

ESP32-WROOM 32 FNN Evaluation

```
import numpy as np
from sklearn.metrics import accuracy_score, precision_score,
recall_score, f1_score, confusion_matrix, classification_report
from sklearn.metrics import roc_auc_score
```

DATA

Dataset: 1133 entry **Test_Dataset:** 126 entry

```
y_test =
[1.00,1.00,0.00,1.00,1.00,1.00,0.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00
,0.00,0.00,1.00,0.00,1.00,0.00,1.00,0.00,0.00,0.00,1.00,1.00,1.00,1.00
,0.00,1.00,1.00,0.00,0.00,1.00,0.00,1.00,1.00,0.00,1.00,1.00,1.00,1.00
,1.00,0.00,0.00,1.00,0.00,1.00,0.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00
,1.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,1.00,1.00,1.00,0.00,1.00,1.00
,0.00,1.00,0.00,0.00,0.00,1.00,1.00,0.00,1.00,0.00,1.00,0.00,1.00,1.00
,1.00,1.00,0.00,1.00,0.00,0.00,0.00,1.00,1.00,0.00,1.00,0.00,0.00,0.00
,0.00,1.00,0.00,1.00,0.00,0.00,1.00,0.00,0.00,0.00,1.00,1.00,0.00,1.00
,1.00,0.00,1.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,1.00,0.00,0.00
]
y_test_pred =
np.array([0.94,1.00,0.00,1.00,0.83,1.00,0.00,0.96,0.67,1.00,1.00,0.98,
0.00,0.00,0.00,0.00,1.00,0.00,0.99,0.00,0.99,0.00,0.01,0.00,0.99,1.00,
0.99,0.99,0.00,1.00,1.00,0.00,0.00,0.96,0.00,0.98,0.95,0.00,1.00,1.00,
1.00,1.00,0.98,0.00,0.99,0.76,0.00,1.00,0.00,1.00,0.99,0.96,1.00,0.99,
1.00,1.00,0.99,0.99,1.00,1.00,0.98,0.99,0.99,0.00,1.00,0.98,1.00,0.00,
1.00,1.00,0.00,1.00,0.00,0.00,0.00,1.00,0.98,0.00,0.99,0.00,0.99,0.00,
1.00,0.99,0.98,0.99,0.00,1.00,0.00,0.00,0.00,0.98,1.00,0.00,1.00,0.00,
0.00,0.00,0.00,1.00,0.00,0.99,0.00,0.00,0.98,0.00,0.00,0.00,0.88,0.99,
0.00,0.99,1.00,0.00,1.00,0.00,0.00,0.33,0.00,1.00,0.99,0.47,0.00,1.00,
0.00,0.00])
y_train =
[0.00,1.00,0.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,1.00
,0.00,0.00,1.00,0.00,0.00,1.00,0.00,1.00,1.00,1.00,1.00,1.00,0.00
,1.00,0.00,1.00,0.00,1.00,1.00,1.00,0.00,1.00,1.00,0.00,0.00,0.00,1.00
,0.00,1.00,1.00,0.00,1.00,0.00,0.00,1.00,1.00,0.00,1.00,0.00,0.00,1.00
,0.00,0.00,1.00,0.00,0.00,0.00,1.00,0.00,0.00,1.00,1.00,0.00,0.00,1.00
,0.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00
,1.00,1.00,1.00,0.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,1.00,1.00,1.00
,0.00,1.00,1.00,1.00,1.00,0.00,1.00,1.00,0.00,0.00,0.00,1.00,1.00,1.00
,1.00,1.00,1.00,0.00,0.00,0.00,1.00,1.00,0.00,0.00,0.00,1.00,0.00,1.00
,0.00,0.00,1.00,1.00,1.00,0.00,1.00,1.00,1.00,1.00,0.00,1.00,0.00,1.00
,0.00,1.00,0.00,0.00,0.00,0.00,1.00,0.00,1.00,1.00,1.00,1.00,0.00,0.00
,1.00,0.00,1.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00,0.00,1.00,0.00,1.00
,1.00,1.00,0.00,1.00,0.00,1.00,0.00,0.00,1.00,1.00,1.00,0.00,1.00,1.00
,0.00,0.00,1.00,1.00,1.00,0.00,1.00,0.00,1.00,1.00,1.00,1.00,0.00,1.00
,0.00,0.00,1.00,1.00,0.00,1.00,1.00,0.00,1.00,0.00,1.00,0.00,0.00,1.00
```

[illegible]

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, 1.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00  
, 1.00, 0.00, 0.00, 1.00, 0.00, 1.00, 0.00, 1.00, 1.00, 1.00, 0.00, 1.00, 1.00, 1.00  
, 1.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 1.00, 1.00, 0.00, 1.00, 0.00, 0.00, 0.00  
, 0.00, 1.00, 0.00, 1.00, 1.00, 0.00, 1.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00  
, 0.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00, 0.00, 1.00, 1.00, 0.00  
, 0.00, 0.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00, 1.00, 0.00, 1.00, 0.00  
, 1.00, 0.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 0.00, 0.00, 1.00, 1.00, 0.00  
, 1.00, 1.00, 1.00, 1.00, 0.00, 1.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 1.00, 1.00  
, 0.00, 1.00, 1.00, 0.00, 0.00, 1.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00, 1.00  
, 1.00, 1.00, 0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 1.00, 1.00, 0.00, 1.00, 0.00, 0.00  
, 1.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00, 1.00, 1.00, 0.00, 0.00, 1.00, 0.00, 1.00  
, 1.00, 0.00, 1.00, 1.00, 1.00, 1.00, 0.00, 0.00, 0.00, 0.00, 1.00, 1.00, 0.00, 0.00  
, 1.00, 0.00, 0.00, 1.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 1.00, 1.00  
, 1.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 1.00, 1.00  
, 1.00, 1.00, 0.00, 1.00, 0.00, 1.00, 0.00, 0.00, 1.00, 0.00, 0.00, 0.00, 1.00, 1.00  
, 0.00, 1.00, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 0.00  
, 1.00, 1.00, 0.00, 1.00, 1.00, 1.00, 0.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00]
```

```
y_train_pred =
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```
np.array([0.21, 0.99, 0.13, 0.99, 1.00, 1.00, 1.00, 1.00, 1.00, 0.48, 0.99, 0.00,  
0.00, 1.00, 0.00, 0.00, 0.99, 0.00, 0.00, 0.98, 0.00, 1.00, 0.98, 0.98, 0.99, 1.00,  
0.99, 0.00, 1.00, 0.00, 1.00, 0.00, 1.00, 1.00, 1.00, 0.00, 1.00, 0.99, 0.00, 0.10,  
0.00, 1.00, 0.00, 0.04, 0.98, 0.00, 1.00, 0.00, 0.03, 1.00, 1.00, 0.00, 1.00, 0.00,  
0.00, 1.00, 0.00, 0.00, 0.98, 0.02, 0.00, 0.00, 1.00, 0.00, 0.18, 0.99, 1.00, 0.00,  
0.00, 1.00, 0.00, 0.99, 1.00, 0.98, 1.00, 1.00, 0.97, 0.46, 0.00, 0.00, 0.00, 0.00,  
0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 1.00, 1.00, 0.99, 0.99, 1.00, 0.00, 0.00, 0.98,  
0.98, 1.00, 0.00, 1.00, 0.52, 1.00, 1.00, 0.00, 1.00, 1.00, 0.00, 0.00, 0.00, 1.00,  
1.00, 0.98, 1.00, 1.00, 1.00, 0.00, 0.00, 0.00, 1.00, 1.00, 0.00, 0.00, 0.00, 1.00,  
0.00, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 0.98, 0.99, 1.00, 0.99, 0.33, 1.00,  
0.00, 0.99, 0.00, 1.00, 0.01, 0.00, 0.00, 0.00, 1.00, 0.00, 1.00, 0.98, 0.99, 0.98,  
0.00, 0.00, 1.00, 0.00, 1.00, 0.17, 0.00, 0.99, 0.98, 1.00, 0.00, 0.00, 0.00, 1.00,  
0.00, 1.00, 0.99, 0.99, 0.00, 0.99, 0.00, 0.99, 0.00, 0.00, 0.98, 0.99, 1.00, 0.00,  
0.99, 1.00, 0.00, 0.00, 1.00, 1.00, 1.00, 0.00, 0.99, 0.00, 1.00, 0.97, 1.00, 0.99,  
0.00, 0.97, 0.00, 0.00, 0.99, 0.99, 0.39, 0.99, 0.99, 0.00, 0.99, 0.00, 1.00, 0.00,  
0.19, 1.00, 0.98, 1.00, 1.00, 1.00, 1.00, 0.03, 0.00, 0.76, 0.00, 0.00, 0.00, 0.00,  
1.00, 0.00, 0.00, 0.99, 1.00, 1.00, 0.00, 0.00, 0.98, 1.00, 0.00, 1.00, 1.00, 0.00,  
0.01, 1.00, 0.00, 0.00, 0.98, 1.00, 0.00, 0.99, 0.00, 1.00, 0.00, 0.00, 0.00, 0.00,  
0.94, 0.00, 0.00, 0.99, 1.00, 1.00, 0.00, 1.00, 0.00, 0.00, 0.99, 1.00, 1.00, 0.00,  
1.00, 1.00, 1.00, 1.00, 0.00, 0.03, 0.83, 0.00, 1.00, 0.00, 1.00, 0.00, 0.00, 1.00,  
0.99, 0.00, 0.98, 1.00, 0.99, 1.00, 1.00, 1.00, 0.99, 1.00, 1.00, 0.99, 0.00, 0.98,  
0.98, 0.99, 0.00, 0.92, 0.70, 1.00, 1.00, 1.00, 1.00, 0.98, 0.00, 0.00, 0.12, 0.00,  
0.98, 1.00, 1.00, 1.00, 0.98, 0.00, 0.99, 1.00, 1.00, 1.00, 1.00, 1.00, 0.98, 0.00,  
0.00, 0.00, 1.00, 1.00, 0.00, 0.00, 0.00, 0.00, 0.00, 0.02, 1.00, 0.00, 0.00, 1.00,  
0.00, 1.00, 1.00, 0.99, 1.00, 0.98, 0.00, 0.00, 0.00, 0.00, 0.33, 1.00, 0.03, 0.00,  
0.99, 0.00, 0.14, 0.00, 0.00, 0.00, 0.00, 0.03, 0.98, 0.00, 0.00, 1.00, 0.98, 0.00,  
0.99, 0.00, 0.00, 1.00, 0.00, 0.00, 0.03, 1.00, 0.00, 0.99, 0.00, 0.02, 0.99, 0.03,  
1.00, 0.00, 0.95, 0.76, 0.00, 0.98, 0.00, 0.98, 1.00, 0.99, 0.00, 0.00, 0.98, 0.00,  
0.98, 1.00, 1.00, 0.98, 0.00, 1.00, 0.99, 0.04, 0.98, 0.00, 0.00, 1.00, 0.00, 1.00,  
0.00, 0.99, 1.00, 0.00, 0.00, 1.00, 0.99, 0.00, 0.00, 0.00, 1.00, 0.00, 0.00, 1.00,  
0.00, 0.00, 0.00, 0.00, 1.00, 0.00, 0.58, 0.54, 0.98, 0.00, 0.99, 0.76, 0.00, 0.98,
```

1.00,0.00,1.00,1.00,0.00,0.00,0.98,0.00,1.00,0.99,1.00,1.00,0.00,0.00,
0.99,0.99,0.80,0.00,1.00,0.99,0.99,1.00,0.00,0.88,0.99,0.00,0.99,1.00,
0.00,0.00,1.00,0.14,0.00,0.96,1.00,0.00,0.99,1.00,0.00,1.00,1.00,0.99,
0.99,0.98,1.00,0.00,0.00,0.98,0.00,0.00,1.00,1.00,0.99,0.00,1.00,1.00,
1.00,0.00,0.99,0.00,1.00,0.00,1.00,0.00,0.00,0.00,0.00,1.00,0.00,0.00,
0.98,0.98,1.00,0.00,1.00,0.15,0.00,0.00,1.00,0.96,0.98,1.00,0.80,0.00,
1.00,1.00,0.98,0.98,1.00,0.00,0.00,0.72,0.99,0.03,0.00,0.99,0.00,0.00,
1.00,1.00,0.00,0.00,1.00,1.00,0.00,0.00,1.00,0.14,0.00,0.96,0.98,0.99,
0.00,0.99,0.00,0.00,0.99,0.99,1.00,1.00,0.58,0.00,0.00,1.00,0.00,0.15,
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1.00,1.00,1.00,0.00,0.00,0.00,1.00,0.00,0.00,0.00,0.13,0.98,0.00,1.00,
0.00,0.98,0.98,0.00,0.00,1.00,0.98,0.00,0.99,0.89,1.00,0.00,1.00,0.98,
0.00,0.00,0.99,1.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,0.00,1.00,1.00,
0.95,0.98,0.69,1.00,0.01,0.00,1.00,0.99,0.00,1.00,0.00,0.00,0.00,1.00,
1.00,1.00,0.99,1.00,1.00,0.98,0.98,1.00,0.00,1.00,0.58,1.00,1.00,1.00,
0.00,0.03,0.00,0.00,1.00,0.96,1.00,0.98,0.00,0.00,0.95,1.00,1.00,1.00,
0.00,0.98,0.00,1.00,0.00,0.99,0.65,1.00,0.98,0.98,0.12,1.00,1.00,1.00,
0.00,0.00,0.56,1.00,0.04,0.00,0.00,0.00,1.00,1.00,0.00,1.00,1.00,0.98,
1.00,0.00,0.00,1.00,0.00,0.00,0.00,0.99,0.00,1.00,0.00,1.00,0.00,0.00,
0.99,0.00,0.99,0.99,0.00,0.94,1.00,1.00,0.00,1.00,1.00,1.00,0.99,1.00,
0.99,0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,0.98,0.01,0.98,0.00,0.00,0.99,
0.98,0.00,0.88,0.99,0.00,0.00,1.00,0.00,0.00,0.00,0.98,0.00,1.00,0.00,
0.00,0.00,1.00,0.99,0.98,1.00,0.98,0.99,1.00,0.00,0.00,1.00,0.99,0.00,
0.00,0.99,0.00,0.00,0.88,0.00,1.00,1.00,0.58,0.00,1.00,0.10,0.98,0.98,
1.00,0.99,0.00,0.96,0.99,0.88,0.00,0.00,0.99,0.00,0.99,1.00,0.99,0.99,
0.00,1.00,0.00,1.00,0.00,0.00,0.03,0.62,0.02,0.63,0.00,0.68,0.00,0.96,
0.00,1.00,1.00,0.04,1.00,1.00,0.99,0.00,1.00,0.03,1.00,0.00,1.00,0.00,
1.00,0.00,1.00,0.99,0.58,1.00,1.00,0.98,0.00,1.00,0.00,1.00,0.00,0.61,
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0.00,0.00,1.00,0.00,0.92,1.00,0.99,1.00,0.00,1.00,0.00,0.00,0.90,1.00,
1.00,0.03,1.00,0.00,0.00,1.00,0.00,0.93,0.00,0.99,1.00,0.98,0.00,0.88,
0.94,0.97,0.71,1.00,0.00,0.00,1.00,1.00,1.00,1.00,1.00,0.00,0.99,0.00,
0.00,0.00,0.00,0.55,0.00,1.00,1.00,0.00,0.35,0.00,0.00,1.00,0.00,0.00,
0.00,0.98,0.00,0.99,0.14,0.00,0.98,0.39,1.00,1.00,0.00,0.00,0.00,1.00,
1.00,0.00,0.00,0.57,1.00,1.00,1.00,1.00,0.99,0.58,0.00,0.00,1.00,0.00,
1.00,0.22,0.98,0.00,0.99,0.00,0.00,1.00,0.99,1.00,0.00,0.00,0.00,1.00,
1.00,0.00,1.00,1.00,0.96,1.00,0.00,0.99,0.00,0.97,0.96,1.00,1.00,0.00,
1.00,1.00,0.00,1.00,0.99,0.03,0.00,0.98,0.00,0.98,1.00,0.88,1.00,0.00,
0.03,1.00,0.55,0.98,0.00,0.00,0.00,0.00,0.62,0.00,0.88,1.00,0.00,1.00,
0.00,0.00,1.00,1.00,0.98,0.99,1.00,0.00,0.00,1.00,1.00,0.00,0.00,0.99,
0.00,1.00,1.00,0.00,0.98,0.98,1.00,0.98,0.00,0.00,0.00,0.00,0.98,0.94,
0.57,0.00,0.98,0.00,0.00,1.00,0.00,0.99,0.00,0.00,0.26,0.99,0.00,0.00,
0.76,0.99,0.99,0.99,0.00,0.00,0.98,0.98,0.98,0.00,0.00,0.58,0.98,1.00,
1.00,0.99,1.00,1.00,0.00,1.00,0.00,1.00,0.00,0.00,1.00,0.00,0.00,0.00,
1.00,1.00,0.00,1.00,0.00,1.00,0.00,0.00,0.00,0.56,0.00,1.00,1.00,1.00,

```
0.00,0.00,0.98,0.98,0.00,1.00,1.00,1.00,0.59,1.00,1.00,1.00,1.00,1.00,
0.99])
```

Set an "acceptance" limit

```
y_train_pred_bin = (y_train_pred >= 0.05).astype(int)
y_test_pred_bin = (y_test_pred >= 0.05).astype(int)
```

Helper function in order to evaluate our model

```
def evaluate_model(y_true, y_pred, dataset_name=""):
    print(f"=== Evaluation for {dataset_name} ===")
    print(f"Accuracy: {accuracy_score(y_true, y_pred):.4f}")
    print(f"Precision: {precision_score(y_true, y_pred):.4f}")
    print(f"Recall: {recall_score(y_true, y_pred):.4f}")
    print(f"F1 Score: {f1_score(y_true, y_pred):.4f}")
    print("Matrice di confusione:")
    print(confusion_matrix(y_true, y_pred))
    print("Report dettagliato:")
    print(classification_report(y_true, y_pred))
    print("\n")
```

Evaluation on training data

```
evaluate_model(y_train, y_train_pred_bin, "Training Set")
```

```
=== Evaluation for Training Set ===
```

```
Accuracy: 0.9629
```

```
Precision: 0.9378
```

```
Recall: 0.9984
```

```
F1 Score: 0.9671
```

```
Matrice di confusione:
```

```
[[473  41]
```

```
 [  1 618]]
```

```
Report dettagliato:
```

	precision	recall	f1-score	support
0.0	1.00	0.92	0.96	514
1.0	0.94	1.00	0.97	619
accuracy			0.96	1133
macro avg	0.97	0.96	0.96	1133
weighted avg	0.97	0.96	0.96	1133

```
auc = roc_auc_score(y_train, y_train_pred)
```

```
print("ROC AUC Score on training data:", auc)
```

```
ROC AUC Score on training data: 0.9983106302999063
```

Evaluation on test data

```
evaluate_model(y_test, y_test_pred_bin, "Test Set")
```

```
=== Evaluation for Test Set ===
```

```
Accuracy: 0.9841
```

```
Precision: 0.9733
```

```
Recall: 1.0000
```

```
F1 Score: 0.9865
```

```
Matrice di confusione:
```

```
[[51  2]
```

```
 [ 0 73]]
```

```
Report dettagliato:
```

	precision	recall	f1-score	support
0.0	1.00	0.96	0.98	53
1.0	0.97	1.00	0.99	73
accuracy			0.98	126
macro avg	0.99	0.98	0.98	126
weighted avg	0.98	0.98	0.98	126

```
auc = roc_auc_score(y_test, y_test_pred)
```

```
print("ROC AUC Score on test data:", auc)
```

```
ROC AUC Score on test data: 0.9926337554923753
```