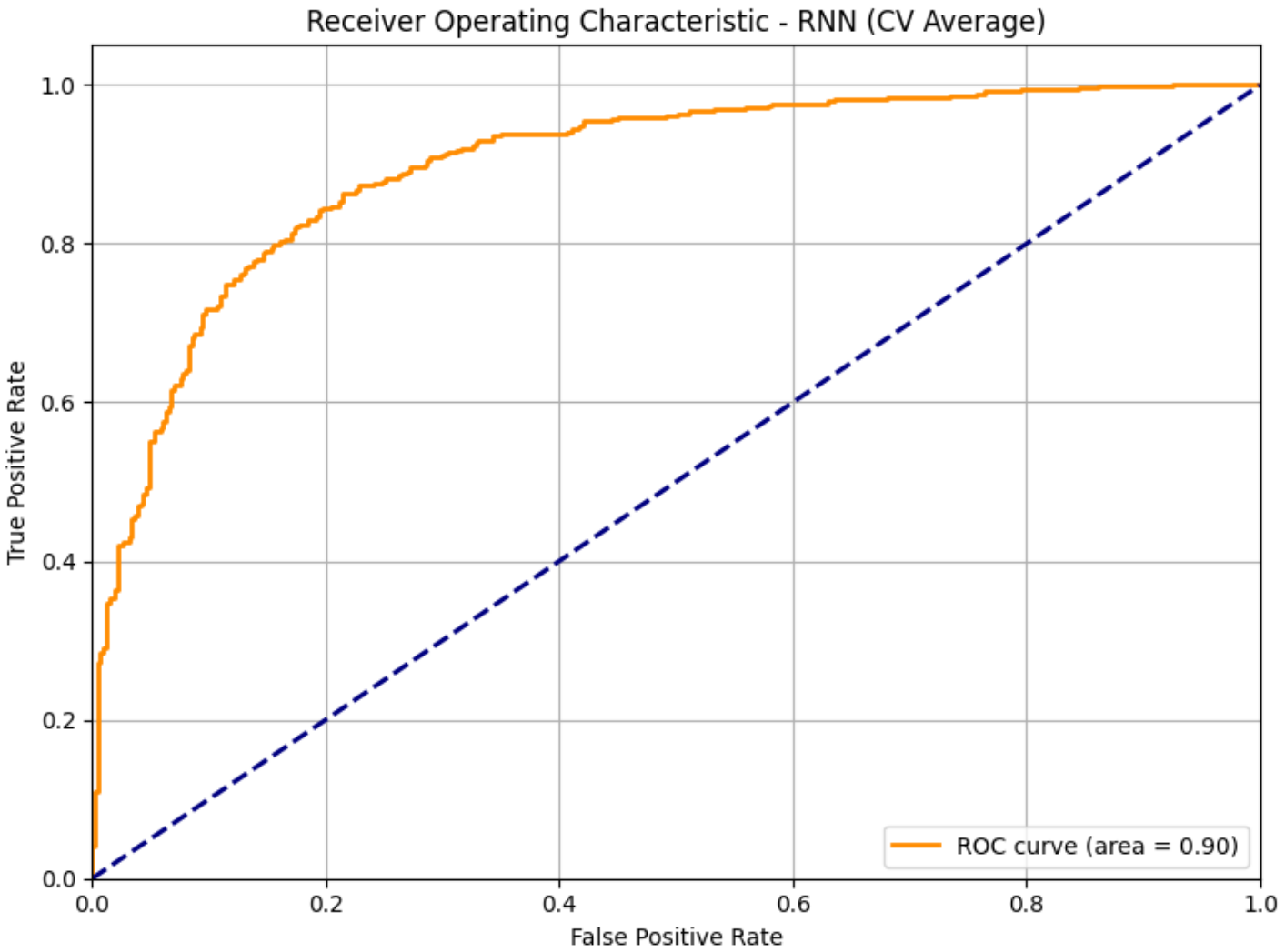


In [25]:

```
# Plot 3: ROC Curve
all_y_true = np.array(all_y_true)
all_y_pred_proba = np.array(all_y_pred_proba)

fpr, tpr, _ = roc_curve(all_y_true, all_y_pred_proba)
roc_auc = auc(fpr, tpr)
```

