

# Notebook

November 9, 2025

## 1 Multiclass classification

### 1.1 Import libraries

```
[1]: import torch
      import torch.nn as nn
      import torchmetrics
      from torch.utils.data import Dataset
      import pandas as pd
      import wandb
```

### 1.2 Config

```
[2]: import torch.nn as nn
      import numpy as np

      torch.manual_seed(42)

      np.random.seed(42)

      BATCH_SIZE = 32
      LR = 0.001
      CLASSES = 6

      TRAIN_VAL_TEST_SPLIT = [0.7, 0.15, 0.15]

      MAX_EPOCHS = 100

      LOSS_WEIGHTS = [4.0, 4.0, 2.0, 3.0, 5.0, 5.0]
      LOSS_FUNCTION = nn.CrossEntropyLoss(weight=torch.
      tensor(LOSS_WEIGHTS))#weight=torch.tensor([2.0, 1.0, 3.0, 4.0, 8.0, 4.0])

      DROPOUT_COEF = 0.35

      SAVE_BEST_MODEL = True
      IS_MULTICLASS = True if CLASSES > 2 else False
      NUM_OF_WORKERS = 0
```

```
REDUCE_LR_PATIENCE = 10
EARLY_STOPPING_PATIENCE = 20
```

### 1.3 WANDB Init

```
[3]: wandb.init(project="zneus-project-1-multiclass", name="Basic model with higher amount of neurons")
```

```
# Config hyperparameters
config = wandb.config

config.batch_size = BATCH_SIZE
config.learning_rate = LR
config.max_epochs = MAX_EPOCHS
config.dropout_coeff = DROPOUT_COEF
config.desc = "MLP: (1024, BatchNorm,ReLU,Dropout) (512,BatchNorm,ReLU,Dropout) (256,BatchNorm, ReLU, Dropout) (1)"
config.loss_function = "BinaryCrossentropy with logits"
config.reduce_lr_patience = REDUCE_LR_PATIENCE
config.early_stopping_patience = EARLY_STOPPING_PATIENCE
config.loss_weights = LOSS_WEIGHTS
```

```
wandb: Currently logged in as: amal-akhmadinurov
(amal-akhmadinurov-stu) to https://api.wandb.ai. Use
`wandb login --relogin` to force relogin
```

```
wandb: setting up run aoi3ni0c
```

```
wandb: Tracking run with wandb version 0.22.3
```

```
wandb: Run data is saved locally in
/Users/amalahmadinurov/Desktop/Subjects_ZS_2025/ZNEUS/zneus-
```

```
project-1/wandb/run-20251109_210224-aoi3ni0c
```

```
wandb: Run `wandb offline` to turn off syncing.
```

```
wandb: Syncing run Basic model with higher amount of
neurons
```

```
wandb: View project at
https://wandb.ai/amal-akhmadinurov-stu/zneus-project-1-multiclass
```

```
wandb: View run at
https://wandb.ai/amal-akhmadinurov-stu/zneus-project-1-multiclass/runs/aoi3ni0c
```

## 1.4 Define Dataset

```
[4]: class SteelPlateDataset(Dataset):  
  
    def __init__(self, dataset_path):  
        super().__init__()  
        self.path = dataset_path  
        self.df = pd.read_csv(self.path)  
  
        self.features = self.df.drop(["Class", *("Pastry Z_Scratch K_Scratch" +  
        "Stains Dirtiness Bumps".split(" "))], axis=1).values.tolist() # V28 V29 V30  
        ↵V31 V32 V33  
        self.labels = self.df[[*"Pastry Z_Scratch K_Scratch Stains Dirtiness"  
        "Bumps".split(" ")]].dot([i for i in range(6)]).values.tolist() # V28 V29 V30  
        ↵V31 V32 V33  
  
    def __getitem__(self, index):  
  
        return torch.tensor(self.features[index]), torch.tensor(self.  
        ↵labels[index]).float()  
  
    def __len__(self):  
        return len(self.labels)
```

## 1.5 Create datasets

```
[5]: from sklearn.model_selection import train_test_split  
from torch.utils.data import DataLoader, Subset  
  
dataset = SteelPlateDataset("data/norm_multiclass_data.csv")  
  
labels = np.array(dataset.labels)  
print(labels)  
train_size, val_size, test_size = TRAIN_VAL_TEST_SPLIT  
  
train_val_indices, test_indices = train_test_split(  
    range(len(dataset)),  
    test_size=TRAIN_VAL_TEST_SPLIT[1],  
    stratify=dataset.labels,  
    random_state=42  
)  
  
# Update labels for train+val indices  
train_val_labels = labels[train_val_indices]  
  
# Second split: train vs val
```

```

train_indices, val_indices = train_test_split(
    train_val_indices,
    test_size=val_size / (train_size + val_size), # Adjust proportion for ↴
    ↪train+val
    stratify=train_val_labels,
    random_state=42
)

train_dataset = Subset(dataset, train_indices)
val_dataset = Subset(dataset, val_indices)
test_dataset = Subset(dataset, test_indices)

```

[0 0 0 ... 0 0 0]

## 1.6 Define device

```
[6]: if torch.cuda.is_available():
    device_name = "cuda"
elif torch.backends.mps.is_available():
    device_name = "mps"
else:
    device_name = "cpu"
```

## 1.7 Create dataloaders

```
[7]: from torch.utils.data import DataLoader

train_dataloader = DataLoader(
    train_dataset,
    batch_size=BATCH_SIZE,

    shuffle=True, # Default shuffling for training
    num_workers=NUM_OF_WORKERS
)
val_dataloader = DataLoader(
    val_dataset,
    batch_size=BATCH_SIZE,
    shuffle=False, # No shuffling for validation
    num_workers=NUM_OF_WORKERS
)
test_dataloader = DataLoader(
    test_dataset,
    batch_size=BATCH_SIZE,
    shuffle=False, # No shuffling for test
```

```

        num_workers=NUM_OF_WORKERS
    )

# Print dataset sizes
print(f"Train dataset size: {len(train_dataset)}")
print(f"Validation dataset size: {len(val_dataset)}")
print(f"Test dataset size: {len(test_dataset)}")

```

Train dataset size: 1129  
 Validation dataset size: 242  
 Test dataset size: 242

## 1.8 Define EarlyStopping class

```
[8]: import torch

class EarlyStopping:
    def __init__(self, patience=5, min_delta=0.0):
        """
        Args:
            patience (int): How many epochs to wait after last improvement.
            min_delta (float): Minimum change to qualify as an improvement.
        """
        self.patience = patience
        self.min_delta = min_delta
        self.counter = 0
        self.best_loss = None
        self.early_stop = False

    def __call__(self, val_loss):
        if self.best_loss is None:
            self.best_loss = val_loss
        elif val_loss > self.best_loss - self.min_delta:
            self.counter += 1
            if self.counter >= self.patience:
                self.early_stop = True
        else:
            self.best_loss = val_loss
            self.counter = 0
```

## 1.9 Define model

```
[9]: from torchmetrics.classification import Accuracy, Precision
from torch.optim.lr_scheduler import ReduceLROnPlateau

class MyModel(nn.Module):
```

```

    def __init__(self, input_size, lr=0.001, loss_fn=nn.BCELoss(), num_classes=2, reduce_lr_patience=10, early_stopping_patience=10):
        super().__init__()
        self.accuracy = Accuracy(task="multiclass", num_classes=num_classes, average="macro")
        self.precision = Precision(task="multiclass", num_classes=num_classes, average="macro")
        self.loss_fn = loss_fn

        self.model = nn.Sequential(
            nn.Linear(input_size, 512),
            nn.BatchNorm1d(512),
            nn.ReLU(),
            nn.Dropout(DROPOUT_COEF),

            nn.Linear(512, 256),
            nn.BatchNorm1d(256),
            nn.ReLU(),
            nn.Dropout(DROPOUT_COEF),

            nn.Linear(256, 128),
            nn.BatchNorm1d(128),
            nn.ReLU(),
            nn.Dropout(DROPOUT_COEF),

            nn.Linear(128, num_classes)
        )
        self.to(device_name)

        self.optimizer = torch.optim.Adam(self.parameters(), lr=lr)

        self.early_stopping = EarlyStopping(patience=early_stopping_patience, min_delta=0.01)

        self.scheduler = ReduceLROnPlateau(
            self.optimizer, mode='min', factor=0.5, patience=reduce_lr_patience
        )

    def forward(self, x):
        return self.model(x)

    def evaluate(self, dataloader):
        self.eval()

```

```

eval_loss = 0

self.precision.reset()
self.accuracy.reset()

with torch.no_grad():
    for batch in dataloader:

        x = batch[0].to(device_name)
        y = batch[1].to(device_name)

        output = self.forward(x)
        output = torch.sigmoid(output).squeeze(1)
        y = y.float()

        loss = self.loss_fn(output, y)

        self.accuracy(output, y)
        self.precision(output, y)

    eval_loss += loss.item()

    self.train()
    return (eval_loss/len(dataloader), self.accuracy.compute(), self.
precision.compute())

```

```

def fit(self, train_dataloader, val_dataloader, epochs=10):
    self.train()
    best_val_loss = 9999

    for i in range(0,epochs):

        self.accuracy.reset()
        epoch_loss = 0
        for batch in train_dataloader:

            x = batch[0].to(device_name)
            y = batch[1].to(device_name)

```

```

        output = self.forward(x)
        output = torch.sigmoid(output).squeeze(1)
        y = y.float()

    loss = self.loss_fn(output, y)

    self.accuracy(output, y)
    self.precision(output, y)

    epoch_loss += loss.item()

    self.zero_grad()
    loss.backward()
    self.optimizer.step()

epoch_loss /= len(train_dataloader)

epoch_acc = self.accuracy.compute()
epoch_precision = self.precision.compute()

val_loss, val_acc, val_precision = self.evaluate(val_dataloader)
if best_val_loss > val_loss:
    best_val_loss = val_loss
    torch.save(self.state_dict(), "best-model-multiclass.pth")

self.scheduler.step(val_loss)
wandb.log({"epoch": i, "Train Loss": epoch_loss, "Train Acc": epoch_acc,
           "Train Precision": epoch_precision, "Val Loss": val_loss, "Val Acc": val_acc,
           "Val Precision": val_precision, "LR": self.optimizer.param_groups[0]['lr']})
print(f"Epoch {i+1} Loss:{epoch_loss:.4f} Accuracy:{epoch_acc:.4f} Precision:{epoch_precision:.4f} Val Loss:{val_loss:.4f} Val Accuracy:{val_acc:.4f} Val Precision:{val_precision:.4f} LR = {self.optimizer.param_groups[0]['lr']}")

self.early_stopping(val_loss)
if self.early_stopping.early_stop:
    print("Early stopping")
    break
wandb.finish()

```

## 1.10 Create model

```
[10]: model = MyModel(  
        input_size=len(dataset.features[0]),  
        num_classes=CLASSES,  
        loss_fn=LOSS_FUNCTION, lr=LR,  
        reduce_lr_patience=REDUCE_LR_PATIENCE,  
        early_stopping_patience=EARLY_STOPPING_PATIENCE  
)
```

## 1.11 Train model

```
[11]: model.fit(train_dataloader, val_dataloader, epochs=MAX_EPOCHS)
```

Epoch 1 Loss:1.5967 Accuracy:0.4945 Precision:0.4459 Val Loss:1.4830 Val Accuracy:0.5605 Val Precision:0.5862 LR = 0.001

Epoch 2 Loss:1.4091 Accuracy:0.4851 Precision:0.6044 Val Loss:1.3765 Val Accuracy:0.5742 Val Precision:0.6283 LR = 0.001

Epoch 3 Loss:1.3436 Accuracy:0.5435 Precision:0.6493 Val Loss:1.3308 Val Accuracy:0.6310 Val Precision:0.6404 LR = 0.001

Epoch 4 Loss:1.3092 Accuracy:0.6271 Precision:0.6611 Val Loss:1.3044 Val Accuracy:0.6447 Val Precision:0.6282 LR = 0.001

Epoch 5 Loss:1.2875 Accuracy:0.6594 Precision:0.6708 Val Loss:1.2955 Val Accuracy:0.6652 Val Precision:0.6433 LR = 0.001

Epoch 6 Loss:1.2728 Accuracy:0.6776 Precision:0.6771 Val Loss:1.2829 Val Accuracy:0.6570 Val Precision:0.6536 LR = 0.001

Epoch 7 Loss:1.2632 Accuracy:0.6880 Precision:0.6814 Val Loss:1.2806 Val Accuracy:0.6638 Val Precision:0.6599 LR = 0.001

Epoch 8 Loss:1.2529 Accuracy:0.6909 Precision:0.6810 Val Loss:1.2727 Val Accuracy:0.6650 Val Precision:0.6529 LR = 0.001

Epoch 9 Loss:1.2445 Accuracy:0.6867 Precision:0.6825 Val Loss:1.2721 Val Accuracy:0.6475 Val Precision:0.6511 LR = 0.001

Epoch 10 Loss:1.2411 Accuracy:0.6932 Precision:0.7644 Val Loss:1.2682 Val Accuracy:0.6387 Val Precision:0.6349 LR = 0.001

Epoch 11 Loss:1.2432 Accuracy:0.7050 Precision:0.8470 Val Loss:1.2677 Val Accuracy:0.6464 Val Precision:0.6393 LR = 0.001

Epoch 12 Loss:1.2281 Accuracy:0.7138 Precision:0.8416 Val Loss:1.2728 Val Accuracy:0.6675 Val Precision:0.6570 LR = 0.001

Epoch 13 Loss:1.2281 Accuracy:0.7204 Precision:0.8631 Val Loss:1.2726 Val Accuracy:0.6750 Val Precision:0.8230 LR = 0.001

Epoch 14 Loss:1.2262 Accuracy:0.7304 Precision:0.8600 Val Loss:1.2767 Val Accuracy:0.6810 Val Precision:0.8052 LR = 0.001

Epoch 15 Loss:1.2239 Accuracy:0.7209 Precision:0.8492 Val Loss:1.2651 Val Accuracy:0.6898 Val Precision:0.8072 LR = 0.001

Epoch 16 Loss:1.2124 Accuracy:0.7318 Precision:0.8419 Val Loss:1.2678 Val Accuracy:0.6825 Val Precision:0.8139 LR = 0.001

Epoch 17 Loss:1.2113 Accuracy:0.7222 Precision:0.8363 Val Loss:1.2784 Val Accuracy:0.6896 Val Precision:0.8084 LR = 0.001

Epoch 18 Loss:1.2156 Accuracy:0.7417 Precision:0.8336 Val Loss:1.2624 Val Accuracy:0.6930 Val Precision:0.8212 LR = 0.001

Epoch 19 Loss:1.2028 Accuracy:0.7387 Precision:0.8302 Val Loss:1.2583 Val Accuracy:0.6989 Val Precision:0.8269 LR = 0.001

Epoch 20 Loss:1.2081 Accuracy:0.7763 Precision:0.8451 Val Loss:1.2606 Val Accuracy:0.7193 Val Precision:0.8251 LR = 0.001

Epoch 21 Loss:1.2037 Accuracy:0.7720 Precision:0.8606 Val Loss:1.2669 Val Accuracy:0.6850 Val Precision:0.8255 LR = 0.001

Epoch 22 Loss:1.2017 Accuracy:0.7716 Precision:0.8289 Val Loss:1.2621 Val Accuracy:0.7254 Val Precision:0.8451 LR = 0.001

Epoch 23 Loss:1.1990 Accuracy:0.8151 Precision:0.8613 Val Loss:1.2576 Val Accuracy:0.7670 Val Precision:0.8456 LR = 0.001

Epoch 24 Loss:1.2040 Accuracy:0.7917 Precision:0.8477 Val Loss:1.2632 Val Accuracy:0.7864 Val Precision:0.8118 LR = 0.001

Epoch 25 Loss:1.2058 Accuracy:0.8112 Precision:0.8367 Val Loss:1.2529 Val Accuracy:0.7491 Val Precision:0.8243 LR = 0.001

Epoch 26 Loss:1.2009 Accuracy:0.8179 Precision:0.8109 Val Loss:1.2601 Val Accuracy:0.7529 Val Precision:0.8369 LR = 0.001

Epoch 27 Loss:1.2057 Accuracy:0.8429 Precision:0.8458 Val Loss:1.2524 Val Accuracy:0.7988 Val Precision:0.7985 LR = 0.001

Epoch 28 Loss:1.1994 Accuracy:0.8106 Precision:0.8230 Val Loss:1.2664 Val Accuracy:0.7480 Val Precision:0.8360 LR = 0.001

Epoch 29 Loss:1.1880 Accuracy:0.8508 Precision:0.8526 Val Loss:1.2606 Val Accuracy:0.7356 Val Precision:0.7688 LR = 0.001

Epoch 30 Loss:1.1903 Accuracy:0.8243 Precision:0.8406 Val Loss:1.2547 Val Accuracy:0.7727 Val Precision:0.8301 LR = 0.001

Epoch 31 Loss:1.1964 Accuracy:0.8203 Precision:0.8360 Val Loss:1.2633 Val Accuracy:0.7699 Val Precision:0.8279 LR = 0.001

Epoch 32 Loss:1.1913 Accuracy:0.8472 Precision:0.8468 Val Loss:1.2653 Val Accuracy:0.7143 Val Precision:0.8346 LR = 0.001

Epoch 33 Loss:1.1890 Accuracy:0.8411 Precision:0.8513 Val Loss:1.2627 Val Accuracy:0.7730 Val Precision:0.8036 LR = 0.001

Epoch 34 Loss:1.1948 Accuracy:0.8212 Precision:0.8356 Val Loss:1.2652 Val Accuracy:0.7666 Val Precision:0.7875 LR = 0.001

Epoch 35 Loss:1.1917 Accuracy:0.8089 Precision:0.8323 Val Loss:1.2637 Val Accuracy:0.7496 Val Precision:0.8006 LR = 0.001

Epoch 36 Loss:1.1959 Accuracy:0.8396 Precision:0.8513 Val Loss:1.2626 Val Accuracy:0.7822 Val Precision:0.8002 LR = 0.001

Epoch 37 Loss:1.1887 Accuracy:0.8371 Precision:0.8442 Val Loss:1.2685 Val Accuracy:0.7643 Val Precision:0.8068 LR = 0.001

Epoch 38 Loss:1.1840 Accuracy:0.8446 Precision:0.8480 Val Loss:1.2667 Val Accuracy:0.7740 Val Precision:0.8098 LR = 0.0005

Epoch 39 Loss:1.1901 Accuracy:0.8412 Precision:0.8422 Val Loss:1.2563 Val Accuracy:0.7826 Val Precision:0.7942 LR = 0.0005

Epoch 40 Loss:1.1943 Accuracy:0.8164 Precision:0.8340 Val Loss:1.2598 Val Accuracy:0.7715 Val Precision:0.8019 LR = 0.0005

Epoch 41 Loss:1.1821 Accuracy:0.8695 Precision:0.8442 Val Loss:1.2625 Val Accuracy:0.7709 Val Precision:0.8096 LR = 0.0005

Epoch 42 Loss:1.1841 Accuracy:0.8606 Precision:0.8344 Val Loss:1.2610 Val Accuracy:0.7722 Val Precision:0.8101 LR = 0.0005

Epoch 43 Loss:1.1728 Accuracy:0.8629 Precision:0.8666 Val Loss:1.2548 Val Accuracy:0.7792 Val Precision:0.8061 LR = 0.0005

Epoch 44 Loss:1.1853 Accuracy:0.8460 Precision:0.8544 Val Loss:1.2544 Val Accuracy:0.7807 Val Precision:0.8077 LR = 0.0005

Epoch 45 Loss:1.1792 Accuracy:0.8442 Precision:0.8599 Val Loss:1.2553 Val Accuracy:0.7822 Val Precision:0.8050 LR = 0.0005

Epoch 46 Loss:1.1866 Accuracy:0.8580 Precision:0.8468 Val Loss:1.2546 Val Accuracy:0.7730 Val Precision:0.8036 LR = 0.0005

wandb: updating run metadata

Epoch 47 Loss:1.1764 Accuracy:0.8481 Precision:0.8453 Val Loss:1.2534 Val Accuracy:0.7838 Val Precision:0.8431 LR = 0.0005

Early stopping

wandb: uploading wandb-summary.json; uploading config.yaml

wandb:

wandb: Run history:

wandb:       LR

wandb:       Train Acc

wandb:       Train Loss

wandb: Train Precision

```

wandb:      Val Acc
wandb:      Val Loss
wandb:  Val Precision
wandb:          epoch
wandb:
wandb: Run summary:
wandb:          LR 0.0005
wandb:  Train Acc 0.84809
wandb:  Train Loss 1.17642
wandb: Train Precision 0.84532
wandb:  Val Acc 0.78377
wandb:  Val Loss 1.25344
wandb:  Val Precision 0.84305
wandb:          epoch 46
wandb:

wandb: View run Basic model with higher amount of
neurons at: https://wandb.ai/amal-akhmadinurov-stu/zneus-project-1-multiclass/runs/aoi3ni0c
wandb: View project at: https://wandb.ai/amal-akhmadinurov-stu/zneus-project-1-multiclass
wandb: Synced 4 W&B file(s), 0 media file(s), 0 artifact file(s)
and 0 other file(s)

wandb: Find logs at:
./wandb/run-20251109_210224-aoi3ni0c/logs

```

```
[12]: val_loss, val_acc, val_precision = model.evaluate(val_dataloader)
print(f"Test Loss:{val_loss} Test Accuracy:{val_acc.item()} Test Precision:
    ↪{val_precision.item()}")

```

```
Test Loss:1.253436490893364 Test Accuracy:0.7837744951248169 Test
Precision:0.8430511355400085
```

## 1.12 Confusion Matrix on validation set

```
[13]: import numpy as np
from sklearn.metrics import confusion_matrix
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay

# Example data (each pixel has an integer class label)
val_dataloader = DataLoader(
    val_dataset,
    batch_size=len(val_dataset),
    shuffle=False, # Use sampler instead of shuffle
    num_workers=NUM_OF_WORKERS
)
```

```

features, ground_truth = next(iter(val_dataloader))

images = features.to(device_name)
model.eval()
predictions = model(images)

predictions = torch.argmax(predictions, dim=1).float()
y_true = ground_truth.numpy()
y_pred = predictions.detach().cpu().int().numpy()

y_true_flat = y_true.flatten()
y_pred_flat = y_pred.flatten()

cm = confusion_matrix(y_true_flat, y_pred_flat, labels=[0, 1, 2, 3, 4, 5])
print(cm)
# Convert to percentage (%)
cm_percent = cm.astype('float') / cm.sum(axis=1, keepdims=True) * 100
disp = ConfusionMatrixDisplay(confusion_matrix=cm_percent,
                               display_labels=["Pastry", "Z_Scratch", "K_Scratch", "Stains", "Dirtiness", "Bumps"])

disp.plot(cmap='Blues', values_format='.1f')

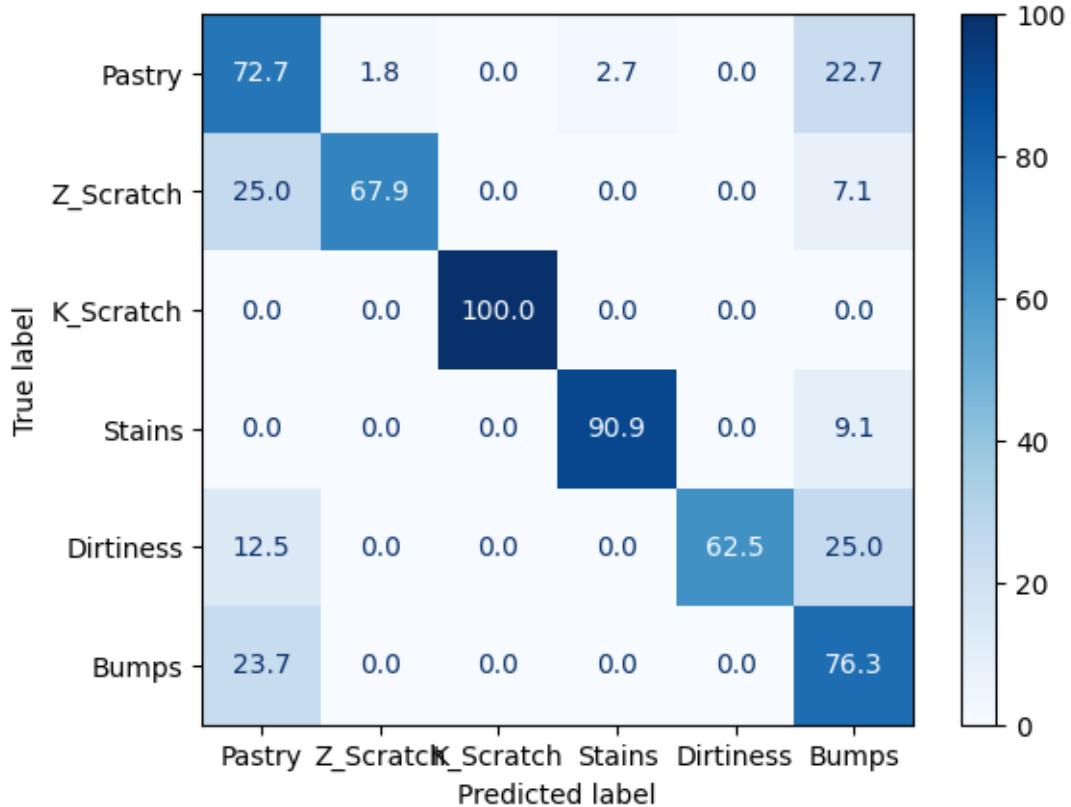
```

```

[[80  2   0   3   0  25]
 [ 7 19   0   0   0   2]
 [ 0   0 26   0   0   0]
 [ 0   0   0 10   0   1]
 [ 1   0   0   0   5   2]
 [14   0   0   0  45]]

```

[13]: <sklearn.metrics.\_plot.confusion\_matrix.ConfusionMatrixDisplay at 0x11fa27230>



### 1.13 Load the best model by loss

```
[14]: model.load_state_dict(torch.load("best-model-multiclass.pth",  
map_location=device_name))
```

[14]: <All keys matched successfully>

### 1.14 Confusion Matrix on validation set

```
[15]: import numpy as np  
from sklearn.metrics import confusion_matrix  
import matplotlib.pyplot as plt  
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay  
  
# Example data (each pixel has an integer class label)  
val_dataloader = DataLoader(  
    val_dataset,  
    batch_size=len(val_dataset),  
    shuffle=False, # Use sampler instead of shuffle  
    num_workers=NUM_OF_WORKERS  
)
```

```

features, ground_truth = next(iter(val_dataloader))

images = features.to(device_name)
model.eval()
predictions = model(images)

predictions = torch.argmax(predictions, dim=1).float()
y_true = ground_truth.numpy()
y_pred = predictions.detach().cpu().int().numpy()

y_true_flat = y_true.flatten()
y_pred_flat = y_pred.flatten()

cm = confusion_matrix(y_true_flat, y_pred_flat, labels=[0, 1, 2, 3, 4, 5])
print(cm)
# Convert to percentage (%)
cm_percent = cm.astype('float') / cm.sum(axis=1, keepdims=True) * 100
disp = ConfusionMatrixDisplay(confusion_matrix=cm_percent,
                               display_labels=["Pastry", "Dough", "Bread", "Crust", "Filling", "Crumb"])
                                         ↵"Z_Scratch", "K_Scratch", "Stains", "Dirtiness", "Bumps"])

disp.plot(cmap='Blues', values_format='.1f')

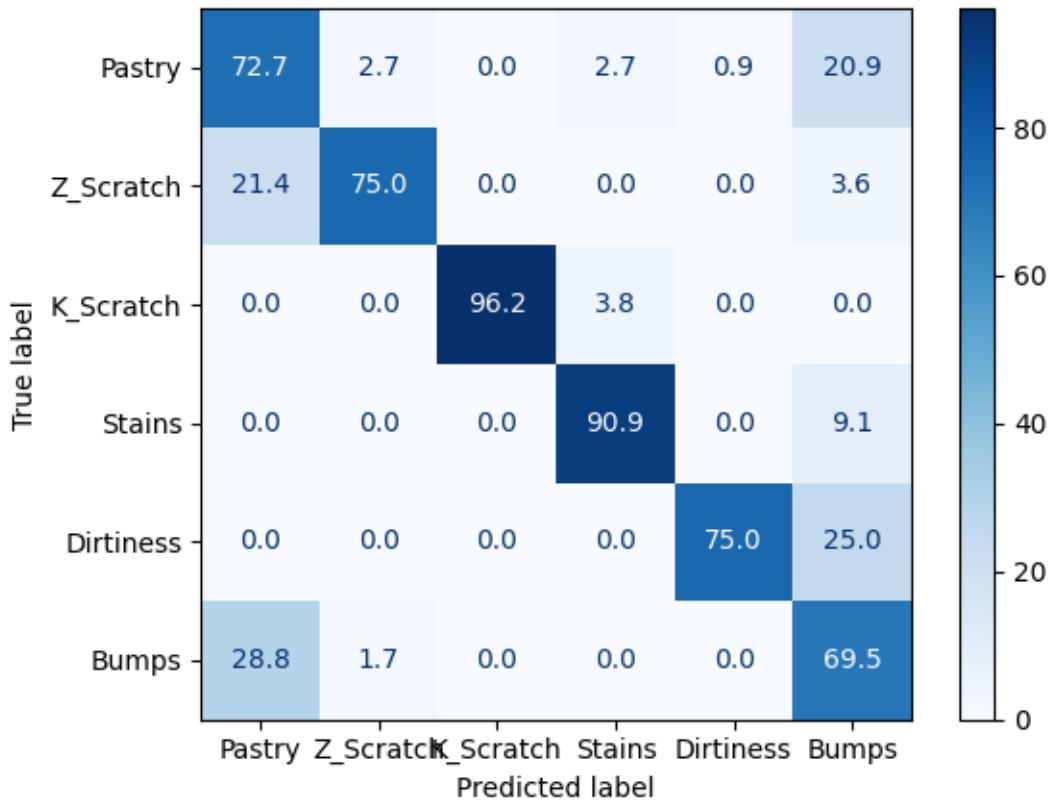
```

```

[[80  3  0  3  1 23]
 [ 6 21  0  0  0  1]
 [ 0  0 25  1  0  0]
 [ 0  0  0 10  0  1]
 [ 0  0  0  0  6  2]
 [17  1  0  0  0 41]]

```

[15]: <sklearn.metrics.\_plot.confusion\_matrix.ConfusionMatrixDisplay at 0x134caccd0>



## 1.15 Test on the test set (only for final evaluation)

### 1.15.1 Test set class distribution

```
[16]: from collections import Counter

labels = [label.item() for _, label in test_dataset]
class_counts = Counter(labels)

print("\nClass Distribution:")
print("-" * 30)
class_names = ["Pastry", "Z_Scratch", "K_Scratch", "Stains", "Dirtiness", "Bumps"]
for cls, count in sorted(class_counts.items()):
    print(f"Class {class_names[int(cls)]} | Count: {count}")
print("-" * 30)
```

Class Distribution:

-----  
 Class Pastry | Count: 110  
 Class Z\_Scratch | Count: 28

```
Class K_Scratch | Count: 26
Class Stains | Count: 11
Class Dirtiness | Count: 8
Class Bumps | Count: 59
```

```
[17]: test_loss, test_acc, test_precision = model.evaluate(test_dataloader)
print(f"Test Loss:{test_loss} Test Accuracy:{test_acc.item()} Test Precision:
      ↪{test_precision.item()}")
```

```
Test Loss:1.24232979118824 Test Accuracy:0.8337084650993347 Test
Precision:0.7915846705436707
```

### 1.15.2 Confusion Matrix

```
[18]: import numpy as np
from sklearn.metrics import confusion_matrix
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay

# Example data (each pixel has an integer class label)
test_dataloader = DataLoader(
    test_dataset,
    batch_size=len(test_dataset),
    shuffle=False, # Use sampler instead of shuffle
    num_workers=NUM_OF_WORKERS
)

features, ground_truth = next(iter(test_dataloader))

images = features.to(device_name)
model.eval()
predictions = model(images)

predictions = torch.argmax(predictions, dim=1).float()
y_true = ground_truth.numpy()
y_pred = predictions.detach().cpu().int().numpy()

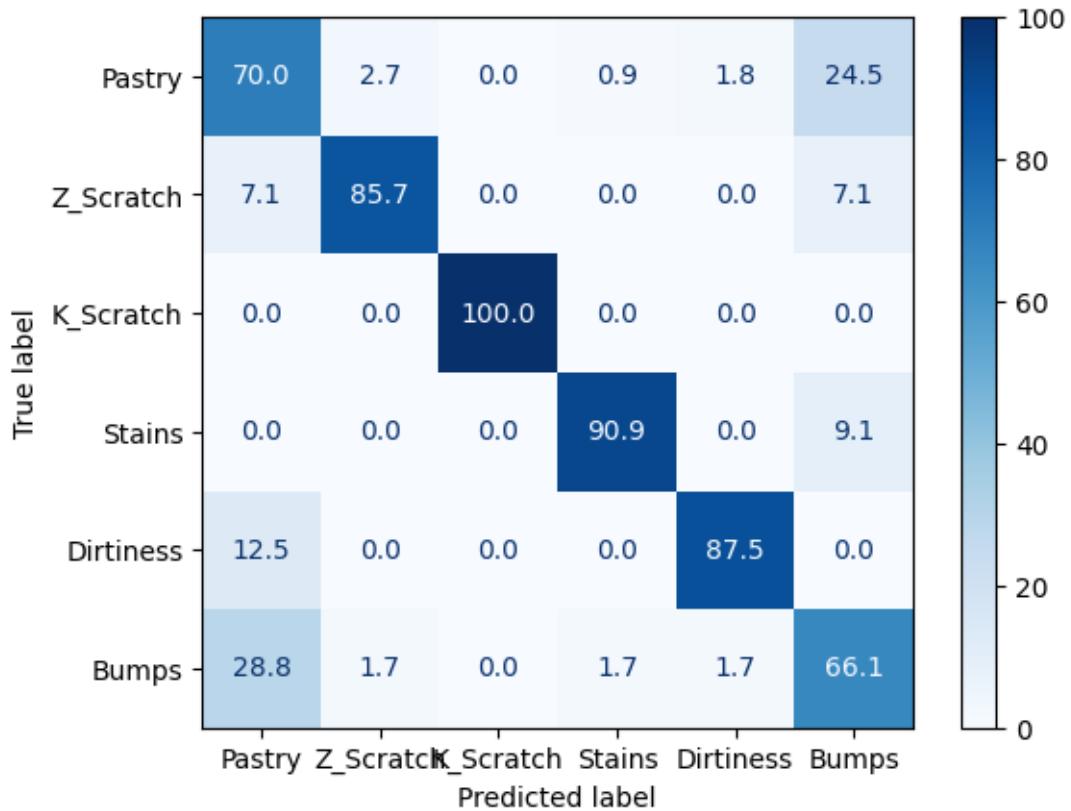
y_true_flat = y_true.flatten()
y_pred_flat = y_pred.flatten()

cm = confusion_matrix(y_true_flat, y_pred_flat, labels=[0, 1, 2, 3, 4, 5])
print(cm)
# Convert to percentage (%)
cm_percent = cm.astype('float') / cm.sum(axis=1, keepdims=True) * 100
disp = ConfusionMatrixDisplay(confusion_matrix=cm_percent,
                               display_labels=["Pastry", "Pastry", "Stains", "Dirtiness", "Bumps"])
      ↪"Z_Scratch", "K_Scratch", "Stains", "Dirtiness", "Bumps"])
```

```
disp.plot(cmap='Blues', values_format='.1f')
```

```
[[77  3  0  1  2 27]
 [ 2 24  0  0  0  2]
 [ 0  0 26  0  0  0]
 [ 0  0  0 10  0  1]
 [ 1  0  0  0  7  0]
 [17  1  0  1  1 39]]
```

[18]: <sklearn.metrics.\_plot.confusion\_matrix.ConfusionMatrixDisplay at 0x11fa739d0>



[ ]: