Notebook

June 29, 2025

[1]:

```python
import os
import shutil
import random
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.metrics import classification_report, confusion_matrix
import seaborn as sns
from tensorflow.keras import layers, models
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint

# Reproduzierbarkeit sicherstellen
tf.random.set_seed(42)
np.random.seed(42)
random.seed(42)
```

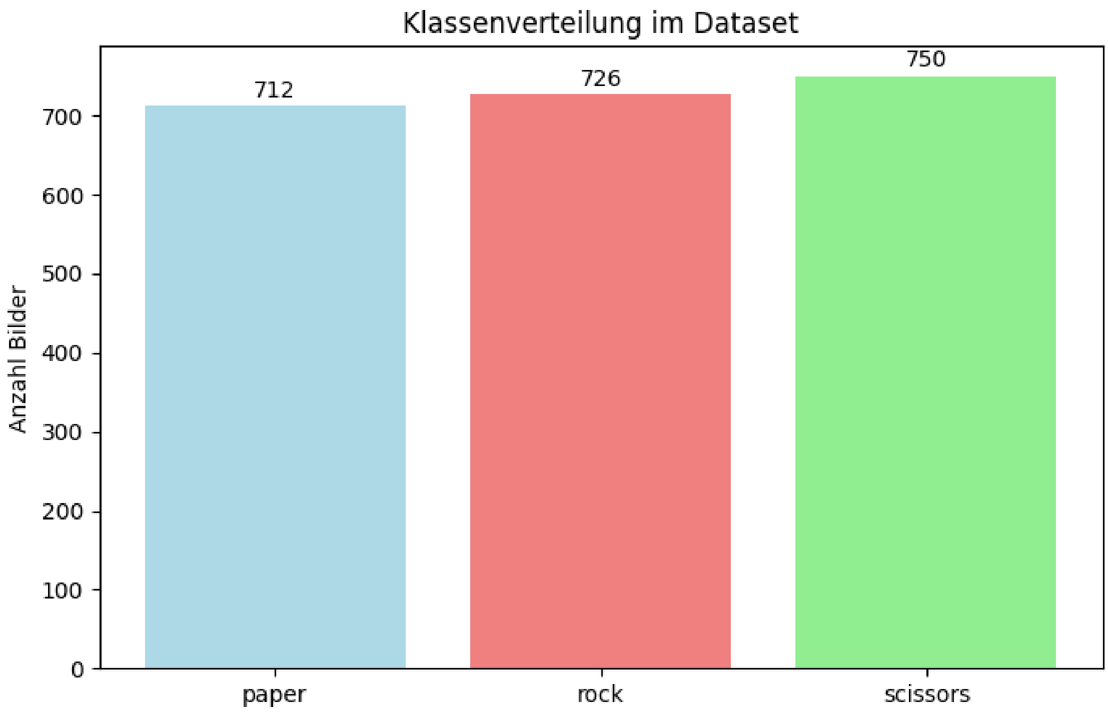
```
2025-06-29 22:22:03.807622: I external/local_xla/xla/tsl/cuda/cudart_stub.cc:32]
Could not find cuda drivers on your machine, GPU will not be used.
2025-06-29 22:22:03.813648: I external/local_xla/xla/tsl/cuda/cudart_stub.cc:32]
Could not find cuda drivers on your machine, GPU will not be used.
2025-06-29 22:22:03.829860: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
E0000 00:00:1751228523.862913   20679 cuda_dnn.cc:8579] Unable to register cuDNN
factory: Attempting to register factory for plugin cuDNN when one has already
been registered
E0000 00:00:1751228523.871574   20679 cuda_blas.cc:1407] Unable to register
cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has
already been registered
W0000 00:00:1751228523.894053   20679 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1751228523.894085   20679 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
```

```
target more than once.
W0000 00:00:1751228523.894087   20679 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1751228523.894089   20679 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
2025-06-29 22:22:03.903361: I tensorflow/core/platform/cpu_feature_guard.cc:210]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebuild
TensorFlow with the appropriate compiler flags.
```

[2]:

```python
DATA_DIR = "../data/raw"
IMG_SIZE = (200, 300)
BATCH_SIZE = 32

classes = ['paper', 'rock', 'scissors']
class_counts = {}

print("=== DATENÜBERSICHT ===")
for cls in classes:
    cls_path = os.path.join(DATA_DIR, cls)
    images = [f for f in os.listdir(cls_path) if f.endswith('.png')]
    class_counts[cls] = len(images)
    print(f"{cls}: {len(images)} Bilder")

total_images = sum(class_counts.values())
print(f"\nGesamtanzahl: {total_images} Bilder")
print(f"Durchschnitt pro Klasse: {total_images/3:.1f}")

plt.figure(figsize=(8,5))
bars = plt.bar(classes, [class_counts[cls] for cls in classes],
               color=['lightblue', 'lightcoral', 'lightgreen'])
plt.title("Klassenverteilung im Dataset")
plt.ylabel("Anzahl Bilder")
for bar, count in zip(bars, [class_counts[cls] for cls in classes]):
    plt.text(bar.get_x() + bar.get_width()/2, bar.get_height() + 5,
             str(count), ha='center', va='bottom')
plt.show()
```

```
=== DATENÜBERSICHT ===
paper: 712 Bilder
rock: 726 Bilder
scissors: 750 Bilder

Gesamtanzahl: 2188 Bilder
Durchschnitt pro Klasse: 729.3
```



[3]:

```
DATA_DIR   = "../data/raw"
IMG_SIZE   = (200, 300)
BATCH_SIZE = 32
SEED       = 42
VAL_SPLIT  = 0.30

train_ds = tf.keras.preprocessing.image_dataset_from_directory(
    DATA_DIR,
    validation_split=VAL_SPLIT,
    subset="training",
    seed=SEED,
    image_size=IMG_SIZE,
    batch_size=BATCH_SIZE
)
val_test_ds = tf.keras.preprocessing.image_dataset_from_directory(
    DATA_DIR,
    validation_split=VAL_SPLIT,
    subset="validation",
    seed=SEED,
    image_size=IMG_SIZE,
    batch_size=BATCH_SIZE
)
```

```
val_batches = tf.data.experimental.cardinality(val_test_ds)
val_ds = val_test_ds.take(val_batches // 2)
test_ds = val_test_ds.skip(val_batches // 2)

print(f"Train-Batches: {tf.data.experimental.cardinality(train_ds)}")
print(f"  Val-Batches: {tf.data.experimental.cardinality(val_ds)}")
print(f" Test-Batches: {tf.data.experimental.cardinality(test_ds)}")
```

```
Found 2188 files belonging to 3 classes.
Using 1532 files for training.
```

```
E0000 00:00:1751228530.318254   20679 cuda_executor.cc:1228] INTERNAL: CUDA
Runtime error: Failed call to cudaGetRuntimeVersion: Error loading CUDA
libraries. GPU will not be used.: Error loading CUDA libraries. GPU will not be
used.
W0000 00:00:1751228530.319164   20679 gpu_device.cc:2341] Cannot dlopen some GPU
libraries. Please make sure the missing libraries mentioned above are installed
properly if you would like to use GPU. Follow the guide at
https://www.tensorflow.org/install/gpu for how to download and setup the
required libraries for your platform.
Skipping registering GPU devices…
```

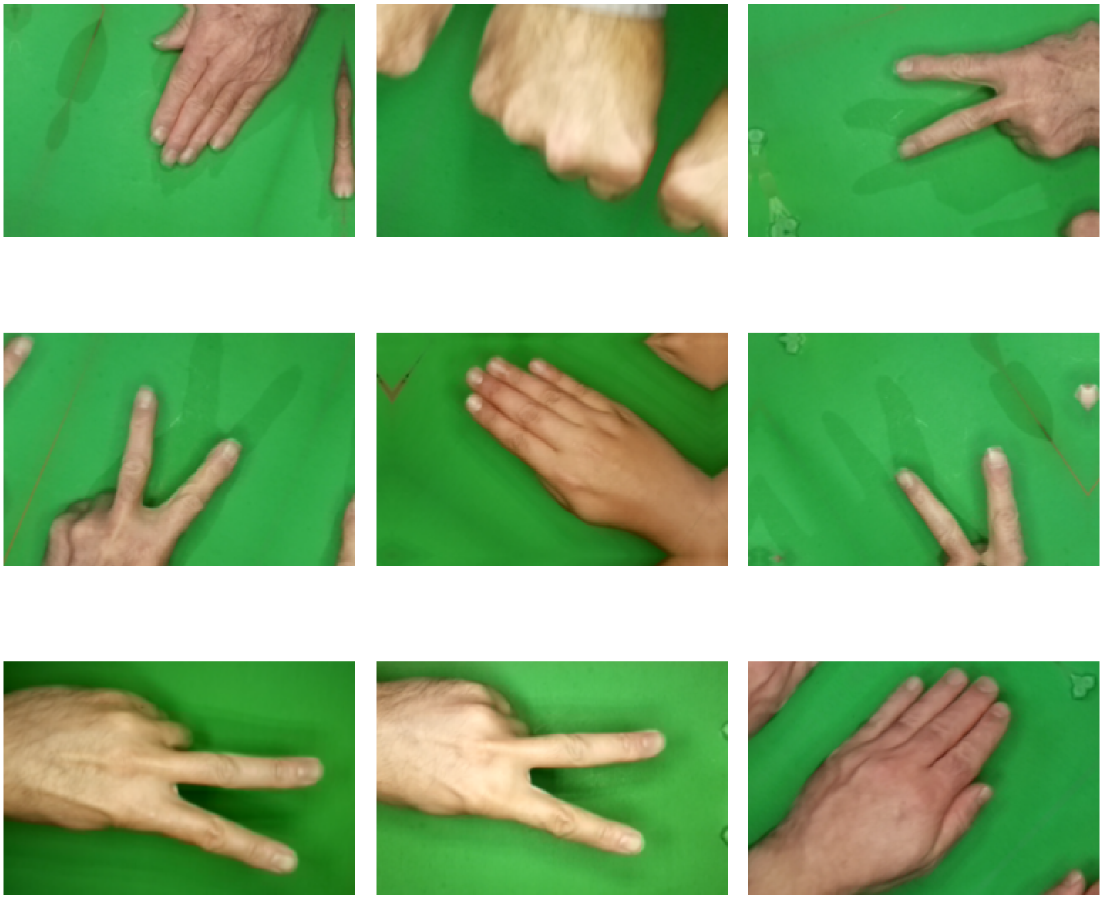
```
Found 2188 files belonging to 3 classes.
Using 656 files for validation.
Train-Batches: 48
  Val-Batches: 10
 Test-Batches: 11
```

[4]:

```
data_augmentation = tf.keras.Sequential([
    layers.RandomFlip("horizontal"),
    layers.RandomRotation(0.2),
    layers.RandomZoom(0.1),
])

plt.figure(figsize=(8,8))
for images, _ in train_ds.take(1):
    for i in range(9):
        ax = plt.subplot(3,3,i+1)
        aug_img = data_augmentation(tf.expand_dims(images[i], 0))
        plt.imshow(aug_img[0].numpy().astype("uint8"))
        plt.axis("off")
plt.suptitle("Live-Augmentation (300×200)")
plt.tight_layout()
plt.show()
```

```
2025-06-29 22:22:12.277385: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```

Live-Augmentation (300×200)



[5]:

```
def build_cnn(input_shape=(200,300,3), n_classes=3):
    model = models.Sequential([
        layers.Input(shape=input_shape),

        layers.Conv2D(32, (3,3), activation='relu', padding='same'),
        layers.MaxPooling2D((2,2)),

        layers.Conv2D(64, (3,3), activation='relu', padding='same'),
        layers.MaxPooling2D((2,2)),

        layers.Conv2D(128, (3,3), activation='relu', padding='same'),
        layers.MaxPooling2D((2,2)),

        layers.GlobalAveragePooling2D(),
        layers.Dropout(0.5),
        layers.Dense(64, activation='relu'),
        layers.Dense(n_classes, activation='softmax'),
    ])
    return model

model = build_cnn()
model.summary()
```

```
Model: "sequential_1"


 Layer (type)                      Output Shape                  Param #

 conv2d (Conv2D)                   (None, 200, 300, 32)              896

 max_pooling2d (MaxPooling2D)      (None, 100, 150, 32)                0

 conv2d_1 (Conv2D)                 (None, 100, 150, 64)           18,496

 max_pooling2d_1 (MaxPooling2D)    (None, 50, 75, 64)                  0

 conv2d_2 (Conv2D)                 (None, 50, 75, 128)            73,856

 max_pooling2d_2 (MaxPooling2D)    (None, 25, 37, 128)                 0

 global_average_pooling2d          (None, 128)                         0
 (GlobalAveragePooling2D)

 dropout (Dropout)                 (None, 128)                         0

 dense (Dense)                     (None, 64)                      8,256

 dense_1 (Dense)                   (None, 3)                         195


 Total params: 101,699 (397.26 KB)

 Trainable params: 101,699 (397.26 KB)

 Non-trainable params: 0 (0.00 B)
```

[6]:

```
model.compile(
    optimizer='adam',
    loss='sparse_categorical_crossentropy',
    metrics=['accuracy']
)

callbacks = [
    EarlyStopping(monitor='val_loss', patience=3, restore_best_weights=True),
    ModelCheckpoint("../models/rps_best.h5", save_best_only=True)
]
```

[7]:
```
history = model.fit(
    train_ds,
    validation_data=val_ds,
    epochs=15,
    callbacks=callbacks
)
```

```
Epoch 1/15
48/48                 0s 932ms/step -
accuracy: 0.3647 - loss: 8.0571

WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48                 49s 987ms/step -
accuracy: 0.3649 - loss: 7.9685 - val_accuracy: 0.4781 - val_loss: 1.0648
Epoch 2/15
48/48                 0s 935ms/step -
accuracy: 0.4106 - loss: 1.0788

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'my_model.keras')`.

48/48                 47s 988ms/step -
accuracy: 0.4110 - loss: 1.0780 - val_accuracy: 0.5688 - val_loss: 0.8289
Epoch 3/15
48/48                 0s 943ms/step -
accuracy: 0.6371 - loss: 0.8010

WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
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`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48                 48s 994ms/step -
```

```
accuracy: 0.6373 - loss: 0.8008 - val_accuracy: 0.9094 - val_loss: 0.5201
Epoch 4/15
48/48            0s 936ms/step -
accuracy: 0.7965 - loss: 0.5493
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.
```

```
48/48            47s 987ms/step -
accuracy: 0.7964 - loss: 0.5489 - val_accuracy: 0.9219 - val_loss: 0.3425
Epoch 5/15
48/48            0s 946ms/step -
accuracy: 0.8644 - loss: 0.3710
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.
```

```
48/48            48s 997ms/step -
accuracy: 0.8646 - loss: 0.3707 - val_accuracy: 0.9594 - val_loss: 0.1904
Epoch 6/15
48/48            48s 1s/step -
accuracy: 0.8898 - loss: 0.3013 - val_accuracy: 0.9563 - val_loss: 0.1908
Epoch 7/15
48/48            0s 938ms/step -
accuracy: 0.9066 - loss: 0.2652
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
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recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.
```
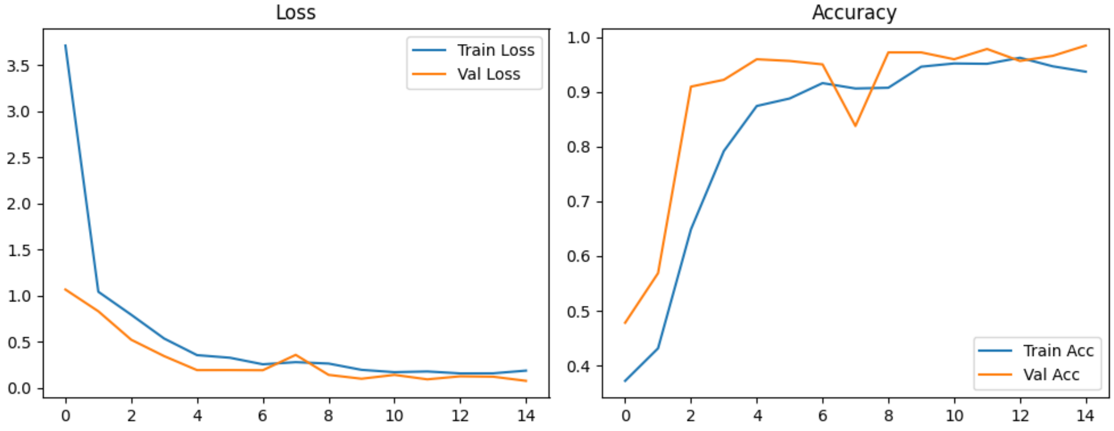

```
48/48            47s 989ms/step -
accuracy: 0.9068 - loss: 0.2650 - val_accuracy: 0.9500 - val_loss: 0.1893
Epoch 8/15
48/48            47s 991ms/step -
accuracy: 0.9036 - loss: 0.2780 - val_accuracy: 0.8375 - val_loss: 0.3559
Epoch 9/15
48/48            0s 943ms/step -
accuracy: 0.8812 - loss: 0.2988
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48            48s 996ms/step -
accuracy: 0.8818 - loss: 0.2980 - val_accuracy: 0.9719 - val_loss: 0.1388
Epoch 10/15
48/48            0s 954ms/step -
accuracy: 0.9403 - loss: 0.1961

WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48            48s 1s/step -
accuracy: 0.9405 - loss: 0.1960 - val_accuracy: 0.9719 - val_loss: 0.0969
Epoch 11/15
48/48            47s 977ms/step -
accuracy: 0.9499 - loss: 0.1865 - val_accuracy: 0.9594 - val_loss: 0.1389
Epoch 12/15
48/48            0s 945ms/step -
accuracy: 0.9480 - loss: 0.1682

WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48            48s 995ms/step -
accuracy: 0.9480 - loss: 0.1683 - val_accuracy: 0.9781 - val_loss: 0.0905
Epoch 13/15
48/48            47s 973ms/step -
accuracy: 0.9656 - loss: 0.1611 - val_accuracy: 0.9563 - val_loss: 0.1233
Epoch 14/15
48/48            47s 973ms/step -
accuracy: 0.9482 - loss: 0.1550 - val_accuracy: 0.9656 - val_loss: 0.1192
Epoch 15/15
48/48            0s 915ms/step -
accuracy: 0.9403 - loss: 0.1661

WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
`keras.saving.save_model(model)`. This file format is considered legacy. We
recommend using instead the native Keras format, e.g.
`model.save('my_model.keras')` or `keras.saving.save_model(model,
'my_model.keras')`.

48/48            46s 964ms/step -
accuracy: 0.9403 - loss: 0.1665 - val_accuracy: 0.9844 - val_loss: 0.0741
```

[8]:

```
hist = history.history
plt.figure(figsize=(10,4))

plt.subplot(1,2,1)
plt.plot(hist['loss'], label='Train Loss')
plt.plot(hist['val_loss'], label='Val Loss')
plt.legend(); plt.title("Loss")

plt.subplot(1,2,2)
plt.plot(hist['accuracy'], label='Train Acc')
plt.plot(hist['val_accuracy'], label='Val Acc')
plt.legend(); plt.title("Accuracy")

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



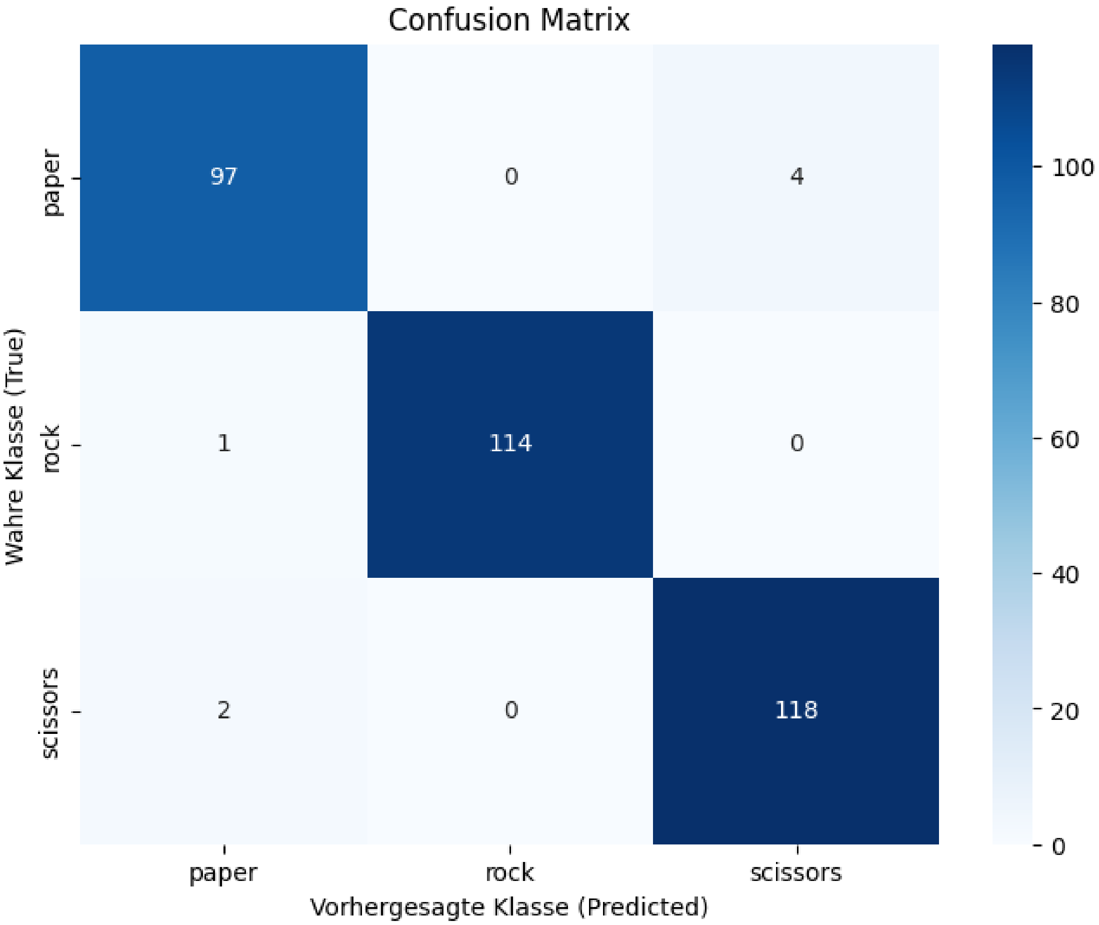
[11]:

```
y_pred_probs_list = []
y_true_list = []

for images, labels in test_ds:
    preds = model.predict_on_batch(images)
    y_pred_probs_list.append(preds)
    y_true_list.append(labels.numpy())

y_pred_probs = np.concatenate(y_pred_probs_list, axis=0)
y_true = np.concatenate(y_true_list, axis=0)

y_pred = np.argmax(y_pred_probs, axis=1)

class_names = train_ds.class_names
```

```python
print("=== Classification Report ===")
print(classification_report(y_true, y_pred, target_names=class_names))

cm = confusion_matrix(y_true, y_pred)

plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues',
            xticklabels=class_names, yticklabels=class_names)
plt.title('Confusion Matrix')
plt.ylabel('Wahre Klasse (True)')
plt.xlabel('Vorhergesagte Klasse (Predicted)')
plt.show()
```

```
=== Classification Report ===
              precision    recall  f1-score   support

       paper       0.97      0.96      0.97       101
        rock       1.00      0.99      1.00       115
    scissors       0.97      0.98      0.98       120

    accuracy                           0.98       336
   macro avg       0.98      0.98      0.98       336
weighted avg       0.98      0.98      0.98       336
```

```
2025-06-29 23:25:48.394135: I tensorflow/core/framework/local_rendezvous.cc:407]
Local rendezvous is aborting with status: OUT_OF_RANGE: End of sequence
```


Confusion Matrix
paper
rock
scissors
Wahre Klasse (True)
97
0
4
1
114
0
2
0
118
paper
rock
scissors
Vorhergesagte Klasse (Predicted)
100
80
60
40
20
0