In [26]:

```
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve (area = {roc_auc:.2f})')
plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
plt.xlim([0.0, 1.0])
plt.ylim([0.0, 1.05])
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Receiver Operating Characteristic - RNN (CV Average)')
plt.legend(loc="lower right")
plt.grid(True)
plt.tight_layout()
plt.show()
```



In [27]:

```
pip install shap
```

```
Requirement already satisfied: shap in /usr/local/lib/python3.11/dist-packages (0.47.2)
Requirement already satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from sha
p) (2.0.2)
Requirement already satisfied: scipy in /usr/local/lib/python3.11/dist-packages (from sha
```

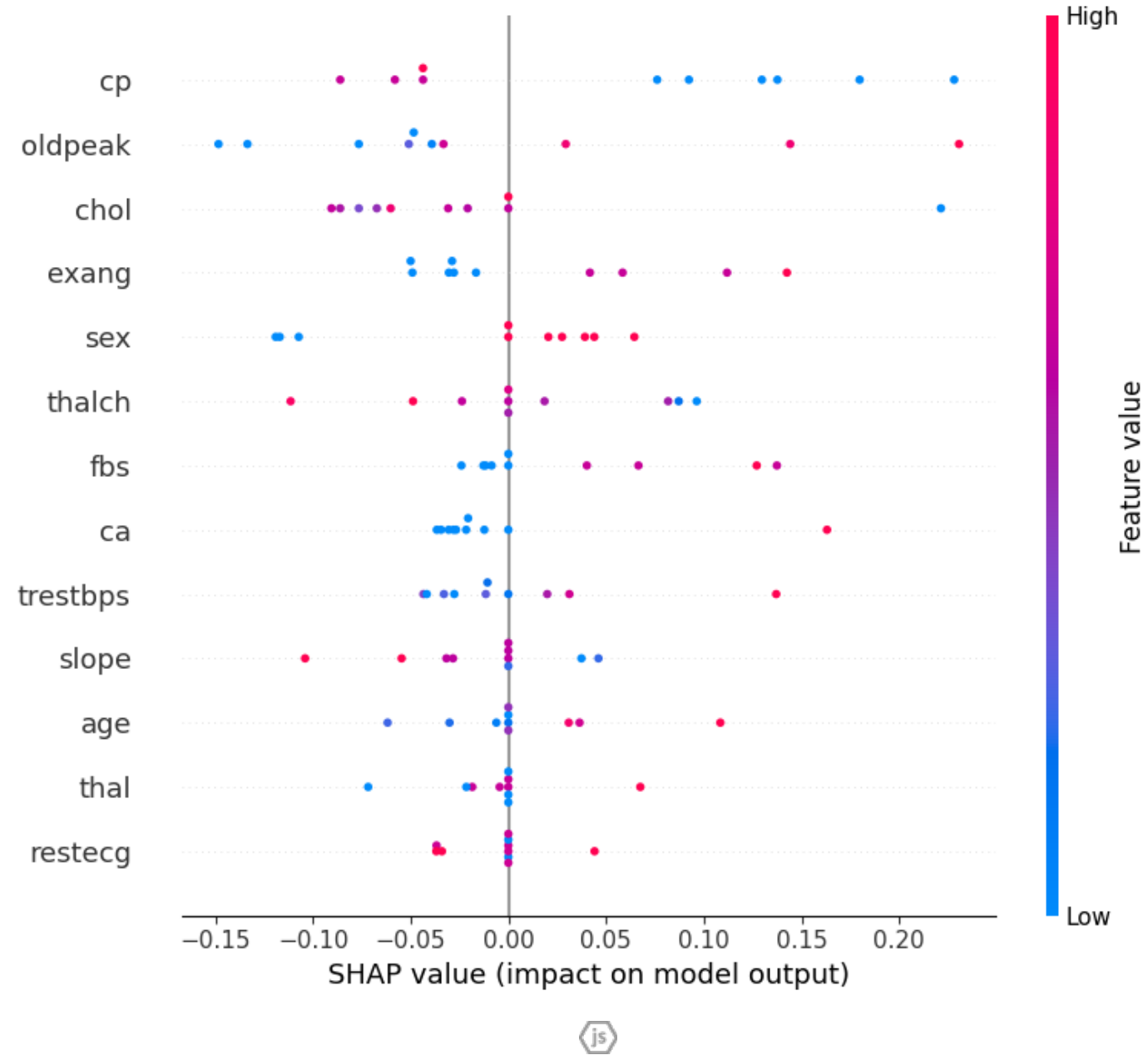
```
p) (1.15.3)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.11/dist-packages (f
rom shap) (1.6.1)
Requirement already satisfied: pandas in /usr/local/lib/python3.11/dist-packages (from sh
ap) (2.2.2)
Requirement already satisfied: tqdm>=4.27.0 in /usr/local/lib/python3.11/dist-packages (f
rom shap) (4.67.1)
Requirement already satisfied: packaging>20.9 in /usr/local/lib/python3.11/dist-packages
(from shap) (24.2)
Requirement already satisfied: slicer==0.0.8 in /usr/local/lib/python3.11/dist-packages (
from shap) (0.0.8)
Requirement already satisfied: numba>=0.54 in /usr/local/lib/python3.11/dist-packages (fr
om shap) (0.60.0)
Requirement already satisfied: cloudpickle in /usr/local/lib/python3.11/dist-packages (fr
om shap) (3.1.1)
Requirement already satisfied: typing-extensions in /usr/local/lib/python3.11/dist-packag
es (from shap) (4.14.0)
Requirement already satisfied: llvmlite<0.44,>=0.43.0dev0 in /usr/local/lib/python3.11/di
st-packages (from numba>=0.54->shap) (0.43.0)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.11/dist-p
ackages (from pandas->shap) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages (f
rom pandas->shap) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dist-packages
(from pandas->shap) (2025.2)
Requirement already satisfied: joblib>=1.2.0 in /usr/local/lib/python3.11/dist-packages (
from scikit-learn->shap) (1.5.1)
Requirement already satisfied: threadpoolctl>=3.1.0 in /usr/local/lib/python3.11/dist-pac
kages (from scikit-learn->shap) (3.6.0)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-packages (from
python-dateutil>=2.8.2->pandas->shap) (1.17.0)
```

