1. Siapkan Data

```python
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler

df = pd.read_csv("processed_kelulusan.csv")

X = df.drop("Lulus", axis=1)
y = df["Lulus"]

sc = StandardScaler()
Xs = sc.fit_transform(X)

#Split menjadi train (60%), val (20%), test (20%)
X_train, X_temp, y_train, y_temp = train_test_split(
    Xs, y, test_size=0.4, stratify=y, random_state=42
)

X_val, X_test, y_val, y_test = train_test_split(
    X_temp, y_temp, test_size=0.5, stratify=y_temp, random_state=42
)

print("Ukuran data:")
print("Train :", X_train.shape)
print("Val   :", X_val.shape)
print("Test  :", X_test.shape)

print("\nDistribusi kelas:")
print("Train:\n", y_train.value_counts())
print("Val:\n", y_val.value_counts())
print("Test:\n", y_test.value_counts())
```

```
Ukuran data:
Train : (6, 5)
Val   : (2, 5)
Test  : (2, 5)

Distribusi kelas:
Train:
 Lulus
1    3
0    3
Name: count, dtype: int64
Val:
 Lulus
1    1
0    1
Name: count, dtype: int64
Test:
 Lulus
1    1
0    1
Name: count, dtype: int64
```

2. Bangun Model ANN

   Model ANN dibangun menggunakan arsitektur **Sequential** dengan tiga lapisan utama:

   - **Dense(32, ReLU)** dan **Dense(16, ReLU)** untuk menangkap pola non-linear,
   - **Dropout(0.3)** untuk mencegah overfitting,
   - **Dense(1, Sigmoid)** sebagai output untuk klasifikasi biner (*lulus/tidak lulus*).

   Model dikompilasi menggunakan **optimizer Adam**, **loss binary crossentropy**, dan metrik evaluasi **accuracy** serta **AUC**. Total parameter yang dilatih sebanyak **737**.

```python
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import layers

model = keras.Sequential([
    layers.Input(shape=(X_train.shape[1],)),
    layers.Dense(32, activation="relu"),
    layers.Dropout(0.3),
    layers.Dense(16, activation="relu"),
    layers.Dense(1, activation="sigmoid")  # klasifikasi biner
])

model.compile(optimizer=keras.optimizers.Adam(1e-3),
              loss="binary_crossentropy",
              metrics=["accuracy", "AUC"])

model.summary()
```

```
Model: "sequential_2"
```

yer (type)	Output Shape	Param #
nse_6 (Dense)	(None, 32)	192
opout_2 (Dropout)	(None, 32)	0
nse_7 (Dense)	(None, 16)	528
nse_8 (Dense)	(None, 1)	17

```
Total params: 737 (2.88 KB)
Trainable params: 737 (2.88 KB)
Non-trainable params: 0 (0.00 B)
```

3. Training dengan Early Stopping

   Early Stopping digunakan untuk menghentikan pelatihan secara otomatis saat performa model di data validasi tidak lagi meningkat, sehingga mencegah overfitting dan menghemat waktu pelatihan.

```
es = keras.callbacks.EarlyStopping(
    monitor="val_loss", patience=10, restore_best_weights=True
)

history = model.fit(
    X_train, y_train,
    validation_data=(X_val, y_val),
    epochs=100, batch_size=32,
    callbacks=[es], verbose=1
)
```

```
Epoch 1/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 10s 10s/step - AUC: 0.2222 - accuracy: 0.5000 - loss: 0.7390 - val
_AUC: 0.5000 - val_accuracy: 0.5000 - val_loss: 0.6953
Epoch 2/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 911ms/step - AUC: 0.5556 - accuracy: 0.6667 - loss: 0.6825 - va
l_AUC: 1.0000 - val_accuracy: 0.5000 - val_loss: 0.6804
Epoch 3/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 246ms/step - AUC: 1.0000 - accuracy: 0.8333 - loss: 0.6342 - va
l_AUC: 1.0000 - val_accuracy: 0.5000 - val_loss: 0.6654
Epoch 4/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 496ms/step - AUC: 0.5556 - accuracy: 0.6667 - loss: 0.6751 - va
l_AUC: 1.0000 - val_accuracy: 0.5000 - val_loss: 0.6513
Epoch 5/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 1s 622ms/step - AUC: 0.4444 - accuracy: 0.5000 - loss: 0.7027 - va
l_AUC: 1.0000 - val_accuracy: 0.5000 - val_loss: 0.6376
Epoch 6/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 315ms/step - AUC: 1.0000 - accuracy: 1.0000 - loss: 0.5859 - va
l_AUC: 1.0000 - val_accuracy: 0.5000 - val_loss: 0.6240
Epoch 7/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 323ms/step - AUC: 0.6667 - accuracy: 0.6667 - loss: 0.6748 - va
l_AUC: 1.0000 - val_accuracy: 1.0000 - val_loss: 0.6115
Epoch 8/100
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 331ms/step - AUC: 0.6667 - accuracy: 0.6667 - loss: 0.6510 - va
l_AUC: 1.0000 - val_accuracy: 1.0000 - val_loss: 0.5997
Epoch 9/100
```

4. Evaluasi di Test Set

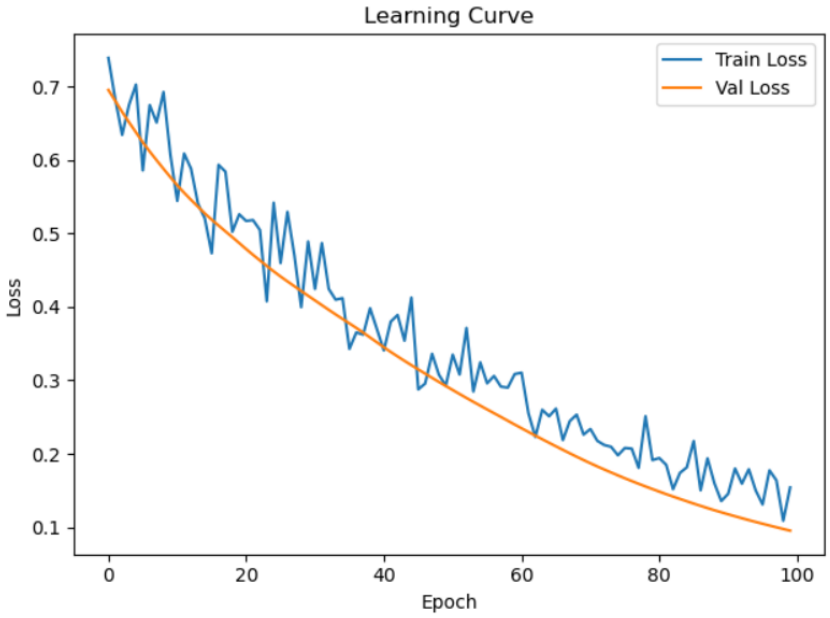
   Hasil evaluasi di test set menunjukkan bahwa model memiliki akurasi dan AUC sempurna (1.0), dengan precision, recall, dan f1-score masing-masing 1.000 untuk kedua kelas. Confusion matrix [[1 0], [0 1]] menandakan tidak ada kesalahan prediksi, sehingga model mampu mengenali data uji dengan sangat baik.

```
from sklearn.metrics import classification_report, confusion_matrix

loss, acc, auc = model.evaluate(X_test, y_test, verbose=0)
print("Test Acc:", acc, "AUC:", auc)

y_proba = model.predict(X_test).ravel()
y_pred = (y_proba >= 0.5).astype(int)

print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred, digits=3))
```

```
Test Acc: 1.0 AUC: 1.0
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 383ms/step
[[1 0]
 [0 1]]
              precision    recall  f1-score   support

           0      1.000     1.000     1.000         1
           1      1.000     1.000     1.000         1

    accuracy                          1.000         2
   macro avg      1.000     1.000     1.000         2
weighted avg      1.000     1.000     1.000         2
```

5. Visualisasi Learning Curve

```python
import matplotlib.pyplot as plt

plt.plot(history.history["loss"], label="Train Loss")
plt.plot(history.history["val_loss"], label="Val Loss")
plt.xlabel("Epoch"); plt.ylabel("Loss"); plt.legend()
plt.title("Learning Curve")
plt.tight_layout(); plt.savefig("learning_curve.png", dpi=120)
```



6. Eksperimen

Berdasarkan hasil eksperimen, peningkatan jumlah neuron dan penambahan Batch Normalization sedikit meningkatkan performa model. Optimizer Adam memberikan hasil konsisten dengan F1 dan AUC tinggi (>0.97), menunjukkan model mampu mengklasifikasi dengan akurasi dan stabilitas yang sangat baik.

```
import numpy as np
import tensorflow as tf
from tensorflow.keras import layers, models, regularizers
from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
from sklearn.metrics import f1_score, roc_auc_score, accuracy_score

# --- 1. Buat data dummy ---
X, y = make_classification(n_samples=2000, n_features=20, n_informative=10, n_classes=2, ra
X_train, X_temp, y_train, y_temp = train_test_split(X, y, test_size=0.3, random_state=42)
X_val, X_test, y_val, y_test = train_test_split(X_temp, y_temp, test_size=0.5, random_state

# --- 2. Fungsi membuat model ---
def build_model(n_neurons=64, optimizer_name="adam", use_batchnorm=False, dropout_rate=0.3,
    model = models.Sequential()
    model.add(layers.Input(shape=(X_train.shape[1],)))

    model.add(layers.Dense(n_neurons, activation='relu', kernel_regularizer=regularizers.l2
    if use_batchnorm:
        model.add(layers.BatchNormalization())
    model.add(layers.Dropout(dropout_rate))

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

    if optimizer_name == "adam":
        optimizer = tf.keras.optimizers.Adam(learning_rate=0.001)
    else:  # sgd
        optimizer = tf.keras.optimizers.SGD(learning_rate=0.01, momentum=0.9)

    model.compile(optimizer=optimizer, loss='binary_crossentropy', metrics=['accuracy'])
    return model

# --- 3. Fungsi train dan evaluasi ---
    model = build_model(**params)

    early_stop = tf.keras.callbacks.EarlyStopping(monitor='val_loss', patience=5, restore_b

    history = model.fit(
        X_train, y_train,
        validation_data=(X_val, y_val),
        epochs=50, batch_size=32, verbose=0,
        callbacks=[early_stop]
    )

    y_pred = (model.predict(X_test) > 0.5).astype("int32")
    y_pred_proba = model.predict(X_test)

    acc = accuracy_score(y_test, y_pred)
    f1 = f1_score(y_test, y_pred)
    auc = roc_auc_score(y_test, y_pred_proba)

    return {"acc": acc, "f1": f1, "auc": auc}

# --- 4. Grid eksperimen ---
grid = [
    {"n_neurons": 32, "optimizer_name": "adam", "use_batchnorm": False},
    {"n_neurons": 64, "optimizer_name": "adam", "use_batchnorm": False},
    {"n_neurons": 128, "optimizer_name": "adam", "use_batchnorm": False},
    {"n_neurons": 64, "optimizer_name": "sgd", "use_batchnorm": False},
    {"n_neurons": 64, "optimizer_name": "adam", "use_batchnorm": True},
]

# --- 5. Jalankan eksperimen ---
for params in grid:
    print(f"\n🔹 Eksperimen: Neuron={params['n_neurons']}, Optimizer={params['optimizer_nam
    res = train_and_eval(params)
    print(f"   Akurasi={res['acc']:.4f} | F1={res['f1']:.4f} | AUC={res['auc']:.4f}")
```

🔹 Eksperimen: Neuron=32, Optimizer=adam, BatchNorm=False
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 22ms/step
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 9ms/step
Akurasi=0.9167 | F1=0.9169 | AUC=0.9683

🔹 Eksperimen: Neuron=64, Optimizer=adam, BatchNorm=False
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 16ms/step
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 7ms/step
Akurasi=0.9267 | F1=0.9257 | AUC=0.9734

🔹 Eksperimen: Neuron=128, Optimizer=adam, BatchNorm=False
10/10 ━━━━━━━━━━━━━━━━━━━━ **1s** 17ms/step
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 9ms/step
Akurasi=0.9300 | F1=0.9298 | AUC=0.9705

🔹 Eksperimen: Neuron=64, Optimizer=sgd, BatchNorm=False
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 29ms/step
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 8ms/step
Akurasi=0.9300 | F1=0.9298 | AUC=0.9750

🔹 Eksperimen: Neuron=64, Optimizer=adam, BatchNorm=True
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 26ms/step
10/10 ━━━━━━━━━━━━━━━━━━━━ **0s** 8ms/step
Akurasi=0.9333 | F1=0.9329 | AUC=0.9719