모델의 성능 향상시키기

1. 데이터의 확인과 검증셋

In [3]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from sklearn.model_selection import train_test_split
import pandas as pd

# 와인 데이터를 불러옵니다.
df = pd.read_csv('./data/wine.csv', header=None)

# 데이터를 미리 보겠습니다.
df
```

Out[3]:

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.99780	3.51	0.56	9.4	5	1
1	7.8	0.88	0.00	2.6	0.098	25.0	67.0	0.99680	3.20	0.68	9.8	5	1
2	7.8	0.76	0.04	2.3	0.092	15.0	54.0	0.99700	3.26	0.65	9.8	5	1
3	11.2	0.28	0.56	1.9	0.075	17.0	60.0	0.99800	3.16	0.58	9.8	6	1
4	7.4	0.70	0.00	1.9	0.076	11.0	34.0	0.99780	3.51	0.56	9.4	5	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...
6492	6.2	0.21	0.29	1.6	0.039	24.0	92.0	0.99114	3.27	0.50	11.2	6	0
6493	6.6	0.32	0.36	8.0	0.047	57.0	168.0	0.99490	3.15	0.46	9.6	5	0
6494	6.5	0.24	0.19	1.2	0.041	30.0	111.0	0.99254	2.99	0.46	9.4	6	0
6495	5.5	0.29	0.30	1.1	0.022	20.0	110.0	0.98869	3.34	0.38	12.8	7	0
6496	6.0	0.21	0.38	0.8	0.020	22.0	98.0	0.98941	3.26	0.32	11.8	6	0

6497 rows × 13 columns

In [4]:
```
# 와인의 속성을 X로 와인의 분류를 y로 저장합니다.
X = df.iloc[:,0:12]
y = df.iloc[:,12]
```

In [5]:
```
# 학습셋과 테스트셋으로 나눕니다.
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, shuffle=True)

# 모델 구조를 설정합니다.
model = Sequential()
model.add(Dense(30,  input_dim=12, activation='relu'))
model.add(Dense(12, activation='relu'))
model.add(Dense(8, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
model.summary()
```

```python
# 모델을 컴파일합니다.
model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])

# 모델을 실행합니다.
history=model.fit(X_train, y_train, epochs=50, batch_size=500, validation_split=0.25) # 0.8 x 0.25 = 0.2
```

```
C:\Users\user\AppData\Roaming\Python\Python312\site-packages\keras\src\layers\core\dense.py:87: UserWarning: Do not pass an `in
put_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first la
yer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 30)	390
dense_1 (Dense)	(None, 12)	372
dense_2 (Dense)	(None, 8)	104
dense_3 (Dense)	(None, 1)	9

Total params: 875 (3.42 KB)

Trainable params: 875 (3.42 KB)

Non-trainable params: 0 (0.00 B)

```
Epoch 1/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 1s 23ms/step - accuracy: 0.7558 - loss: 1.9709 - val_accuracy: 0.7500 - val_loss: 1.7307
Epoch 2/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.7501 - loss: 1.5994 - val_accuracy: 0.7500 - val_loss: 1.2843
Epoch 3/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.7485 - loss: 1.1191 - val_accuracy: 0.7500 - val_loss: 0.9053
Epoch 4/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.7532 - loss: 0.7874 - val_accuracy: 0.7500 - val_loss: 0.5716
Epoch 5/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.7516 - loss: 0.4918 - val_accuracy: 0.7500 - val_loss: 0.4042
Epoch 6/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.7607 - loss: 0.4053 - val_accuracy: 0.7762 - val_loss: 0.3976
Epoch 7/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.7847 - loss: 0.3702 - val_accuracy: 0.7985 - val_loss: 0.3602
Epoch 8/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.8270 - loss: 0.3357 - val_accuracy: 0.8808 - val_loss: 0.3314
Epoch 9/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.8931 - loss: 0.3007 - val_accuracy: 0.8892 - val_loss: 0.3000
Epoch 10/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9090 - loss: 0.2696 - val_accuracy: 0.9077 - val_loss: 0.2716
Epoch 11/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9237 - loss: 0.2414 - val_accuracy: 0.9169 - val_loss: 0.2496
Epoch 12/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9225 - loss: 0.2391 - val_accuracy: 0.9154 - val_loss: 0.2390
Epoch 13/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9304 - loss: 0.2169 - val_accuracy: 0.9185 - val_loss: 0.2301
Epoch 14/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9296 - loss: 0.2109 - val_accuracy: 0.9215 - val_loss: 0.2243
Epoch 15/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9323 - loss: 0.2072 - val_accuracy: 0.9208 - val_loss: 0.2193
Epoch 16/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9327 - loss: 0.2025 - val_accuracy: 0.9231 - val_loss: 0.2158
Epoch 17/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9363 - loss: 0.1910 - val_accuracy: 0.9231 - val_loss: 0.2133
Epoch 18/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9306 - loss: 0.2016 - val_accuracy: 0.9215 - val_loss: 0.2121
Epoch 19/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9376 - loss: 0.1869 - val_accuracy: 0.9238 - val_loss: 0.2079
Epoch 20/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9386 - loss: 0.1858 - val_accuracy: 0.9254 - val_loss: 0.2062
Epoch 21/50
```

```
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9357 - loss: 0.1906 - val_accuracy: 0.9262 - val_loss: 0.2031
Epoch 22/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.9371 - loss: 0.1882 - val_accuracy: 0.9262 - val_loss: 0.2019
Epoch 23/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9394 - loss: 0.1799 - val_accuracy: 0.9277 - val_loss: 0.1987
Epoch 24/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9381 - loss: 0.1845 - val_accuracy: 0.9269 - val_loss: 0.1985
Epoch 25/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9389 - loss: 0.1771 - val_accuracy: 0.9285 - val_loss: 0.1957
Epoch 26/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9419 - loss: 0.1741 - val_accuracy: 0.9277 - val_loss: 0.1952
Epoch 27/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9394 - loss: 0.1769 - val_accuracy: 0.9308 - val_loss: 0.1917
Epoch 28/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9415 - loss: 0.1673 - val_accuracy: 0.9315 - val_loss: 0.1904
Epoch 29/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9477 - loss: 0.1599 - val_accuracy: 0.9308 - val_loss: 0.1879
Epoch 30/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9370 - loss: 0.1742 - val_accuracy: 0.9300 - val_loss: 0.1883
Epoch 31/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9422 - loss: 0.1646 - val_accuracy: 0.9315 - val_loss: 0.1841
Epoch 32/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9422 - loss: 0.1672 - val_accuracy: 0.9308 - val_loss: 0.1832
Epoch 33/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9377 - loss: 0.1708 - val_accuracy: 0.9315 - val_loss: 0.1835
Epoch 34/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9417 - loss: 0.1642 - val_accuracy: 0.9338 - val_loss: 0.1784
Epoch 35/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9405 - loss: 0.1659 - val_accuracy: 0.9323 - val_loss: 0.1818
Epoch 36/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9454 - loss: 0.1533 - val_accuracy: 0.9354 - val_loss: 0.1758
Epoch 37/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9436 - loss: 0.1592 - val_accuracy: 0.9323 - val_loss: 0.1748
Epoch 38/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9434 - loss: 0.1539 - val_accuracy: 0.9323 - val_loss: 0.1737
Epoch 39/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9431 - loss: 0.1581 - val_accuracy: 0.9346 - val_loss: 0.1709
Epoch 40/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9440 - loss: 0.1555 - val_accuracy: 0.9315 - val_loss: 0.1710
Epoch 41/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9480 - loss: 0.1473 - val_accuracy: 0.9431 - val_loss: 0.1665
```

```
Epoch 42/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9450 - loss: 0.1536 - val_accuracy: 0.9331 - val_loss: 0.1702
Epoch 43/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9490 - loss: 0.1452 - val_accuracy: 0.9438 - val_loss: 0.1656
Epoch 44/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9457 - loss: 0.1543 - val_accuracy: 0.9338 - val_loss: 0.1680
Epoch 45/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9485 - loss: 0.1426 - val_accuracy: 0.9423 - val_loss: 0.1602
Epoch 46/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9467 - loss: 0.1471 - val_accuracy: 0.9415 - val_loss: 0.1589
Epoch 47/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9476 - loss: 0.1469 - val_accuracy: 0.9415 - val_loss: 0.1566
Epoch 48/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9521 - loss: 0.1352 - val_accuracy: 0.9392 - val_loss: 0.1576
Epoch 49/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9470 - loss: 0.1451 - val_accuracy: 0.9423 - val_loss: 0.1539
Epoch 50/50
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9479 - loss: 0.1380 - val_accuracy: 0.9454 - val_loss: 0.1513
```

In [6]:
```python
# 테스트 결과를 출력합니다.
score=model.evaluate(X_test, y_test)
print('Test accuracy:', score[1])
```

```
41/41 ━━━━━━━━━━━━━━━━━━━━ 0s 1ms/step - accuracy: 0.9564 - loss: 0.1246
Test accuracy: 0.9515384435653687
```

2. 모델 업데이트하기

기본 코드 불러오기

In [9]:
```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from tensorflow.keras.callbacks import ModelCheckpoint
from sklearn.model_selection import train_test_split

import os
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
```

```
# 와인 데이터를 불러옵니다.
df = pd.read_csv('./data/wine.csv', header=None)

# 와인의 속성을 X로 와인의 분류를 y로 저장합니다.
X = df.iloc[:,0:12]
y = df.iloc[:,12]

# 학습셋과 테스트셋으로 나눕니다.
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
                                                    shuffle=True)

# 모델 구조를 설정합니다.
model = Sequential()
model.add(Dense(30,  input_dim=12, activation='relu'))
model.add(Dense(12, activation='relu'))
model.add(Dense(8, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
model.summary()

# 모델을 컴파일합니다.
model.compile(loss='binary_crossentropy', optimizer='adam',
              metrics=['accuracy'])
```

```
C:\Users\user\AppData\Roaming\Python\Python312\site-packages\keras\src\layers\core\dense.py:87: UserWarning: Do not pass an `in
put_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first la
yer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

Model: "sequential_1"

Layer (type)	Output Shape	Param #
dense_4 (Dense)	(None, 30)	390
dense_5 (Dense)	(None, 12)	372
dense_6 (Dense)	(None, 8)	104
dense_7 (Dense)	(None, 1)	9

Total params: 875 (3.42 KB)

Trainable params: 875 (3.42 KB)

Non-trainable params: 0 (0.00 B)

모델의 저장 설정 및 실행

In [11]:
```
# 모델 저장의 조건을 설정합니다.
modelpath="./data/model/all/{epoch:02d}-{val_accuracy:.4f}.keras"
checkpointer = ModelCheckpoint(filepath=modelpath, verbose=1)

# 모델을 실행합니다.
history=model.fit(X_train, y_train, epochs=50, batch_size=500, validation_split=0.25, verbose=0,
                  callbacks=[checkpointer])
```

```
Epoch 1: saving model to ./data/model/all/01-0.7692.keras

Epoch 2: saving model to ./data/model/all/02-0.7300.keras

Epoch 3: saving model to ./data/model/all/03-0.7685.keras

Epoch 4: saving model to ./data/model/all/04-0.8246.keras

Epoch 5: saving model to ./data/model/all/05-0.8585.keras

Epoch 6: saving model to ./data/model/all/06-0.8462.keras

Epoch 7: saving model to ./data/model/all/07-0.8762.keras

Epoch 8: saving model to ./data/model/all/08-0.8923.keras

Epoch 9: saving model to ./data/model/all/09-0.9054.keras

Epoch 10: saving model to ./data/model/all/10-0.9138.keras

Epoch 11: saving model to ./data/model/all/11-0.9200.keras

Epoch 12: saving model to ./data/model/all/12-0.9269.keras

Epoch 13: saving model to ./data/model/all/13-0.9308.keras

Epoch 14: saving model to ./data/model/all/14-0.9338.keras

Epoch 15: saving model to ./data/model/all/15-0.9354.keras

Epoch 16: saving model to ./data/model/all/16-0.9369.keras

Epoch 17: saving model to ./data/model/all/17-0.9369.keras

Epoch 18: saving model to ./data/model/all/18-0.9377.keras

Epoch 19: saving model to ./data/model/all/19-0.9369.keras

Epoch 20: saving model to ./data/model/all/20-0.9392.keras

Epoch 21: saving model to ./data/model/all/21-0.9385.keras
```

```
Epoch 22: saving model to ./data/model/all/22-0.9392.keras

Epoch 23: saving model to ./data/model/all/23-0.9392.keras

Epoch 24: saving model to ./data/model/all/24-0.9392.keras

Epoch 25: saving model to ./data/model/all/25-0.9400.keras

Epoch 26: saving model to ./data/model/all/26-0.9408.keras

Epoch 27: saving model to ./data/model/all/27-0.9408.keras

Epoch 28: saving model to ./data/model/all/28-0.9415.keras

Epoch 29: saving model to ./data/model/all/29-0.9408.keras

Epoch 30: saving model to ./data/model/all/30-0.9431.keras

Epoch 31: saving model to ./data/model/all/31-0.9423.keras

Epoch 32: saving model to ./data/model/all/32-0.9423.keras

Epoch 33: saving model to ./data/model/all/33-0.9431.keras

Epoch 34: saving model to ./data/model/all/34-0.9454.keras

Epoch 35: saving model to ./data/model/all/35-0.9454.keras

Epoch 36: saving model to ./data/model/all/36-0.9454.keras

Epoch 37: saving model to ./data/model/all/37-0.9462.keras

Epoch 38: saving model to ./data/model/all/38-0.9469.keras

Epoch 39: saving model to ./data/model/all/39-0.9477.keras

Epoch 40: saving model to ./data/model/all/40-0.9477.keras

Epoch 41: saving model to ./data/model/all/41-0.9485.keras
```

```
Epoch 42: saving model to ./data/model/all/42-0.9492.keras

Epoch 43: saving model to ./data/model/all/43-0.9492.keras

Epoch 44: saving model to ./data/model/all/44-0.9508.keras

Epoch 45: saving model to ./data/model/all/45-0.9508.keras

Epoch 46: saving model to ./data/model/all/46-0.9500.keras

Epoch 47: saving model to ./data/model/all/47-0.9515.keras

Epoch 48: saving model to ./data/model/all/48-0.9515.keras

Epoch 49: saving model to ./data/model/all/49-0.9515.keras

Epoch 50: saving model to ./data/model/all/50-0.9508.keras
```

In [12]:
```python
# 테스트 결과를 출력합니다.
score=model.evaluate(X_test, y_test)
print('Test accuracy:', score[1])
```

```
41/41 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step - accuracy: 0.9442 - loss: 0.1441
Test accuracy: 0.9430769085884094
```

3. 그래프로 과적합 확인하기

In [14]:
```python
from tensorflow.keras.callbacks import LambdaCallback
import tensorflow as tf

# 50번마다 한 번씩 출력하는 콜백 함수
def custom_log(epoch, logs):
    if (epoch + 1) % 50 == 0:
        num_batches = len(X_train) // 500
        print(f"Epoch {epoch+1}/2000")
        tf.print(f"{num_batches}/{num_batches} ━━━━━━━━━━━━━━━━━━━━ "
                 f"accuracy: {logs['accuracy']:.4f} - loss: {logs['loss']:.4f} - "
                 f"val_accuracy: {logs['val_accuracy']:.4f} - val_loss: {logs['val_loss']:.4f}")
show_status = LambdaCallback(on_epoch_end=custom_log)
```

```
# 그래프 확인을 위한 긴 학습
history=model.fit(X_train, y_train, epochs=2000, batch_size=500, validation_split=0.25, verbose=0, callbacks=show_status)
```

```
Epoch 50/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9582 - loss: 0.1133 - val_accuracy: 0.9623 - val_loss: 0.1137
Epoch 100/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9749 - loss: 0.0833 - val_accuracy: 0.9769 - val_loss: 0.0899
Epoch 150/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9820 - loss: 0.0604 - val_accuracy: 0.9838 - val_loss: 0.0688
Epoch 200/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9851 - loss: 0.0532 - val_accuracy: 0.9862 - val_loss: 0.0623
Epoch 250/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9854 - loss: 0.0498 - val_accuracy: 0.9862 - val_loss: 0.0593
Epoch 300/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9872 - loss: 0.0472 - val_accuracy: 0.9862 - val_loss: 0.0630
Epoch 350/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9892 - loss: 0.0442 - val_accuracy: 0.9877 - val_loss: 0.0621
Epoch 400/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9877 - loss: 0.0423 - val_accuracy: 0.9838 - val_loss: 0.0641
Epoch 450/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9905 - loss: 0.0400 - val_accuracy: 0.9915 - val_loss: 0.0543
Epoch 500/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9910 - loss: 0.0370 - val_accuracy: 0.9908 - val_loss: 0.0536
Epoch 550/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9908 - loss: 0.0370 - val_accuracy: 0.9908 - val_loss: 0.0540
Epoch 600/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9908 - loss: 0.0367 - val_accuracy: 0.9908 - val_loss: 0.0519
Epoch 650/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9900 - loss: 0.0400 - val_accuracy: 0.9908 - val_loss: 0.0559
Epoch 700/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9926 - loss: 0.0326 - val_accuracy: 0.9869 - val_loss: 0.0560
Epoch 750/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9923 - loss: 0.0341 - val_accuracy: 0.9923 - val_loss: 0.0519
Epoch 800/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9923 - loss: 0.0315 - val_accuracy: 0.9908 - val_loss: 0.0538
Epoch 850/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9936 - loss: 0.0315 - val_accuracy: 0.9892 - val_loss: 0.0550
Epoch 900/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9905 - loss: 0.0347 - val_accuracy: 0.9885 - val_loss: 0.0565
Epoch 950/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9933 - loss: 0.0297 - val_accuracy: 0.9900 - val_loss: 0.0518
Epoch 1000/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9918 - loss: 0.0314 - val_accuracy: 0.9862 - val_loss: 0.0638
Epoch 1050/2000
```

```
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9936 - loss: 0.0291 - val_accuracy: 0.9908 - val_loss: 0.0503
Epoch 1100/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9928 - loss: 0.0293 - val_accuracy: 0.9908 - val_loss: 0.0502
Epoch 1150/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9926 - loss: 0.0298 - val_accuracy: 0.9869 - val_loss: 0.0570
Epoch 1200/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9931 - loss: 0.0319 - val_accuracy: 0.9915 - val_loss: 0.0538
Epoch 1250/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9938 - loss: 0.0270 - val_accuracy: 0.9915 - val_loss: 0.0498
Epoch 1300/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9946 - loss: 0.0272 - val_accuracy: 0.9915 - val_loss: 0.0509
Epoch 1350/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9941 - loss: 0.0275 - val_accuracy: 0.9908 - val_loss: 0.0514
Epoch 1400/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9936 - loss: 0.0261 - val_accuracy: 0.9923 - val_loss: 0.0508
Epoch 1450/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9923 - loss: 0.0285 - val_accuracy: 0.9846 - val_loss: 0.0642
Epoch 1500/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9946 - loss: 0.0259 - val_accuracy: 0.9923 - val_loss: 0.0505
Epoch 1550/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9944 - loss: 0.0243 - val_accuracy: 0.9908 - val_loss: 0.0502
Epoch 1600/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9954 - loss: 0.0240 - val_accuracy: 0.9915 - val_loss: 0.0510
Epoch 1650/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9944 - loss: 0.0222 - val_accuracy: 0.9915 - val_loss: 0.0518
Epoch 1700/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9938 - loss: 0.0229 - val_accuracy: 0.9877 - val_loss: 0.0569
Epoch 1750/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9949 - loss: 0.0219 - val_accuracy: 0.9885 - val_loss: 0.0565
Epoch 1800/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9931 - loss: 0.0245 - val_accuracy: 0.9915 - val_loss: 0.0544
Epoch 1850/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9954 - loss: 0.0231 - val_accuracy: 0.9915 - val_loss: 0.0526
Epoch 1900/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9951 - loss: 0.0223 - val_accuracy: 0.9915 - val_loss: 0.0531
Epoch 1950/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9936 - loss: 0.0241 - val_accuracy: 0.9885 - val_loss: 0.0562
Epoch 2000/2000
10/10 ━━━━━━━━━━━━━━━━━━━━ accuracy: 0.9962 - loss: 0.0207 - val_accuracy: 0.9846 - val_loss: 0.0666
```

In [15]:
```
# history에 저장된 학습 결과를 확인해 보겠습니다.
hist_df=pd.DataFrame(history.history)
hist_df
```

Out[15]:

	accuracy	loss	val_accuracy	val_loss
0	0.943546	0.150582	0.951538	0.145386
1	0.942520	0.150171	0.951538	0.145063
2	0.943546	0.149691	0.951538	0.144617
3	0.944060	0.147804	0.953077	0.143880
4	0.945086	0.146677	0.952308	0.142740
...	...	...	...	...
1995	0.994098	0.023762	0.990000	0.056442
1996	0.993585	0.026300	0.992308	0.053771
1997	0.995124	0.021154	0.991538	0.054268
1998	0.995638	0.020580	0.990769	0.054781
1999	0.996151	0.020651	0.984615	0.066585

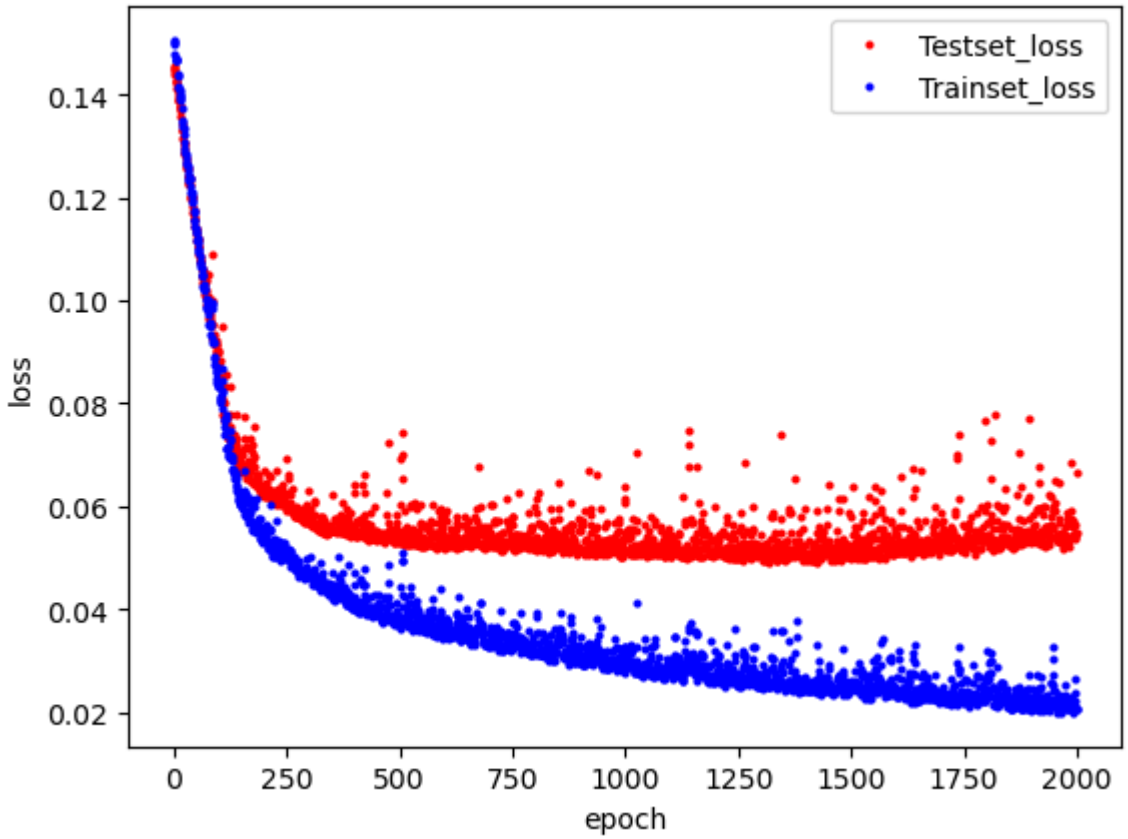
2000 rows × 4 columns

In [16]:
```
# y_vloss에 테스트셋(여기서는 검증셋)의 오차를 저장합니다.
y_vloss=hist_df['val_loss']

# y_loss에 학습셋의 오차를 저장합니다.
y_loss=hist_df['loss']

#x 값을 지정하고 테스트셋(검증셋)의 오차를 빨간색으로, 학습셋의 오차를 파란색으로 표시합니다.
x_len = np.arange(len(y_loss))
plt.plot(x_len, y_vloss, "o", c="red", markersize=2, label='Testset_loss')
plt.plot(x_len, y_loss, "o", c="blue", markersize=2, label='Trainset_loss')
```

```
plt.legend(loc='upper right')
plt.xlabel('epoch')
plt.ylabel('loss')
plt.show()
```



4. 학습의 자동 중단

기본 코드 불러오기

In [19]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from sklearn.model_selection import train_test_split
```

```python
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping
import os
import pandas as pd

# 와인 데이터를 불러옵니다.
df = pd.read_csv('./data/wine.csv', header=None)

# 와인의 속성을 X로 와인의 분류를 y로 저장합니다.
X = df.iloc[:,0:12]
y = df.iloc[:,12]

# 학습셋과 테스트셋으로 나눕니다.
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, shuffle=True)

# 모델 구조를 설정합니다.
model = Sequential()
model.add(Dense(30,  input_dim=12, activation='relu'))
model.add(Dense(12, activation='relu'))
model.add(Dense(8, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
model.summary()

# 모델을 컴파일합니다.
model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])
```

```
C:\Users\user\AppData\Roaming\Python\Python312\site-packages\keras\src\layers\core\dense.py:87: UserWarning: Do not pass an `in
put_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first la
yer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
dense_8 (Dense)	(None, 30)	390
dense_9 (Dense)	(None, 12)	372
dense_10 (Dense)	(None, 8)	104
dense_11 (Dense)	(None, 1)	9

Total params: 875 (3.42 KB)

Trainable params: 875 (3.42 KB)

Non-trainable params: 0 (0.00 B)

학습의 자동 중단 및 최적화 모델 저장

In [21]:
```
# 학습이 언제 자동 중단될지를 설정합니다.
early_stopping_callback = EarlyStopping(monitor='val_loss', patience=20)

# 최적화 모델이 저장될 폴더와 모델의 이름을 정합니다.
modelpath="./data/model/bestmodel.keras"

# 최적화 모델을 업데이트하고 저장합니다.
checkpointer = ModelCheckpoint(filepath=modelpath, monitor='val_loss', verbose=0, save_best_only=True)

# 모델을 실행합니다.
history=model.fit(X_train, y_train, epochs=2000, batch_size=500, validation_split=0.25, verbose=1,
                  callbacks=[early_stopping_callback,checkpointer])
```

```
Epoch 1/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 1s 28ms/step - accuracy: 0.8228 - loss: 0.4367 - val_accuracy: 0.8969 - val_loss: 0.3219
Epoch 2/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step - accuracy: 0.9017 - loss: 0.3084 - val_accuracy: 0.9046 - val_loss: 0.2796
Epoch 3/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9008 - loss: 0.2824 - val_accuracy: 0.9023 - val_loss: 0.2661
Epoch 4/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9081 - loss: 0.2622 - val_accuracy: 0.9192 - val_loss: 0.2474
Epoch 5/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9252 - loss: 0.2372 - val_accuracy: 0.9208 - val_loss: 0.2348
Epoch 6/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9344 - loss: 0.2177 - val_accuracy: 0.9223 - val_loss: 0.2238
Epoch 7/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9317 - loss: 0.2200 - val_accuracy: 0.9246 - val_loss: 0.2160
Epoch 8/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9350 - loss: 0.1999 - val_accuracy: 0.9246 - val_loss: 0.2099
Epoch 9/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9358 - loss: 0.1981 - val_accuracy: 0.9254 - val_loss: 0.2012
Epoch 10/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9362 - loss: 0.1914 - val_accuracy: 0.9254 - val_loss: 0.1946
Epoch 11/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step - accuracy: 0.9446 - loss: 0.1738 - val_accuracy: 0.9262 - val_loss: 0.1910
Epoch 12/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9451 - loss: 0.1725 - val_accuracy: 0.9254 - val_loss: 0.1886
Epoch 13/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9430 - loss: 0.1683 - val_accuracy: 0.9269 - val_loss: 0.1860
Epoch 14/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9396 - loss: 0.1782 - val_accuracy: 0.9238 - val_loss: 0.1856
Epoch 15/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9391 - loss: 0.1738 - val_accuracy: 0.9269 - val_loss: 0.1829
Epoch 16/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9438 - loss: 0.1635 - val_accuracy: 0.9262 - val_loss: 0.1808
Epoch 17/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9412 - loss: 0.1689 - val_accuracy: 0.9269 - val_loss: 0.1779
Epoch 18/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9407 - loss: 0.1671 - val_accuracy: 0.9285 - val_loss: 0.1763
Epoch 19/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9418 - loss: 0.1682 - val_accuracy: 0.9285 - val_loss: 0.1753
Epoch 20/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9408 - loss: 0.1657 - val_accuracy: 0.9292 - val_loss: 0.1724
Epoch 21/2000
```

```
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step - accuracy: 0.9444 - loss: 0.1605 - val_accuracy: 0.9308 - val_loss: 0.1699
Epoch 22/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9455 - loss: 0.1540 - val_accuracy: 0.9300 - val_loss: 0.1679
Epoch 23/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9469 - loss: 0.1540 - val_accuracy: 0.9300 - val_loss: 0.1658
Epoch 24/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9476 - loss: 0.1503 - val_accuracy: 0.9315 - val_loss: 0.1639
Epoch 25/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9469 - loss: 0.1478 - val_accuracy: 0.9323 - val_loss: 0.1615
Epoch 26/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9452 - loss: 0.1576 - val_accuracy: 0.9308 - val_loss: 0.1607
Epoch 27/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9496 - loss: 0.1389 - val_accuracy: 0.9377 - val_loss: 0.1577
Epoch 28/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9493 - loss: 0.1415 - val_accuracy: 0.9377 - val_loss: 0.1543
Epoch 29/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9504 - loss: 0.1433 - val_accuracy: 0.9338 - val_loss: 0.1549
Epoch 30/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9533 - loss: 0.1453 - val_accuracy: 0.9385 - val_loss: 0.1524
Epoch 31/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 13ms/step - accuracy: 0.9498 - loss: 0.1434 - val_accuracy: 0.9415 - val_loss: 0.1458
Epoch 32/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9505 - loss: 0.1417 - val_accuracy: 0.9438 - val_loss: 0.1427
Epoch 33/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9578 - loss: 0.1283 - val_accuracy: 0.9469 - val_loss: 0.1399
Epoch 34/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step - accuracy: 0.9540 - loss: 0.1410 - val_accuracy: 0.9446 - val_loss: 0.1369
Epoch 35/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9556 - loss: 0.1261 - val_accuracy: 0.9462 - val_loss: 0.1347
Epoch 36/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9554 - loss: 0.1319 - val_accuracy: 0.9485 - val_loss: 0.1343
Epoch 37/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9556 - loss: 0.1302 - val_accuracy: 0.9508 - val_loss: 0.1300
Epoch 38/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9561 - loss: 0.1289 - val_accuracy: 0.9431 - val_loss: 0.1344
Epoch 39/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9527 - loss: 0.1322 - val_accuracy: 0.9438 - val_loss: 0.1308
Epoch 40/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9533 - loss: 0.1289 - val_accuracy: 0.9477 - val_loss: 0.1248
Epoch 41/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9583 - loss: 0.1221 - val_accuracy: 0.9508 - val_loss: 0.1234
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Epoch 42/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9587 - loss: 0.1196 - val_accuracy: 0.9623 - val_loss: 0.1324
Epoch 43/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9591 - loss: 0.1268 - val_accuracy: 0.9531 - val_loss: 0.1191
Epoch 44/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9600 - loss: 0.1260 - val_accuracy: 0.9454 - val_loss: 0.1251
Epoch 45/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9592 - loss: 0.1169 - val_accuracy: 0.9508 - val_loss: 0.1159
Epoch 46/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9564 - loss: 0.1220 - val_accuracy: 0.9569 - val_loss: 0.1151
Epoch 47/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9565 - loss: 0.1234 - val_accuracy: 0.9546 - val_loss: 0.1128
Epoch 48/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9640 - loss: 0.1037 - val_accuracy: 0.9508 - val_loss: 0.1141
Epoch 49/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9641 - loss: 0.1005 - val_accuracy: 0.9631 - val_loss: 0.1097
Epoch 50/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9629 - loss: 0.1161 - val_accuracy: 0.9477 - val_loss: 0.1139
Epoch 51/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9599 - loss: 0.1104 - val_accuracy: 0.9546 - val_loss: 0.1074
Epoch 52/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9663 - loss: 0.0983 - val_accuracy: 0.9646 - val_loss: 0.1032
Epoch 53/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9656 - loss: 0.1087 - val_accuracy: 0.9685 - val_loss: 0.1047
Epoch 54/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9647 - loss: 0.1050 - val_accuracy: 0.9692 - val_loss: 0.1075
Epoch 55/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9644 - loss: 0.1073 - val_accuracy: 0.9685 - val_loss: 0.1027
Epoch 56/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9711 - loss: 0.1027 - val_accuracy: 0.9731 - val_loss: 0.0957
Epoch 57/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9696 - loss: 0.1005 - val_accuracy: 0.9708 - val_loss: 0.0950
Epoch 58/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9717 - loss: 0.0966 - val_accuracy: 0.9723 - val_loss: 0.0984
Epoch 59/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9711 - loss: 0.1038 - val_accuracy: 0.9715 - val_loss: 0.0908
Epoch 60/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9696 - loss: 0.0973 - val_accuracy: 0.9623 - val_loss: 0.0934
Epoch 61/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 15ms/step - accuracy: 0.9676 - loss: 0.0908 - val_accuracy: 0.9662 - val_loss: 0.0909
Epoch 62/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9681 - loss: 0.0984 - val_accuracy: 0.9692 - val_loss: 0.0882
Epoch 63/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9713 - loss: 0.0976 - val_accuracy: 0.9685 - val_loss: 0.0883
Epoch 64/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9706 - loss: 0.0857 - val_accuracy: 0.9731 - val_loss: 0.0840
Epoch 65/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9725 - loss: 0.0896 - val_accuracy: 0.9754 - val_loss: 0.0841
Epoch 66/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9784 - loss: 0.0755 - val_accuracy: 0.9738 - val_loss: 0.0822
Epoch 67/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9731 - loss: 0.0878 - val_accuracy: 0.9746 - val_loss: 0.0805
Epoch 68/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9728 - loss: 0.0861 - val_accuracy: 0.9762 - val_loss: 0.0801
Epoch 69/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9731 - loss: 0.0840 - val_accuracy: 0.9769 - val_loss: 0.0789
Epoch 70/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9720 - loss: 0.0876 - val_accuracy: 0.9762 - val_loss: 0.0775
Epoch 71/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9738 - loss: 0.0771 - val_accuracy: 0.9762 - val_loss: 0.0772
Epoch 72/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9745 - loss: 0.0781 - val_accuracy: 0.9777 - val_loss: 0.0759
Epoch 73/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9762 - loss: 0.0820 - val_accuracy: 0.9777 - val_loss: 0.0746
Epoch 74/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9758 - loss: 0.0753 - val_accuracy: 0.9785 - val_loss: 0.0740
Epoch 75/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9780 - loss: 0.0775 - val_accuracy: 0.9785 - val_loss: 0.0732
Epoch 76/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9761 - loss: 0.0860 - val_accuracy: 0.9800 - val_loss: 0.0718
Epoch 77/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9720 - loss: 0.0885 - val_accuracy: 0.9769 - val_loss: 0.0726
Epoch 78/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9759 - loss: 0.0842 - val_accuracy: 0.9746 - val_loss: 0.0739
Epoch 79/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9791 - loss: 0.0711 - val_accuracy: 0.9777 - val_loss: 0.0710
Epoch 80/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9764 - loss: 0.0820 - val_accuracy: 0.9769 - val_loss: 0.0714
Epoch 81/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9792 - loss: 0.0757 - val_accuracy: 0.9792 - val_loss: 0.0695
Epoch 82/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9764 - loss: 0.0816 - val_accuracy: 0.9785 - val_loss: 0.0691
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Epoch 83/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step - accuracy: 0.9752 - loss: 0.0880 - val_accuracy: 0.9738 - val_loss: 0.0736
Epoch 84/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9727 - loss: 0.0886 - val_accuracy: 0.9723 - val_loss: 0.0755
Epoch 85/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9777 - loss: 0.0705 - val_accuracy: 0.9823 - val_loss: 0.0656
Epoch 86/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 26ms/step - accuracy: 0.9791 - loss: 0.0667 - val_accuracy: 0.9800 - val_loss: 0.0641
Epoch 87/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9780 - loss: 0.0739 - val_accuracy: 0.9823 - val_loss: 0.0638
Epoch 88/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.9772 - loss: 0.0747 - val_accuracy: 0.9823 - val_loss: 0.0622
Epoch 89/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9763 - loss: 0.0861 - val_accuracy: 0.9808 - val_loss: 0.0637
Epoch 90/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9823 - loss: 0.0643 - val_accuracy: 0.9808 - val_loss: 0.0630
Epoch 91/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9803 - loss: 0.0685 - val_accuracy: 0.9738 - val_loss: 0.0720
Epoch 92/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9805 - loss: 0.0687 - val_accuracy: 0.9823 - val_loss: 0.0603
Epoch 93/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9826 - loss: 0.0657 - val_accuracy: 0.9792 - val_loss: 0.0649
Epoch 94/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9799 - loss: 0.0688 - val_accuracy: 0.9831 - val_loss: 0.0585
Epoch 95/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9814 - loss: 0.0664 - val_accuracy: 0.9823 - val_loss: 0.0579
Epoch 96/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9822 - loss: 0.0651 - val_accuracy: 0.9831 - val_loss: 0.0577
Epoch 97/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9789 - loss: 0.0670 - val_accuracy: 0.9838 - val_loss: 0.0560
Epoch 98/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9817 - loss: 0.0635 - val_accuracy: 0.9831 - val_loss: 0.0557
Epoch 99/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9752 - loss: 0.0780 - val_accuracy: 0.9831 - val_loss: 0.0549
Epoch 100/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9827 - loss: 0.0590 - val_accuracy: 0.9792 - val_loss: 0.0628
Epoch 101/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9790 - loss: 0.0707 - val_accuracy: 0.9792 - val_loss: 0.0624
Epoch 102/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9776 - loss: 0.0710 - val_accuracy: 0.9831 - val_loss: 0.0558
Epoch 103/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9811 - loss: 0.0653 - val_accuracy: 0.9846 - val_loss: 0.0529
Epoch 104/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9856 - loss: 0.0521 - val_accuracy: 0.9831 - val_loss: 0.0513
Epoch 105/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9842 - loss: 0.0596 - val_accuracy: 0.9823 - val_loss: 0.0527
Epoch 106/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9800 - loss: 0.0679 - val_accuracy: 0.9846 - val_loss: 0.0526
Epoch 107/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9826 - loss: 0.0567 - val_accuracy: 0.9838 - val_loss: 0.0500
Epoch 108/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9834 - loss: 0.0552 - val_accuracy: 0.9831 - val_loss: 0.0527
Epoch 109/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9796 - loss: 0.0685 - val_accuracy: 0.9838 - val_loss: 0.0512
Epoch 110/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9821 - loss: 0.0629 - val_accuracy: 0.9846 - val_loss: 0.0505
Epoch 111/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9845 - loss: 0.0526 - val_accuracy: 0.9838 - val_loss: 0.0503
Epoch 112/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step - accuracy: 0.9865 - loss: 0.0506 - val_accuracy: 0.9846 - val_loss: 0.0512
Epoch 113/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9833 - loss: 0.0543 - val_accuracy: 0.9838 - val_loss: 0.0528
Epoch 114/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9835 - loss: 0.0570 - val_accuracy: 0.9854 - val_loss: 0.0546
Epoch 115/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9818 - loss: 0.0646 - val_accuracy: 0.9846 - val_loss: 0.0501
Epoch 116/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9832 - loss: 0.0521 - val_accuracy: 0.9831 - val_loss: 0.0548
Epoch 117/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9800 - loss: 0.0625 - val_accuracy: 0.9854 - val_loss: 0.0509
Epoch 118/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9841 - loss: 0.0537 - val_accuracy: 0.9862 - val_loss: 0.0493
Epoch 119/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9837 - loss: 0.0565 - val_accuracy: 0.9854 - val_loss: 0.0492
Epoch 120/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9827 - loss: 0.0604 - val_accuracy: 0.9862 - val_loss: 0.0490
Epoch 121/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9819 - loss: 0.0609 - val_accuracy: 0.9854 - val_loss: 0.0501
Epoch 122/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9855 - loss: 0.0507 - val_accuracy: 0.9846 - val_loss: 0.0488
Epoch 123/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.9824 - loss: 0.0563 - val_accuracy: 0.9862 - val_loss: 0.0484
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Epoch 124/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9832 - loss: 0.0603 - val_accuracy: 0.9846 - val_loss: 0.0497
Epoch 125/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9831 - loss: 0.0537 - val_accuracy: 0.9854 - val_loss: 0.0494
Epoch 126/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9840 - loss: 0.0528 - val_accuracy: 0.9854 - val_loss: 0.0489
Epoch 127/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9814 - loss: 0.0588 - val_accuracy: 0.9846 - val_loss: 0.0497
Epoch 128/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9844 - loss: 0.0556 - val_accuracy: 0.9846 - val_loss: 0.0486
Epoch 129/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9836 - loss: 0.0565 - val_accuracy: 0.9831 - val_loss: 0.0533
Epoch 130/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9853 - loss: 0.0559 - val_accuracy: 0.9838 - val_loss: 0.0507
Epoch 131/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9857 - loss: 0.0591 - val_accuracy: 0.9838 - val_loss: 0.0528
Epoch 132/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9855 - loss: 0.0563 - val_accuracy: 0.9831 - val_loss: 0.0514
Epoch 133/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0602 - val_accuracy: 0.9838 - val_loss: 0.0495
Epoch 134/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9867 - loss: 0.0546 - val_accuracy: 0.9838 - val_loss: 0.0560
Epoch 135/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step - accuracy: 0.9807 - loss: 0.0619 - val_accuracy: 0.9869 - val_loss: 0.0469
Epoch 136/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0563 - val_accuracy: 0.9854 - val_loss: 0.0552
Epoch 137/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0530 - val_accuracy: 0.9846 - val_loss: 0.0560
Epoch 138/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step - accuracy: 0.9813 - loss: 0.0639 - val_accuracy: 0.9854 - val_loss: 0.0467
Epoch 139/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9890 - loss: 0.0423 - val_accuracy: 0.9869 - val_loss: 0.0499
Epoch 140/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9825 - loss: 0.0527 - val_accuracy: 0.9862 - val_loss: 0.0476
Epoch 141/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9873 - loss: 0.0496 - val_accuracy: 0.9846 - val_loss: 0.0497
Epoch 142/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0535 - val_accuracy: 0.9846 - val_loss: 0.0505
Epoch 143/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 13ms/step - accuracy: 0.9827 - loss: 0.0575 - val_accuracy: 0.9862 - val_loss: 0.0463
Epoch 144/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9853 - loss: 0.0504 - val_accuracy: 0.9831 - val_loss: 0.0515
Epoch 145/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9838 - loss: 0.0509 - val_accuracy: 0.9846 - val_loss: 0.0506
Epoch 146/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9849 - loss: 0.0533 - val_accuracy: 0.9800 - val_loss: 0.0579
Epoch 147/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9836 - loss: 0.0552 - val_accuracy: 0.9815 - val_loss: 0.0545
Epoch 148/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9775 - loss: 0.0647 - val_accuracy: 0.9815 - val_loss: 0.0557
Epoch 149/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9794 - loss: 0.0628 - val_accuracy: 0.9838 - val_loss: 0.0501
Epoch 150/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9846 - loss: 0.0538 - val_accuracy: 0.9846 - val_loss: 0.0508
Epoch 151/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9864 - loss: 0.0524 - val_accuracy: 0.9846 - val_loss: 0.0487
Epoch 152/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9834 - loss: 0.0586 - val_accuracy: 0.9862 - val_loss: 0.0466
Epoch 153/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9857 - loss: 0.0482 - val_accuracy: 0.9862 - val_loss: 0.0458
Epoch 154/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9869 - loss: 0.0467 - val_accuracy: 0.9862 - val_loss: 0.0462
Epoch 155/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9865 - loss: 0.0489 - val_accuracy: 0.9838 - val_loss: 0.0497
Epoch 156/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9841 - loss: 0.0547 - val_accuracy: 0.9862 - val_loss: 0.0463
Epoch 157/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0556 - val_accuracy: 0.9846 - val_loss: 0.0471
Epoch 158/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9861 - loss: 0.0518 - val_accuracy: 0.9823 - val_loss: 0.0510
Epoch 159/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9855 - loss: 0.0491 - val_accuracy: 0.9869 - val_loss: 0.0461
Epoch 160/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9868 - loss: 0.0521 - val_accuracy: 0.9854 - val_loss: 0.0478
Epoch 161/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9794 - loss: 0.0659 - val_accuracy: 0.9846 - val_loss: 0.0453
Epoch 162/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9835 - loss: 0.0559 - val_accuracy: 0.9846 - val_loss: 0.0493
Epoch 163/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9840 - loss: 0.0563 - val_accuracy: 0.9762 - val_loss: 0.0621
Epoch 164/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9857 - loss: 0.0538 - val_accuracy: 0.9808 - val_loss: 0.0567
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Epoch 165/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9843 - loss: 0.0520 - val_accuracy: 0.9831 - val_loss: 0.0504
Epoch 166/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9876 - loss: 0.0472 - val_accuracy: 0.9846 - val_loss: 0.0471
Epoch 167/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0550 - val_accuracy: 0.9846 - val_loss: 0.0476
Epoch 168/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9835 - loss: 0.0551 - val_accuracy: 0.9854 - val_loss: 0.0457
Epoch 169/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.9853 - loss: 0.0537 - val_accuracy: 0.9862 - val_loss: 0.0446
Epoch 170/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9861 - loss: 0.0542 - val_accuracy: 0.9869 - val_loss: 0.0444
Epoch 171/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9884 - loss: 0.0420 - val_accuracy: 0.9823 - val_loss: 0.0531
Epoch 172/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9878 - loss: 0.0441 - val_accuracy: 0.9815 - val_loss: 0.0556
Epoch 173/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9862 - loss: 0.0530 - val_accuracy: 0.9846 - val_loss: 0.0473
Epoch 174/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9861 - loss: 0.0512 - val_accuracy: 0.9862 - val_loss: 0.0455
Epoch 175/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9859 - loss: 0.0445 - val_accuracy: 0.9862 - val_loss: 0.0447
Epoch 176/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9869 - loss: 0.0452 - val_accuracy: 0.9862 - val_loss: 0.0443
Epoch 177/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9883 - loss: 0.0474 - val_accuracy: 0.9846 - val_loss: 0.0452
Epoch 178/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9878 - loss: 0.0435 - val_accuracy: 0.9846 - val_loss: 0.0465
Epoch 179/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9887 - loss: 0.0430 - val_accuracy: 0.9846 - val_loss: 0.0447
Epoch 180/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9835 - loss: 0.0571 - val_accuracy: 0.9862 - val_loss: 0.0454
Epoch 181/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9870 - loss: 0.0515 - val_accuracy: 0.9854 - val_loss: 0.0468
Epoch 182/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9849 - loss: 0.0518 - val_accuracy: 0.9862 - val_loss: 0.0452
Epoch 183/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9857 - loss: 0.0478 - val_accuracy: 0.9846 - val_loss: 0.0447
Epoch 184/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9851 - loss: 0.0453 - val_accuracy: 0.9854 - val_loss: 0.0448
Epoch 185/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0451 - val_accuracy: 0.9854 - val_loss: 0.0446
Epoch 186/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9867 - loss: 0.0495 - val_accuracy: 0.9846 - val_loss: 0.0463
Epoch 187/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9860 - loss: 0.0536 - val_accuracy: 0.9838 - val_loss: 0.0486
Epoch 188/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9851 - loss: 0.0582 - val_accuracy: 0.9862 - val_loss: 0.0450
Epoch 189/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9843 - loss: 0.0549 - val_accuracy: 0.9846 - val_loss: 0.0469
Epoch 190/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9880 - loss: 0.0430 - val_accuracy: 0.9869 - val_loss: 0.0438
Epoch 191/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9866 - loss: 0.0453 - val_accuracy: 0.9854 - val_loss: 0.0463
Epoch 192/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9869 - loss: 0.0496 - val_accuracy: 0.9854 - val_loss: 0.0461
Epoch 193/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0484 - val_accuracy: 0.9854 - val_loss: 0.0446
Epoch 194/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 12ms/step - accuracy: 0.9843 - loss: 0.0530 - val_accuracy: 0.9869 - val_loss: 0.0448
Epoch 195/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9885 - loss: 0.0425 - val_accuracy: 0.9854 - val_loss: 0.0443
Epoch 196/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9886 - loss: 0.0456 - val_accuracy: 0.9831 - val_loss: 0.0502
Epoch 197/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9850 - loss: 0.0508 - val_accuracy: 0.9846 - val_loss: 0.0441
Epoch 198/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9859 - loss: 0.0498 - val_accuracy: 0.9854 - val_loss: 0.0457
Epoch 199/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9832 - loss: 0.0507 - val_accuracy: 0.9869 - val_loss: 0.0490
Epoch 200/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9825 - loss: 0.0549 - val_accuracy: 0.9854 - val_loss: 0.0477
Epoch 201/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9823 - loss: 0.0485 - val_accuracy: 0.9862 - val_loss: 0.0442
Epoch 202/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9892 - loss: 0.0436 - val_accuracy: 0.9823 - val_loss: 0.0521
Epoch 203/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9853 - loss: 0.0512 - val_accuracy: 0.9869 - val_loss: 0.0439
Epoch 204/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9840 - loss: 0.0527 - val_accuracy: 0.9854 - val_loss: 0.0448
Epoch 205/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9846 - loss: 0.0508 - val_accuracy: 0.9846 - val_loss: 0.0439
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Epoch 206/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9862 - loss: 0.0478 - val_accuracy: 0.9854 - val_loss: 0.0433
Epoch 207/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9872 - loss: 0.0421 - val_accuracy: 0.9862 - val_loss: 0.0433
Epoch 208/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9857 - loss: 0.0515 - val_accuracy: 0.9854 - val_loss: 0.0444
Epoch 209/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9882 - loss: 0.0441 - val_accuracy: 0.9877 - val_loss: 0.0436
Epoch 210/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9884 - loss: 0.0429 - val_accuracy: 0.9862 - val_loss: 0.0452
Epoch 211/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9820 - loss: 0.0540 - val_accuracy: 0.9862 - val_loss: 0.0441
Epoch 212/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9865 - loss: 0.0478 - val_accuracy: 0.9869 - val_loss: 0.0440
Epoch 213/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9876 - loss: 0.0461 - val_accuracy: 0.9862 - val_loss: 0.0433
Epoch 214/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9899 - loss: 0.0451 - val_accuracy: 0.9862 - val_loss: 0.0442
Epoch 215/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9862 - loss: 0.0465 - val_accuracy: 0.9877 - val_loss: 0.0433
Epoch 216/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9885 - loss: 0.0407 - val_accuracy: 0.9862 - val_loss: 0.0432
Epoch 217/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9842 - loss: 0.0578 - val_accuracy: 0.9862 - val_loss: 0.0440
Epoch 218/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9831 - loss: 0.0568 - val_accuracy: 0.9823 - val_loss: 0.0504
Epoch 219/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9867 - loss: 0.0424 - val_accuracy: 0.9846 - val_loss: 0.0462
Epoch 220/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9861 - loss: 0.0432 - val_accuracy: 0.9815 - val_loss: 0.0534
Epoch 221/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9856 - loss: 0.0520 - val_accuracy: 0.9838 - val_loss: 0.0490
Epoch 222/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 14ms/step - accuracy: 0.9854 - loss: 0.0512 - val_accuracy: 0.9723 - val_loss: 0.0690
Epoch 223/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9829 - loss: 0.0520 - val_accuracy: 0.9815 - val_loss: 0.0511
Epoch 224/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9832 - loss: 0.0551 - val_accuracy: 0.9808 - val_loss: 0.0574
Epoch 225/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9841 - loss: 0.0468 - val_accuracy: 0.9838 - val_loss: 0.0483
Epoch 226/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9829 - loss: 0.0619 - val_accuracy: 0.9846 - val_loss: 0.0471
Epoch 227/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9846 - loss: 0.0499 - val_accuracy: 0.9854 - val_loss: 0.0434
Epoch 228/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9836 - loss: 0.0512 - val_accuracy: 0.9862 - val_loss: 0.0435
Epoch 229/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9886 - loss: 0.0405 - val_accuracy: 0.9846 - val_loss: 0.0436
Epoch 230/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9854 - loss: 0.0510 - val_accuracy: 0.9862 - val_loss: 0.0448
Epoch 231/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9866 - loss: 0.0406 - val_accuracy: 0.9823 - val_loss: 0.0493
Epoch 232/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0468 - val_accuracy: 0.9846 - val_loss: 0.0448
Epoch 233/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9879 - loss: 0.0494 - val_accuracy: 0.9862 - val_loss: 0.0427
Epoch 234/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9863 - loss: 0.0409 - val_accuracy: 0.9838 - val_loss: 0.0464
Epoch 235/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9897 - loss: 0.0347 - val_accuracy: 0.9862 - val_loss: 0.0448
Epoch 236/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9859 - loss: 0.0488 - val_accuracy: 0.9838 - val_loss: 0.0467
Epoch 237/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9870 - loss: 0.0467 - val_accuracy: 0.9877 - val_loss: 0.0433
Epoch 238/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0444 - val_accuracy: 0.9862 - val_loss: 0.0430
Epoch 239/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9879 - loss: 0.0497 - val_accuracy: 0.9862 - val_loss: 0.0443
Epoch 240/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9874 - loss: 0.0415 - val_accuracy: 0.9869 - val_loss: 0.0424
Epoch 241/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9882 - loss: 0.0434 - val_accuracy: 0.9854 - val_loss: 0.0438
Epoch 242/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9839 - loss: 0.0555 - val_accuracy: 0.9846 - val_loss: 0.0452
Epoch 243/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9861 - loss: 0.0475 - val_accuracy: 0.9823 - val_loss: 0.0506
Epoch 244/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9835 - loss: 0.0478 - val_accuracy: 0.9823 - val_loss: 0.0477
Epoch 245/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0484 - val_accuracy: 0.9823 - val_loss: 0.0489
Epoch 246/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9825 - loss: 0.0603 - val_accuracy: 0.9746 - val_loss: 0.0603
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Epoch 247/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9831 - loss: 0.0556 - val_accuracy: 0.9823 - val_loss: 0.0519
Epoch 248/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9876 - loss: 0.0413 - val_accuracy: 0.9862 - val_loss: 0.0430
Epoch 249/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9874 - loss: 0.0387 - val_accuracy: 0.9815 - val_loss: 0.0488
Epoch 250/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9839 - loss: 0.0543 - val_accuracy: 0.9854 - val_loss: 0.0451
Epoch 251/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 6ms/step - accuracy: 0.9886 - loss: 0.0442 - val_accuracy: 0.9869 - val_loss: 0.0428
Epoch 252/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9863 - loss: 0.0442 - val_accuracy: 0.9869 - val_loss: 0.0429
Epoch 253/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9863 - loss: 0.0430 - val_accuracy: 0.9854 - val_loss: 0.0424
Epoch 254/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9884 - loss: 0.0428 - val_accuracy: 0.9854 - val_loss: 0.0441
Epoch 255/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9891 - loss: 0.0385 - val_accuracy: 0.9831 - val_loss: 0.0472
Epoch 256/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9862 - loss: 0.0496 - val_accuracy: 0.9846 - val_loss: 0.0454
Epoch 257/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9863 - loss: 0.0462 - val_accuracy: 0.9877 - val_loss: 0.0434
Epoch 258/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9888 - loss: 0.0371 - val_accuracy: 0.9869 - val_loss: 0.0425
Epoch 259/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9859 - loss: 0.0477 - val_accuracy: 0.9862 - val_loss: 0.0432
Epoch 260/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9878 - loss: 0.0428 - val_accuracy: 0.9838 - val_loss: 0.0460
Epoch 261/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9855 - loss: 0.0498 - val_accuracy: 0.9854 - val_loss: 0.0448
Epoch 262/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9877 - loss: 0.0480 - val_accuracy: 0.9869 - val_loss: 0.0432
Epoch 263/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9867 - loss: 0.0427 - val_accuracy: 0.9854 - val_loss: 0.0427
Epoch 264/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9868 - loss: 0.0414 - val_accuracy: 0.9862 - val_loss: 0.0418
Epoch 265/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9847 - loss: 0.0492 - val_accuracy: 0.9823 - val_loss: 0.0487
Epoch 266/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9874 - loss: 0.0469 - val_accuracy: 0.9854 - val_loss: 0.0436
Epoch 267/2000
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8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9874 - loss: 0.0499 - val_accuracy: 0.9831 - val_loss: 0.0473
Epoch 268/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9868 - loss: 0.0446 - val_accuracy: 0.9846 - val_loss: 0.0437
Epoch 269/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9867 - loss: 0.0439 - val_accuracy: 0.9815 - val_loss: 0.0544
Epoch 270/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9858 - loss: 0.0501 - val_accuracy: 0.9831 - val_loss: 0.0470
Epoch 271/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9862 - loss: 0.0471 - val_accuracy: 0.9831 - val_loss: 0.0450
Epoch 272/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9848 - loss: 0.0520 - val_accuracy: 0.9862 - val_loss: 0.0432
Epoch 273/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9853 - loss: 0.0468 - val_accuracy: 0.9869 - val_loss: 0.0432
Epoch 274/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9890 - loss: 0.0405 - val_accuracy: 0.9838 - val_loss: 0.0534
Epoch 275/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9815 - loss: 0.0590 - val_accuracy: 0.9862 - val_loss: 0.0423
Epoch 276/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9862 - loss: 0.0529 - val_accuracy: 0.9854 - val_loss: 0.0421
Epoch 277/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9882 - loss: 0.0418 - val_accuracy: 0.9862 - val_loss: 0.0418
Epoch 278/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9897 - loss: 0.0411 - val_accuracy: 0.9862 - val_loss: 0.0434
Epoch 279/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9861 - loss: 0.0461 - val_accuracy: 0.9862 - val_loss: 0.0413
Epoch 280/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step - accuracy: 0.9917 - loss: 0.0352 - val_accuracy: 0.9862 - val_loss: 0.0413
Epoch 281/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9889 - loss: 0.0384 - val_accuracy: 0.9877 - val_loss: 0.0416
Epoch 282/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9877 - loss: 0.0376 - val_accuracy: 0.9854 - val_loss: 0.0429
Epoch 283/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9864 - loss: 0.0450 - val_accuracy: 0.9862 - val_loss: 0.0436
Epoch 284/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9882 - loss: 0.0434 - val_accuracy: 0.9854 - val_loss: 0.0433
Epoch 285/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9889 - loss: 0.0465 - val_accuracy: 0.9823 - val_loss: 0.0484
Epoch 286/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9874 - loss: 0.0429 - val_accuracy: 0.9854 - val_loss: 0.0415
Epoch 287/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9866 - loss: 0.0394 - val_accuracy: 0.9877 - val_loss: 0.0425
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```
Epoch 288/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9856 - loss: 0.0469 - val_accuracy: 0.9869 - val_loss: 0.0429
Epoch 289/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9883 - loss: 0.0423 - val_accuracy: 0.9846 - val_loss: 0.0445
Epoch 290/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9889 - loss: 0.0397 - val_accuracy: 0.9823 - val_loss: 0.0473
Epoch 291/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 9ms/step - accuracy: 0.9878 - loss: 0.0416 - val_accuracy: 0.9862 - val_loss: 0.0406
Epoch 292/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 11ms/step - accuracy: 0.9865 - loss: 0.0463 - val_accuracy: 0.9854 - val_loss: 0.0414
Epoch 293/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9883 - loss: 0.0500 - val_accuracy: 0.9846 - val_loss: 0.0441
Epoch 294/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9876 - loss: 0.0417 - val_accuracy: 0.9854 - val_loss: 0.0420
Epoch 295/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9894 - loss: 0.0417 - val_accuracy: 0.9838 - val_loss: 0.0466
Epoch 296/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9878 - loss: 0.0446 - val_accuracy: 0.9862 - val_loss: 0.0411
Epoch 297/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9882 - loss: 0.0443 - val_accuracy: 0.9862 - val_loss: 0.0423
Epoch 298/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9892 - loss: 0.0400 - val_accuracy: 0.9862 - val_loss: 0.0436
Epoch 299/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9851 - loss: 0.0480 - val_accuracy: 0.9862 - val_loss: 0.0423
Epoch 300/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9865 - loss: 0.0481 - val_accuracy: 0.9885 - val_loss: 0.0433
Epoch 301/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9857 - loss: 0.0502 - val_accuracy: 0.9862 - val_loss: 0.0409
Epoch 302/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9894 - loss: 0.0399 - val_accuracy: 0.9838 - val_loss: 0.0447
Epoch 303/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9899 - loss: 0.0383 - val_accuracy: 0.9854 - val_loss: 0.0431
Epoch 304/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9895 - loss: 0.0395 - val_accuracy: 0.9862 - val_loss: 0.0419
Epoch 305/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9918 - loss: 0.0338 - val_accuracy: 0.9831 - val_loss: 0.0443
Epoch 306/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9899 - loss: 0.0474 - val_accuracy: 0.9815 - val_loss: 0.0500
Epoch 307/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 10ms/step - accuracy: 0.9871 - loss: 0.0442 - val_accuracy: 0.9831 - val_loss: 0.0450
Epoch 308/2000
```

```
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9850 - loss: 0.0510 - val_accuracy: 0.9846 - val_loss: 0.0416
Epoch 309/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 8ms/step - accuracy: 0.9888 - loss: 0.0401 - val_accuracy: 0.9862 - val_loss: 0.0419
Epoch 310/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9871 - loss: 0.0440 - val_accuracy: 0.9846 - val_loss: 0.0416
Epoch 311/2000
8/8 ━━━━━━━━━━━━━━━━━━━━ 0s 7ms/step - accuracy: 0.9897 - loss: 0.0331 - val_accuracy: 0.9854 - val_loss: 0.0433
```

In [22]:
```
# 테스트 결과를 출력합니다.
score=model.evaluate(X_test, y_test)
print('Test accuracy:', score[1])
```

```
41/41 ━━━━━━━━━━━━━━━━━━━━ 0s 968us/step - accuracy: 0.9840 - loss: 0.0447
Test accuracy: 0.9823076725006104
```