In [28]:

```
import shap
import numpy as np
import random

# 1. Choosing background dataset (subset of training data)
X_background = X[np.random.choice(X.shape[0], 100, replace=False)]

# 2. Defining prediction function
predict_fn = lambda data: final_model.predict(data).flatten()

# 3. Creating SHAP KernelExplainer
explainer = shap.KernelExplainer(predict_fn, X_background)

# 4. Choosing a few samples to explain
X_explain = X[np.random.choice(X.shape[0], 10, replace=False)]

# 5. Computing SHAP values
shap_values = explainer.shap_values(X_explain)
feature_names = numerical + categorical

# 6: Global Summary Plot
shap.summary_plot(shap_values, X_explain, feature_names=feature_names)

# 7: Individual prediction plot
shap.initjs()
shap.force_plot(explainer.expected_value, shap_values[0], X_explain[0], feature_names=fea
ture_names)
```

```
4/4 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step

1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 35ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 36ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 57ms/step
```

```
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 49ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 34ms/step
6482/6482 ━━━━━━━━━━━━━━━━━━━━ 7s 1ms/step
```



Out[28]:

Visualization omitted, Javascript library not loaded!

Have you run `initjs()` in this notebook? If this notebook was from another user you must also trust this notebook (File -> Trust notebook). If you are viewing this notebook on github the Javascript has been stripped for security. If you are using JupyterLab this error is because a JupyterLab extension has not yet been written.

In [28]: