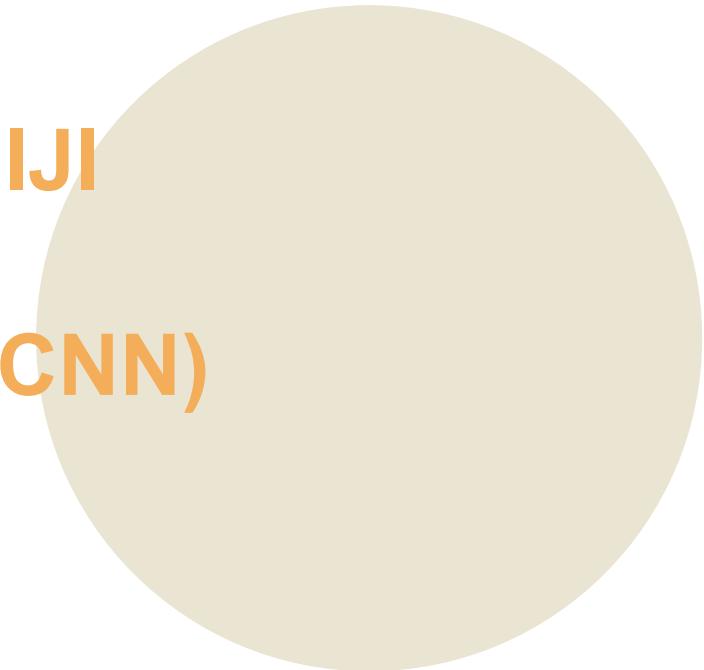


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# **KLASIFIKASI TINGKAT KEMATANGAN BIJI KOPI MENGGUNAKAN ALGORITMA CONVOLUTIONAL NEURAL NETWORK (CNN) DENGAN ARSITEKTUR DENSENET-121**



Mochamad Arival Khoiruddin H

# BAB 1

## PENDAHULUAN

### LATAR BELAKANG

Pengolahan tingkat kematangan biji kopi merupakan proses penting dalam industri kopi. Kematangan biji kopi sangat berperan penting dalam menentukan kualitas dan citra rasa kopi. Proses klasifikasi biji kopi pada saat ini dilakukan secara visual dan pemahaman subjektif manusia dan diperlukan seorang pakar atau ahli pada bidang ini, sehingga memungkinkan terjadinya human error yang diakibatkan kelelahan ataupun kelalaian.

Oleh karena itu, adanya **bantuan teknologi** secara alternatif diharapkan dapat membantu meningkatkan efektifitas dari proses klasifikasi biji kopi berdasarkan tingkat kematangannya menjadi lebih baik dan lebih efisien.

# BAB 1

## PENDAHULUAN

### LATAR BELAKANG

Saat ini metode yang popular dalam bidang computer vision termasuk klasifikasi citra adalah deep learning. Dalam beberapa tahun terakhir, deep learning telah mencapai hasil yang luar biasa dalam berbagai machine learning.

Maka arsitektur Densenet121 dipilih karena beberapa hasil penelitian terdahulu mencatat keunggulan kinerja model ini terhadap model lainnya dan diharapkan bisa meningkatkan efisiensi proses klasifikasi tingkat kematangan biji kopi

## RUMUSAN MASALAH

Penelitian ini berfokus pada pertanyaan yaitu bagaimana tingkat performansi arsitektur DenseNet-121 dalam mengklasifikasikan tingkat kematangan biji kopi jenis arabica dengan mengeksplorasi tuning parameter, seperti learning rate, dan jumlah epochs terhadap peningkatan akurasi model.

# BAB 1

## PENDAHULUAN

# **MAKSUD DAN TUJUAN**

## **MAKSUD**

Melakukan implementasi metode Convolutional Neural Network dengan arsitektur DenseNet121 untuk klasifikasi biji kopi .

## **TUJUAN**

Mengetahui peforma dari arsitektur DenseNet121 yang efisien dalam mengklasifikasikan tingkat kematangan biji kopi

## BATASAN MASALAH

- JENIS BIJI KOPI YANG DIGUNAKAN DALAM PENELITIAN INI ADALAH JENIS BIJI KOPI ARABIKA.
- DATA YANG DIGUNAKAN YAITU CITRA BIJI KOPI YANG TELAH DI ROASTING YANG TERDIRI DARI 4 JENIS YAITU GREEN BEAN, LIGHT ROAST, MEDIUM ROAST, DAN DARK ROAST.DAN MEMILIKI UKURAN **224X224**
- DATASET PENELITIAN INI MENGGUNAKAN DATASET PUBLIK YANG DIPEROLEH DARI KAGGLE

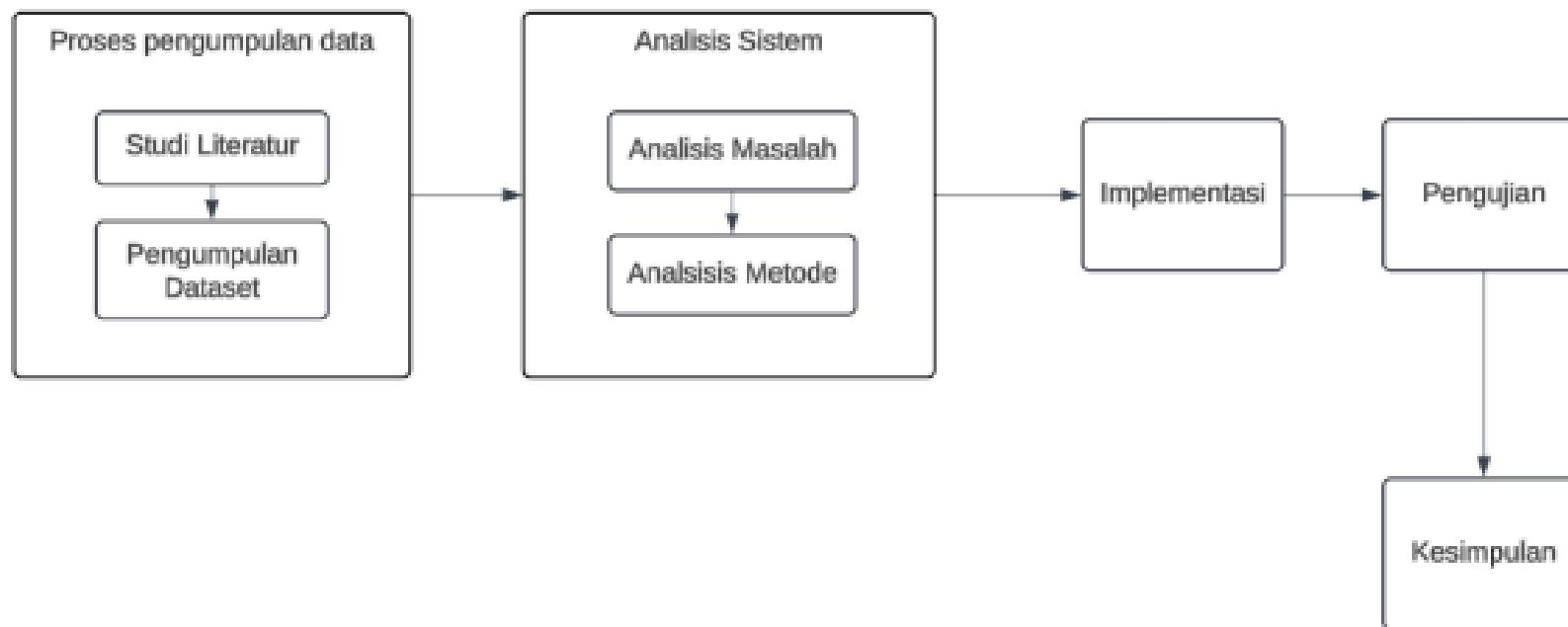
# BAB 1

## PENDAHULUAN

# BAB 1

## PENDAHULUAN

## METODE PENELITIAN



## **ANALISIS MASALAH**

Penelitian berjudul Analisis Perbandingan Kinerja Arsitektur Transfer learning pada Model Jaringan CNN dengan Kumpulan Data Beragam dilakukan perbandingan kinerja MobileNet, VGG-19, Resnet50V2, DenseNet121, dan NASNetMobile.

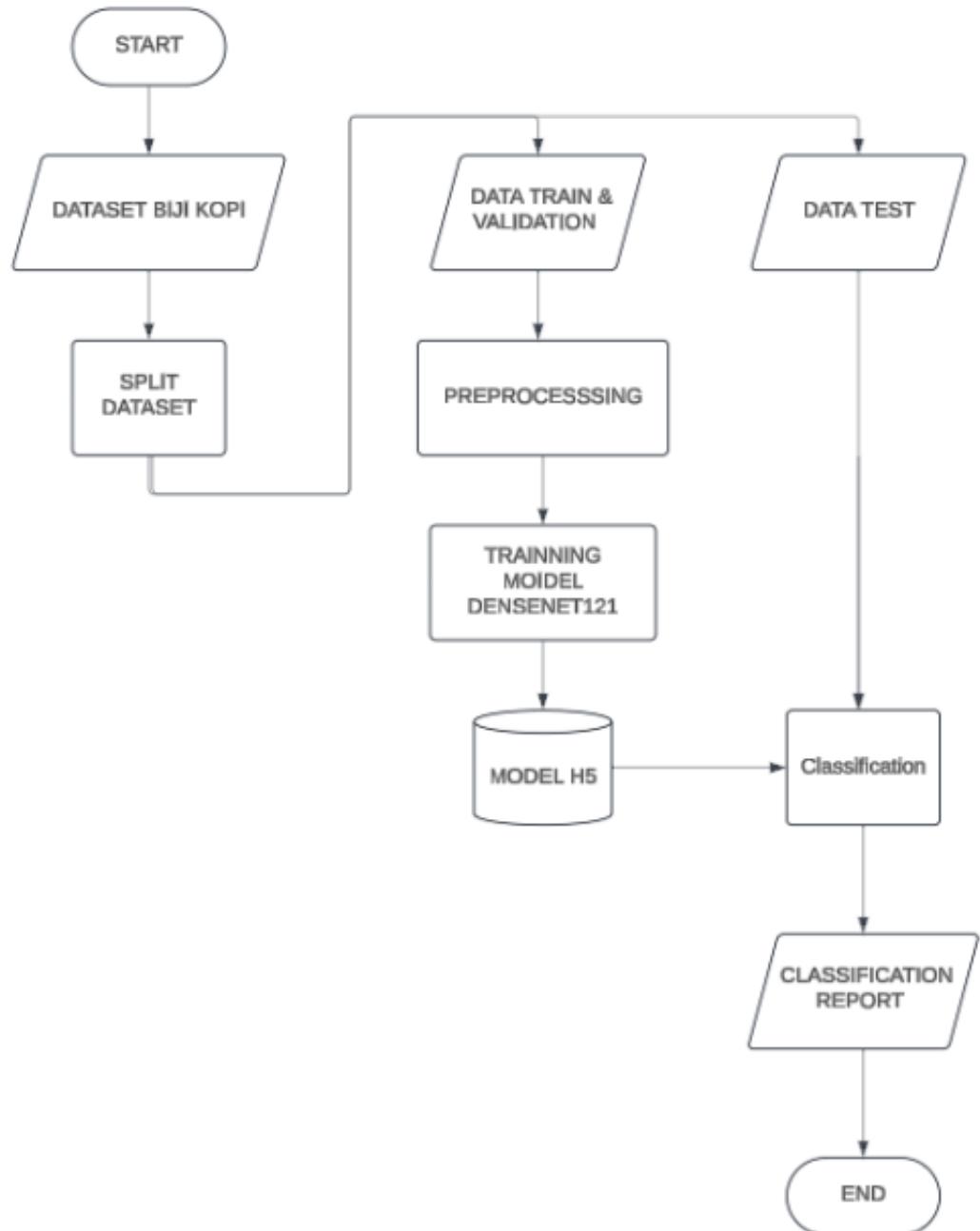
## **BAB 3**

### **ANALISIS DAN PERANCANGAN SISTEM**

Dari lima arsitektur tersebut diperoleh bahwa arsitektur DenseNet121 memberikan skor evaluasi tertinggi dan cepat pada proses klasifikasi citra dengan menggunakan learning rate yang sama sebesar 0.001

Maka dari itu pada penelitian ini akan mengimplementasikan algoritma CNN yang menggunakan arsitektur DenseNet121 pada objek biji kopi.

## GAMBARAN UMUM

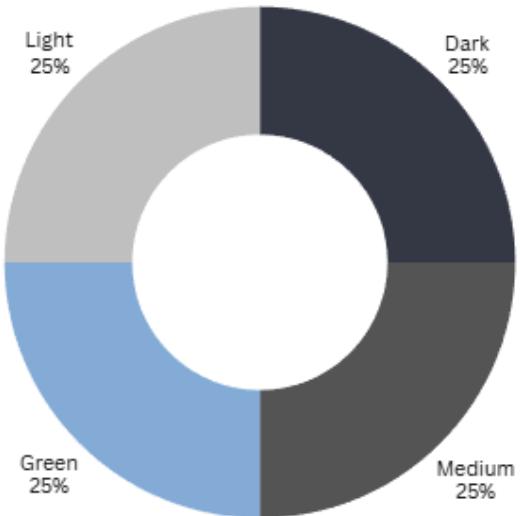
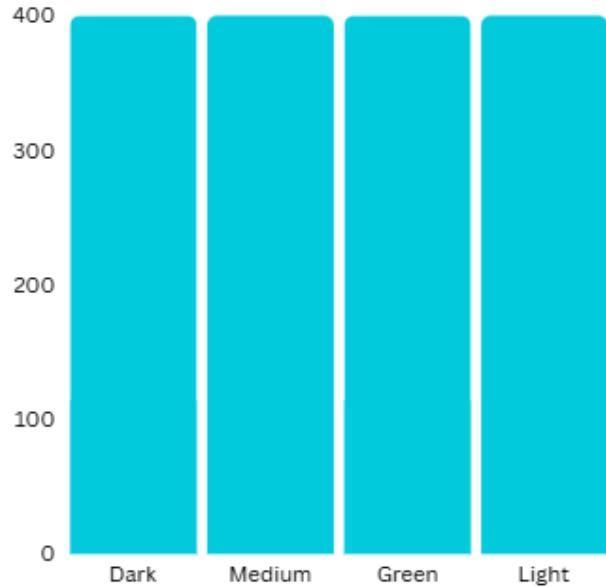


## BAB 3

### ANALISIS DAN PERANCANGAN SISTEM



# DATASET



Dataset penelitian ini menggunakan dataset publik yang diambil dari Kaggle  
[kaggle.com/datasets/gpiosenka/coffee-bean-dataset-resized-224-x-224](https://kaggle.com/datasets/gpiosenka/coffee-bean-dataset-resized-224-x-224) dengan format png. Dataset berjumlah **1600 gambar** yang terdiri dari 400 citra dark, 400 citra medium, 400 citra green, dan 400 citra light.

Dark



Medium



Green



Light



# DATASET

| Data         | Training (60%) | Testing (25%) | Validation (15%) |
|--------------|----------------|---------------|------------------|
|              | Jumlah         | Jumlah        | Jumlah           |
| Dark         | 240            | 100           | 60               |
| Medium       | 240            | 100           | 60               |
| Green        | 240            | 100           | 60               |
| Light        | 240            | 100           | 60               |
| <b>Total</b> | <b>960</b>     | <b>400</b>    | <b>240</b>       |

Data dibagi menjadi data training, data testing dan data validasi. Dari total **1600** data citra, akan dibagi sebanyak 60% data latih, 25% data validasi dan 15% data tes.

## BAB 3

### ANALISIS DAN PERANCANGAN SISTEM



# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### ANALISIS METODE PREPROCESSING



Dimensions    224 x 224  
Width            224 pixels  
Height          224 pixels

Dikarenakan data yang diambil sudah berukuran 224x224 dan sudah memenuhi kebutuhan model DenseNet121, maka tahap ini akan dilakukan augmentasi data yaitu horizontal flip.

# PREPROCESSING

## HORIZONTAL FLIP

dari gambar input diambil sample matrix dengan ukuran 5x5 untuk contoh perhitungan horizontal flip dan melakukan perhitungan dengan rumus:

$$M'[i][j][k] = M[i][n-j+1][k]$$



|   | 0                       | 1                       | 2                       | 3                       | 4                       |
|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 0 | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 |
| 1 | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  |
| 2 | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   |
| 3 | R=99<br>G=56<br>B=121   | R=120<br>G=210<br>B=121 | R=131<br>G=67<br>B=45   | R=12<br>G=56<br>B=123   | R=100<br>G=210<br>B=131 |
| 4 | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   |

i adalah indeks baris (dari 0 hingga n-1)

j adalah indeks kolom (dari 0 hingga n-1)

k adalah indeks channel warna (0 untuk merah, 1 untuk hijau, 2 untuk biru)

n adalah ukuran matriks (dalam kasus ini, n = 5)

# PREPROCESSING

## HORIZONTAL FLIP

diambil contoh perhitungan pada titik 0.0

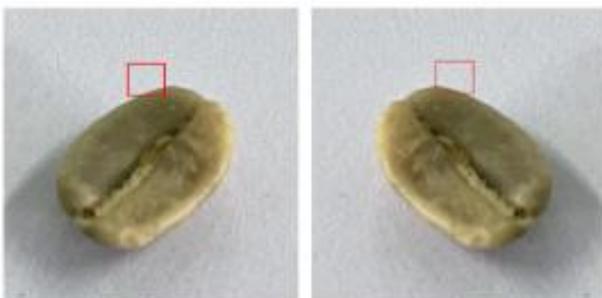
$$M'[i][j][k] = M[i][n-j+1][k]$$

$$M'[0][0][0] = M[0][5-1+1][0] = M[0][5][0] = 121 \text{ (merah)}$$

$$M'[0][0][1] = M[0][5-1+1][1] = M[0][5][1] = 123 \text{ (hijau)}$$

$$M'[0][0][2] = M[0][5-1+1][2] = M[0][5][2] = 221 \text{ (biru)}$$

maka nilai pada koordinat (0.0) yang semula adalah [120, 210, 121] telah berpindah ke koordinat (0, 4) dengan nilai [121, 123, 221] dan berikut matriks baru menjadi:



|   | 0                       | 1                       | 2                       | 3                       | 4                       |
|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 0 | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 |
| 1 | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  |
| 2 | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   |
| 3 | R=99<br>G=56<br>B=121   | R=120<br>G=210<br>B=121 | R=131<br>G=67<br>B=45   | R=12<br>G=56<br>B=123   | R=100<br>G=210<br>B=131 |
| 4 | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   |

|   | 0                       | 1                       | 2                       | 3                       | 4                       |
|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 0 | R=121<br>G=123<br>B=221 | R=111<br>G=78<br>B=99   | R=12<br>G=234<br>B=124  | R=67<br>G=208<br>B=223  | R=120<br>G=210<br>B=121 |
| 1 | R=111<br>G=123<br>B=32  | R=212<br>G=23<br>B=67   | R=220<br>G=110<br>B=11  | R=190<br>G=54<br>B=19   | R=90<br>G=78<br>B=122   |
| 2 | R=67<br>G=210<br>B=11   | R=34<br>G=89<br>B=23    | R=190<br>G=248<br>B=145 | R=120<br>G=210<br>B=121 | R=132<br>G=142<br>B=90  |
| 3 | R=100<br>G=210<br>B=131 | R=12<br>G=56<br>B=123   | R=131<br>G=67<br>B=45   | R=120<br>G=210<br>B=121 | R=99<br>G=56<br>B=121   |
| 4 | R=90<br>G=202<br>B=90   | R=111<br>G=200<br>B=156 | R=11<br>G=34<br>B=123   | R=120<br>G=210<br>B=121 | R=88<br>G=202<br>B=90   |

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

# ARSITEKTUR DENSENET

| Layers               | Output Size      | DenseNet-121                                       | DenseNet-169                                       | DenseNet-201                                       | DenseNet-264                                       |
|----------------------|------------------|--|--|--|--|
| Convolution          | $112 \times 112$ |  | $7 \times 7$ conv, stride 2                        |  |  |
| Pooling              | $56 \times 56$   |  | $3 \times 3$ max pool, stride 2                    |  |  |
| Dense Block (1)      | $56 \times 56$   | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 6$  | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 6$  | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 6$  | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 6$  |
| Transition Layer (1) | $56 \times 56$   |  |  | $1 \times 1$ conv                                  |  |
|                      | $28 \times 28$   |  |  | $2 \times 2$ average pool, stride 2                |  |
| Dense Block (2)      | $28 \times 28$   | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 12$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 12$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 12$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 12$ |
| Transition Layer (2) | $28 \times 28$   |  |  | $1 \times 1$ conv                                  |  |
|                      | $14 \times 14$   |  |  | $2 \times 2$ average pool, stride 2                |  |
| Dense Block (3)      | $14 \times 14$   | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 24$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 32$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 48$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 64$ |
| Transition Layer (3) | $14 \times 14$   |  |  | $1 \times 1$ conv                                  |  |
|                      | $7 \times 7$     |  |  | $2 \times 2$ average pool, stride 2                |  |
| Dense Block (4)      | $7 \times 7$     | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 16$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 32$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 32$ | $1 \times 1$ conv<br>$3 \times 3$ conv $\times 48$ |
| Classification Layer | $1 \times 1$     |  | $7 \times 7$ global average pool                   |  |  |
|                      |                  |  |  | 1000D fully-connected, softmax                     |  |

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121

#### CITRA INPUTAN

Pada proses konvolusi ini matriks dikeluarkan diambil dari gambar untuk proses perhitungan



|     | 0                       | 1                       | 2                       | 3                       | 4                       | ... | 223                    |
|-----|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-----|------------------------|
| 0   | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ... | R=76<br>G=89<br>B=224  |
| 1   | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  | ... | R=210<br>G=12<br>B=87  |
| 2   | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 3   | R=99<br>G=56<br>B=121   | R=120<br>G=210<br>B=121 | R=131<br>G=67<br>B=45   | R=12<br>G=56<br>B=123   | R=100<br>G=210<br>B=131 | ... | R=67<br>G=122<br>B=90  |
| 4   | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=80<br>B=111  |
| ... | ...                     | ...                     | ...                     | ...                     | ...                     | ... | ...                    |
| 223 | R=113<br>G=45<br>B=189  | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249  | ... | R=50<br>G=201<br>B=191 |

# PEMODELAN DENSENET 121

# ZERO PADDING

Pada proses zero padding dilakukan penambahan angka 0 di setiap sisi matriks sehingga ketika melakukan convolutional layer jumlah matriksnya akan sama

|     | 0                       | 1                       | 2                       | 3                       | 4                       | ... | 223                    |
|-----|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-----|------------------------|
| 0   | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ... | R=76<br>G=89<br>B=224  |
| 1   | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  | ... | R=210<br>G=12<br>B=87  |
| 2   | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 3   | R=99<br>G=56<br>B=121   | R=120<br>G=210<br>B=121 | R=131<br>G=67<br>B=45   | R=12<br>G=56<br>B=123   | R=100<br>G=210<br>B=131 | ... | R=67<br>G=122<br>B=90  |
| 4   | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=80<br>B=111  |
| ... | ...                     | ...                     | ...                     | ...                     | ...                     | ... | ...                    |
| 223 | R=113<br>G=45<br>B=189  | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249  | ... | R=50<br>G=201<br>B=191 |



### PEMODELAN DENSENET 121

#### PERHITUNGAN KERNEL

$$(O) = \frac{I - K + 2P}{S} + 1$$

- O ADALAH UKURAN OUTPUT
- I ADALAH UKURAN INPUT
- K ADALAH UKURAN KERNEL
- P ADALAH PADDING
- S ADALAH STRIDE

$$(O) = \frac{224 - 7 + 2 \times 3}{2} + 1$$

$$(O) = \frac{222}{2} + 1$$

$$(O) = 111 + 1$$

$$(O) = 112$$

Jadi, ukuran output C1 adalah 112x112. Ini adalah ukuran matriks hasil konvolusi setelah kernel 7×7 diterapkan ke matriks input dengan stride 2.



# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

# PEMODELAN DENSENET 121

## KONVOLUSI 7X7 STRIDE 2

Pada proses konvolusi ini dilakukan proses perkalian antara matriks citra input dengan kernel filter 7x7.

|     | 0 | 1                       | 2                      | 3                      | 4                       | 5                       | 6                       | 7                      | ... | 226                    |
|-----|---|-------------------------|------------------------|------------------------|-------------------------|-------------------------|-------------------------|------------------------|-----|------------------------|
| 0   | 0 | 0                       | 0                      | 0                      | 0                       | 0                       | 0                       | 0                      | 0   | 0                      |
| 1   | 0 | 0                       | 0                      | 0                      | 0                       | 0                       | 0                       | 0                      | 0   | 0                      |
| 2   | 0 | 0                       | 0                      | 0                      | 0                       | 0                       | 0                       | 0                      | 0   | 0                      |
| 3   |   | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223 | R=12<br>G=234<br>B=124 | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ...                     | R=76<br>G=89<br>B=224  |     |                        |
| 4   | 0 | 0                       | 0                      | R=90<br>G=78<br>B=122  | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32 | ... | R=210<br>G=12<br>B=87  |
| 5   | 0 | 0                       | 0                      | R=132<br>G=142<br>B=90 | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11  | ... | R=121<br>G=67<br>B=45  |
| 6   | 0 | 0                       | 0                      | R=88<br>G=211<br>B=129 | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90  | ... | R=91<br>G=80<br>B=111  |
| ... | 0 | 0                       | 0                      | ...                    | ...                     | ...                     | ...                     | ...                    | ... | 0 0 0                  |
| 226 | 0 | 0                       | 0                      | R=113<br>G=45<br>B=189 | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249 | ... | R=50<br>G=201<br>B=191 |
|     | 0 | 0                       | 0                      | 0                      | 0                       | 0                       | 0                       | 0                      | 0   | 0 0 0                  |
|     | 0 | 0                       | 0                      | 0                      | 0                       | 0                       | 0                       | 0                      | 0   | 0 0 0                  |

matriks citra inputan 15x15

X

|    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| -1 | -3 | 7  | 24 | 7  | -3 | -1 |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |

Kernel filter 7x7

# PEMODELAN DENSENET 121

## KONVOLUSI 7X7 STRIDE 2 (0,0)

Pada proses konvolusi ini dilakukan proses perkalian antara matriks citra input dengan kernel filter 7x7.

|     | 0 | 1 | 2 | 3                       | 4                       | 5                       | 6                       | 7                       | ... | 226                    |
|-----|---|---|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-----|------------------------|
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 1   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 2   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 3   | 0 | 0 | 0 | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ... | R=76<br>G=89<br>B=224  |
| 4   | 0 | 0 | 0 | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  | ... | R=210<br>G=12<br>B=87  |
| 5   | 0 | 0 | 0 | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 6   | 0 | 0 | 0 | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=80<br>B=111  |
| ... | 0 | 0 | 0 | ...                     | ...                     | ...                     | ...                     | ...                     | 0   | 0                      |
| 226 | 0 | 0 | 0 | R=113<br>G=45<br>B=189  | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249  | ... | R=50<br>G=201<br>B=191 |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |

|   | RED |   |   |     |     |     |     |
|---|-----|---|---|-----|-----|-----|-----|
|   | 1   | 2 | 3 | 4   | 5   | 6   | 7   |
| 1 | 0   | 0 | 0 | 0   | 0   | 0   | 0   |
| 2 | 0   | 0 | 0 | 0   | 0   | 0   | 0   |
| 3 | 0   | 0 | 0 | 0   | 0   | 0   | 0   |
| 4 | 0   | 0 | 0 | 120 | 67  | 12  | 111 |
| 5 | 0   | 0 | 0 | 90  | 190 | 220 | 212 |
| 6 | 0   | 0 | 0 | 132 | 120 | 190 | 34  |
| 7 | 0   | 0 | 0 | 88  | 120 | 11  | 111 |

X

|    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| -1 | -3 | 7  | 24 | 7  | -3 | -1 |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |

$$\text{RED}(0,0) = (0*0) + (0*0) + (0*-1) + (0*-1) + (0*-1) + (0*0) + (0*0) + (0*0) + \dots + (111*0) = 65$$

## PEMODELAN DENSENET 121

### KONVOLUSI 7X7 STRIDE 2 (0,0)

Pada proses konvolusi ini dilakukan proses perkalian antara matriks citra input dengan kernel filter 7x7.

|     | 0 | 1 | 2 | 3                       | 4                       | 5                       | 6                       | 7                       | ... | 226                    |
|-----|---|---|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-----|------------------------|
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 1   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 2   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 3   | 0 | 0 | 0 | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ... | R=76<br>G=89<br>B=224  |
| 4   | 0 | 0 | 0 | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  | ... | R=210<br>G=12<br>B=87  |
| 5   | 0 | 0 | 0 | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 6   | 0 | 0 | 0 | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=80<br>B=111  |
| ... | 0 | 0 | 0 | ...                     | ...                     | ...                     | ...                     | ...                     | 0   | 0                      |
| 226 | 0 | 0 | 0 | R=113<br>G=45<br>B=189  | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249  | ... | R=50<br>G=201<br>B=191 |
|     | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
|     | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
|     | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |

**GREEN**

|   | 1 | 2 | 3 | 4   | 5   | 6   | 7   |
|---|---|---|---|-----|-----|-----|-----|
| 1 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 2 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 3 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 4 | 0 | 0 | 0 | 210 | 208 | 234 | 78  |
| 5 | 0 | 0 | 0 | 78  | 54  | 110 | 23  |
| 6 | 0 | 0 | 0 | 142 | 210 | 248 | 89  |
| 7 | 0 | 0 | 0 | 211 | 210 | 34  | 200 |

**X**

|    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| -1 | -3 | 7  | 24 | 7  | -3 | -1 |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |

$$\text{GREEN}(0,0) = (0*0) + (0*0) + (0*-1) + (0*-1) + (0*0) + (0*0) + (0*0) + (0*0) \dots + (200*0) = 74$$

# PEMODELAN DENSENET 121

## KONVOLUSI 7X7 STRIDE 2 (0,0)

Pada proses konvolusi ini dilakukan proses perkalian antara matriks citra input dengan kernel filter 7x7.

|     | 0 | 1 | 2 | 3                       | 4                       | 5                       | 6                       | 7                       | ... | 226                    |
|-----|---|---|---|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-----|------------------------|
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 1   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 2   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 3   | 0 | 0 | 0 | R=120<br>G=210<br>B=121 | R=67<br>G=208<br>B=223  | R=12<br>G=234<br>B=124  | R=111<br>G=78<br>B=99   | R=121<br>G=123<br>B=221 | ... | R=76<br>G=89<br>B=224  |
| 4   | 0 | 0 | 0 | R=90<br>G=78<br>B=122   | R=190<br>G=54<br>B=19   | R=220<br>G=110<br>B=11  | R=212<br>G=23<br>B=67   | R=111<br>G=123<br>B=32  | ... | R=210<br>G=12<br>B=87  |
| 5   | 0 | 0 | 0 | R=132<br>G=142<br>B=90  | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23    | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 6   | 0 | 0 | 0 | R=88<br>G=211<br>B=129  | R=120<br>G=210<br>B=121 | R=11<br>G=34<br>B=123   | R=111<br>G=200<br>B=156 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=80<br>B=111  |
| ... | 0 | 0 | 0 | ...                     | ...                     | ...                     | ...                     | ...                     | 0   | 0                      |
| 226 | 0 | 0 | 0 | R=113<br>G=45<br>B=189  | R=156<br>G=40<br>B=91   | R=80<br>G=99<br>B=124   | R=120<br>G=243<br>B=187 | R=98<br>G=102<br>B=249  | ... | R=50<br>G=201<br>B=191 |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |
| 0   | 0 | 0 | 0 | 0                       | 0                       | 0                       | 0                       | 0                       | 0   | 0                      |

**BLUE**

|   | 1 | 2 | 3 | 4   | 5   | 6   | 7   |
|---|---|---|---|-----|-----|-----|-----|
| 1 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 2 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 3 | 0 | 0 | 0 | 0   | 0   | 0   | 0   |
| 4 | 0 | 0 | 0 | 121 | 223 | 124 | 99  |
| 5 | 0 | 0 | 0 | 122 | 19  | 11  | 67  |
| 6 | 0 | 0 | 0 | 90  | 121 | 145 | 23  |
| 7 | 0 | 0 | 0 | 129 | 121 | 123 | 156 |

X

|    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| -1 | -3 | 7  | 24 | 7  | -3 | -1 |
| -1 | -3 | 0  | 7  | 0  | -3 | -1 |
| 0  | -1 | -3 | -3 | -3 | -1 | 0  |
| 0  | 0  | -1 | -1 | -1 | 0  | 0  |

$$\text{Blue}(0,0) = (0*0) + (0*0) + (0*-1) + (0*-1) + (0*0) + (0*0) + (0*0) + (0*0) + \dots + (0*0) = 91$$

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

## PEMODELAN DENSENET 121

### HASIL KONVOLUSI 7X7 STRIDE 2

DAPAT DISIMPULKAN BAHWA HASIL DARI KONVOLUSI 7X7 DENGAN STRIDE 2 PADA POSISI 0,0 UNTUK SETIAP SALURAN (R,G,B) ADALAH (65,74,91) DAN HASIL TERSEBUT AKAN DIMASUKAN KEDALAM MATRIKS BARU BERUKURAN 112X112

|     | 0   | 1                       | 2                       | 3                      | 4                       | ... | 111                    |
|-----|---|-------------------------|-------------------------|------------------------|-------------------------|-----|------------------------|
| 0   | <b>R=65</b><br><b>G=74</b><br><b>B=91</b> | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23   | R=67<br>G=210<br>B=11   | ... | R=76<br>G=89<br>B=224  |
| 1   | R=45<br>G=19<br>B=121                     | R=89<br>G=90<br>B=12    | R=131<br>G=99<br>B=11   | R=89<br>G=23<br>B=67   | R=90<br>G=56<br>B=32    | ... | R=45<br>G=19<br>B=121  |
| 2   | R=132<br>G=142<br>B=90                    | R=120<br>G=210<br>B=121 | R=190<br>G=248<br>B=145 | R=34<br>G=89<br>B=23   | R=67<br>G=210<br>B=11   | ... | R=121<br>G=67<br>B=45  |
| 3   | R=222<br>G=207<br>B=24                    | R=224<br>G=210<br>B=23  | R=219<br>G=209<br>B=15  | R=220<br>G=210<br>B=22 | R=100<br>G=210<br>B=131 | ... | R=221<br>G=22<br>B=131 |
| 4   | R=222<br>G=208<br>B=24                    | R=221<br>G=211<br>B=20  | R=224<br>G=215<br>B=20  | R=214<br>G=206<br>B=17 | R=90<br>G=202<br>B=90   | ... | R=91<br>G=90<br>B=78   |
| ... | ...                                       | ...                     | ...                     | ...                    | ...                     | ... | ...                    |
| 111 | R=136<br>G=122<br>B=33                    | R=143<br>G=129<br>B=40  | R=158<br>G=144<br>B=55  | R=166<br>G=152<br>B=63 | R=174<br>G=162<br>B=71  | ... | R=50<br>G=212<br>B=90  |

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121

#### BATCH NORMALIZATION

Setelah proses convolutional layer maka hasilnya dilakukan untuk kebutuhan proses ***batch normalization***, pada tahap proses batch normalization terdapat beberapa tahapan diantaranya ***mean mini batch, varians mini batch, normalize.***

##### **1. MEAN MINI BATCH**

DIASUMSIKAN UNTUK HASIL MEAN MINI BATCH DARI PADA BATCH PERTAMA ADALAH  
 $R = 117.28, G = 126.4, B = 46.12$

##### **2. VARIANS MINI BATCH**

DI ASUMSIKAN UNTUK HASIL VARIANCE MINI BATCH DARI PADA BATCH PERTAMA ADALAH  
 $R = 117.28, G = 126.4, B = 46.12$

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 HASIL BATCH NORMALIZATION - NORMALIZE

|     | 0   | 1                                  | 2                                 | 3                                  | 4                               | ... | 111                                |
|-----|---|------------------------------------|-----------------------------------|------------------------------------|---------------------------------|-----|------------------------------------|
| 0   | R= <b>-0.688</b><br>G= <b>-0.643</b><br>B= <b>0.709</b> | R= 0.035<br>G= 1.026<br>B= 1.184   | R= 0.912<br>G= -0.643<br>B= 0.709 | R= 0.956<br>G= 1.643<br>B= 1.709   | R=0.694<br>G=0.616<br>B=-0.812  | ... | R=0.914<br>G=0.875<br>B=-0.114     |
| 1   | R= 0.122<br>G= 0.012<br>B= -0.686                       | R=1.688<br>G=1.643<br>B= -0.709    | R=0.757<br>G=0.686<br>B= -0.843   | R=0.678<br>G=0.616<br>B= -0.859    | R=0.718<br>G=0.647<br>B= -0.788 | ... | R=-0.688<br>G=-0.643<br>B=0.709    |
| 2   | R=0.239<br>G=0.129<br>B=-0.569                          | R=1.288<br>G=0.893<br>B=0.709      | R=0.710<br>G=0.639<br>B=-0.867    | R=0.678<br>G=0.616<br>B=-0.859     | R=0.631<br>G=0.561<br>B=-0.898  | ... | R=1.688<br>G=0.943<br>B=1.909      |
| 3   | R=0.302<br>G=0.192<br>B=-0.506                          | R= -0.881<br>G= -0.234<br>B= 0.455 | R= 0.912<br>G= -0.643<br>B= 0.709 | R= -0.688<br>G= -0.643<br>B= 0.709 | R=0.671<br>G=0.592<br>B= -0.843 | ... | R= -0.688<br>G= -0.643<br>B= 0.709 |
| 4   | R=0.749<br>G=0.671<br>B=-0.725                          | R= 0.912<br>G= -0.643<br>B= 0.709  | R=0.749<br>G=0.671<br>B= -0.725   | R= 0.912<br>G= -0.643<br>B= 0.709  | R=0.749<br>G=0.671<br>B= -0.725 | ... | R= 0.956<br>G= 1.643<br>B= 1.709   |
| ... | ...   | ...                                | ...                               | ...                                | ...                             | ... | ...                                |
| 111 | R=0.741<br>G=0.631<br>B=-0.812                          | R=0.733<br>G=0.655<br>B=-0.843     | R=0.757<br>G=0.686<br>B=-0.843    | R=0.678<br>G=0.616<br>B=-0.859     | R=-0.123<br>G=-0.634<br>B=0.234 | ... | R= -0.645<br>G= -0.234<br>B= 0.342 |

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 RELU ACTIVATION

|     | 0                                  | 1                                  | 2                                 | 3                                  | 4                                 | ... | 111                              |
|-----|------------------------------------|------------------------------------|-----------------------------------|------------------------------------|-----------------------------------|-----|----------------------------------|
| 0   | R= -0.688<br>G= -0.643<br>B= 0.709 | R= 0.035<br>G= 1.026<br>B= 1.184   | R= 0.912<br>G= -0.643<br>B= 0.709 | R= 0.956<br>G= 1.643<br>B= 1.709   | R= 0.694<br>G= 0.616<br>B= -0.812 | ... | R=0.914<br>G=0.875<br>B=-0.114   |
| 1   | R= 0.122<br>G= 0.012<br>B= -0.686  | R=1.688<br>G=1.643<br>B=-0.709     | R=0.757<br>G=0.686<br>B=-0.843    | R=0.678<br>G=0.616<br>B=-0.859     | R=0.718<br>G=0.647<br>B=-0.788    | ... | R=-0.688<br>G=-0.643<br>B=0.709  |
| 2   | R=0.239<br>G=0.129<br>B=-0.569     | R=1.288<br>G=0.893<br>B=0.709      | R=0.710<br>G=0.639<br>B=-0.867    | R=0.678<br>G=0.616<br>B=-0.859     | R=0.631<br>G=0.561<br>B=-0.898    | ... | R=1.688<br>G=0.943<br>B=1.909    |
| 3   | R=0.302<br>G=0.192<br>B=-0.506     | R= -0.881<br>G= -0.234<br>B= 0.455 | R= 0.912<br>G= -0.643<br>B= 0.709 | R= -0.688<br>G= -0.643<br>B= 0.709 | R= 0.671<br>G= 0.592<br>B= -0.843 | ... | R=-0.688<br>G=-0.643<br>B=0.709  |
| 4   | R=0.749<br>G=0.671<br>B=-0.725     | R= 0.912<br>G= -0.643<br>B= 0.709  | R=0.749<br>G=0.671<br>B=-0.725    | R= 0.912<br>G= -0.643<br>B= 0.709  | R= 0.749<br>G= 0.671<br>B= -0.725 | ... | R= 0.956<br>G= 1.643<br>B= 1.709 |
| ... | ...                                | ...                                | ...                               | ...                                | ...                               | ... | ...                              |
| 111 | R=0.741<br>G=0.631<br>B=-0.812     | R=0.733<br>G=0.655<br>B=-0.843     | R=0.757<br>G=0.686<br>B=-0.843    | R=0.678<br>G=0.616<br>B=-0.859     | R=0.123<br>G=0.634<br>B=0.234     | ... | R=-0.645<br>G=-0.234<br>B=0.342  |

$$R \text{ (RED)} = -0.688$$

$$F(X) = \text{MAKS}(0, X)$$

$$F(0.0) = \text{MAKS}(0, -0.688) = 0$$

$$G \text{ (GREEN)} = -0.688$$

$$F(X) = \text{MAKS}(0, X)$$

$$F(0.0) = \text{MAKS}(0, -0.688) = 0$$

$$B \text{ (BLUE)} = 0.709$$

$$F(X) = \text{MAKS}(0, X)$$

$$F(0.0) = \text{MAKS}(0, 0.709) = 0.709$$

# PEMODELAN DENSENET 121

## HASIL RELU ACTIVATION

### BAB 3

#### ANALISIS DAN PERANCANGAN SISTEM

|     | 0                            | 1                                | 2                            | 3                                | 4                          | ... | 111                                |
|-----|------------------------------|----------------------------------|------------------------------|----------------------------------|----------------------------|-----|------------------------------------|
| 0   | R= 0<br>G= 0<br>B= 0.709     | R= 0.035<br>G= 1.026<br>B= 1.184 | R= 0.912<br>G= 0<br>B= 0.709 | R= 0.956<br>G= 1.643<br>B= 1.709 | R=0.694<br>G=0.616<br>B= 0 | ... | R=0.914<br>G=0.875<br>B=0          |
| 1   | R= 0.122<br>G= 0.012<br>B= 0 | R=1.688<br>G=1.643<br>B= 0       | R=0.757<br>G=0.686<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R=0.718<br>G=0.647<br>B= 0 | ... | R= 0<br>G= 0<br>B=0.709            |
| 2   | R=0.239<br>G=0.129<br>B= 0   | R=1.288<br>G=0.893<br>B= 0.709   | R=0.710<br>G=0.639<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R=0.631<br>G=0.561<br>B= 0 | ... | R=1.688<br>G=0.943<br>B=1.909      |
| 3   | R=0.302<br>G=0.192<br>B= 0   | R=0<br>G= 0<br>B= 0.455          | R= 0.912<br>G= 0<br>B= 0.709 | R=-0.688<br>G= 0<br>B=0.709      | R=0.671<br>G=0.592<br>B= 0 | ... | R= 0<br>G= 0<br>B=0.709            |
| 4   | R=0.749<br>G=0.671<br>B= 0   | R= 0.912<br>G= 0<br>B= 0.709     | R=0.749<br>G=0.671<br>B= 0   | R= 0.912<br>G= 0<br>B= 0.709     | R=0.749<br>G=0.671<br>B= 0 | ... | R= 0.956<br>G= 1.643<br>B= 1.709   |
| ... | ...                          | ...                              | ...                          | ...                              | ...                        | ... | ...                                |
| 111 | R=0.741<br>G=0.631<br>B= 0   | R=0.733<br>G=0.655<br>B= 0       | R=0.757<br>G=0.686<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R= 0<br>G= 0<br>B= 0.234   | ... | R= -0.645<br>G= -0.234<br>B= 0.342 |

MATRIKS RGB SETELAH RELU ACTIVATION

# PEMODELAN DENSENET 121

## BAB 3

### MAX POOLING 3X3 STRIDE 2

PADA PROSES MAX POOLING AKAN MEMILIH OPERASI MATRIKS 3X3 2 STRIDES DAN DIAMBIL NILAI PALING BESAR

ANALISIS DAN  
PERANCANGAN SISTEM

|     | 0                            | 1                                | 2                            | 3                                | 4                            | ... | 111                              |
|-----|------------------------------|----------------------------------|------------------------------|----------------------------------|------------------------------|-----|----------------------------------|
| 0   | R= 0<br>G= 0<br>B= 0.709     | R= 0.035<br>G= 1.026<br>B= 1.184 | R= 0.912<br>G= 0<br>B= 0.709 | R= 0.956<br>G= 1.643<br>B= 1.709 | R= 0.694<br>G= 0.616<br>B= 0 | ... | R=0.914<br>G=0.875<br>B=0        |
| 1   | R= 0.122<br>G= 0.012<br>B= 0 | R=1.688<br>G=1.643<br>B= 0       | R=0.757<br>G=0.686<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R=0.718<br>G=0.647<br>B= 0   | ... | R= 0<br>G= 0<br>B=0.709          |
| 2   | R=0.239<br>G=0.129<br>B= 0   | R=1.288<br>G=0.893<br>B= 0.709   | R=0.710<br>G=0.639<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R=0.631<br>G=0.561<br>B= 0   | ... | R=1.688<br>G=0.943<br>B=1.909    |
| 3   | R=0.302<br>G=0.192<br>B= 0   | R=0<br>G= 0<br>B= 0.455          | R= 0.912<br>G= 0<br>B= 0.709 | R=-0.688<br>G= 0<br>B= 0.709     | R=0.671<br>G=0.592<br>B= 0   | ... | R= 0<br>G= 0<br>B=0.709          |
| 4   | R=0.749<br>G=0.671<br>B= 0   | R= 0.912<br>G= 0<br>B= 0.709     | R=0.749<br>G=0.671<br>B= 0   | R=0.912<br>G=0.671<br>B= 0.709   | R=0.749<br>G=0.671<br>B= 0   | ... | R= 0.956<br>G= 1.643<br>B= 1.709 |
| ... | ...                          | ...                              | ...                          | ...                              | ...                          | ... | ...                              |
| 111 | R=0.741<br>G=0.631<br>B= 0   | R=0.733<br>G=0.655<br>B= 0       | R=0.757<br>G=0.686<br>B= 0   | R=0.678<br>G=0.616<br>B= 0       | R= 0<br>G= 0<br>B= 0.234     | ... | R=-0.645<br>G=-0.234<br>B= 0.342 |

Proses max pooling 3x3 stride 2

- A) R (RED) = MAX{0, 0.035, 0.912, 0.122, 1.688, 0.757, 0.239, 1.288, 0.710}  
= 1.688
- B) G (GREEN) = MAX{ 0, 1.026, 0, 0.012, 1.643, 0.686, 0.129, 0.893, 0.639}  
= 1.643
- C) B (BLUE) = MAX{0.709, 1.184, 0.709, 0, 0, 0, 0, 0.709, 0}  
= 1.184

|     | 0                                | 1                                | 2                                | 3                                | 4                                | ... | 55                               |
|-----|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-----|----------------------------------|
| 0   | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 0.912<br>G= 1.643<br>B= 0.709 | R= 0.956<br>G= 1.643<br>B= 1.709 | R= 0.694<br>G= 0.616<br>B= 1.709 | ... | R=1.234<br>G=1.452<br>B=1.322    |
| 1   | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.688<br>G=1.643<br>B= 0.871   | R= 1.694<br>G= 1.012<br>B= 1.909 | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.122<br>G= 1.012<br>B= 0.987 | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 2   | R=1.239<br>G=1.129<br>B= 1.236   | R=1.288<br>G=0.893<br>B= 0.709   | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 1.749<br>G=1.671<br>B= 0.982  | R= 1.749<br>G=1.671<br>B= 0.982  | ... | R=1.688<br>G=0.943<br>B=1.909    |
| 3   | R=1.302<br>G=1.192<br>B= 0.872   | R=0.694<br>G= 0.616<br>B= 1.709  | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.749<br>G=0.981<br>B= 1.125  | R= 1.749<br>G=1.671<br>B= 0.982  | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 4   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.912<br>G= 1.123<br>B= 1.709 | R= 1.749<br>G= 0.981<br>B= 1.125 | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.749<br>G=0.671<br>B= 1.762  | ... | R= 0.956<br>G= 1.643<br>B= 1.709 |
| ... | ...                              | ...                              | ...                              | ...                              | ...                              | ... | ...                              |
| 55  | R=0.741<br>G=0.631<br>B= 1.125   | R=1.733<br>G=0.655<br>B= 0.987   | R=1.757<br>G=1.686<br>B= 1.896   | R=1.678<br>G=0.616<br>B= 1.243   | R= 0.956<br>G= 1.643<br>B= 1.709 | ... | R= 1.956<br>G= 0.633<br>B= 1.709 |

hasil max pooling 3x3 stride 2

# PEMODELAN DENSENET 121

## AVERAGE POOLING 3X3 STRIDE 2

SETELAH MELAKUKAN MAX POOLING DAN MENGHASILKAN OUTPUT BERUKURAN 56 X 56 MAKA DILAKUKAN PROSES AVERAGE POOLING 3X3 STRIDE 2

|     | 0                                | 1                                | 2                                | 3                                | 4                                | ... | 56                               |
|-----|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-----|----------------------------------|
| 0   | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 0.912<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.643<br>B= 0.709 | R= 0.694<br>G= 0.616<br>B= 1.709 | ... | R=1.234<br>G=1.452<br>B=1.322    |
| 1   | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.688<br>G= 1.643<br>B= 0.871 | R= 1.694<br>G= 0.161<br>B= 1.909 | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.122<br>G= 1.012<br>B= 0.987 | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 2   | R=1.239<br>G=1.129<br>B= 1.236   | R=1.288<br>G=0.893<br>B=0.709    | R= 0.694<br>G= 0.616<br>B= 1.709 | R=1.749<br>G=1.671<br>B= 0.982   | R=1.749<br>G=1.671<br>B= 0.982   | ... | R=1.688<br>G=0.943<br>B=1.909    |
| 3   | R=1.302<br>G=1.192<br>B= 0.872   | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 0.956<br>G= 1.026<br>B= 1.184 | R=1.749<br>G=1.671<br>B= 1.125   | R=1.749<br>G=1.671<br>B= 0.982   | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 4   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.912<br>G= 1.123<br>B= 1.709 | R= 1.749<br>G= 0.981<br>B= 1.125 | R= 1.749<br>G= 1.012<br>B= 0.987 | R= 1.749<br>G= 1.012<br>B= 1.762 | ... | R= 0.956<br>G= 1.026<br>B= 1.709 |
| ... | ...                              | ...                              | ...                              | ...                              | ...                              | ... | ...                              |
| 56  | R=0.741<br>G=0.631<br>B= 1.125   | R=1.733<br>G=0.655<br>B= 0.987   | R=1.757<br>G=1.686<br>B= 1.896   | R=1.678<br>G=0.616<br>B= 1.243   | R= 0.956<br>G= 1.643<br>B= 1.709 | ... | R= 1.956<br>G= 0.633<br>B= 1.709 |

Proses average pooling 3x3 stride 2

$$\begin{aligned} \text{A) R (RED)} &= (1.688+0.956+0.912+1.122+1.688+1.694 +1.239+1.288+0.694)/9 \\ &= 1.253 \\ \text{A) G (GREEN)} &= (1.122+1.026+0.643+1.012+1.643+1.161 +1.129+0.893+0.616)/9 \\ &= 1.027 \\ \text{A) B (BLUE)} &= (1.184+0.184+0.709+0.987+1.688+0.871 +1.909+1.709+0.709)/9 \\ &= 1.016 \end{aligned}$$

|     | 0                                | 1                                | 2                                | 3                                | 4                                | ... | 27                               |
|-----|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-----|----------------------------------|
| 0   | R=1.253<br>G=1.027<br>B= 1.016   | R=1.757<br>G=1.686<br>B= 1.896   | R=1.688<br>G=0.943<br>B=1.909    | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | ... | R=1.749<br>G=1.671<br>B= 0.982   |
| 1   | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.733<br>G= 0.655<br>B= 0.987 | R= 1.122<br>G= 1.012<br>B= 0.987 | ... | R= 1.749<br>G= 0.981<br>B= 1.125 |
| 2   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 1.125 | R= 1.749<br>G= 1.671<br>B= 0.982 | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | ... | R= 1.688<br>G= 0.943<br>B= 1.909 |
| 3   | R=1.688<br>G=0.943<br>B=1.909    | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.122<br>G= 1.012<br>B= 0.987  | R=1.688<br>G=1.643<br>B= 0.871   | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 4   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.749<br>G= 1.671<br>B= 0.982 | R= 1.749<br>G= 1.671<br>B= 0.982 | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 0.956<br>G= 1.026<br>B= 1.184 | ... | R= 0.956<br>G= 1.026<br>B= 1.184 |
| ... | ...                              | ...                              | ...                              | ...                              | ...                              | ... | ...                              |
| 27  | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.688<br>G= 0.943<br>B= 1.909 | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.688<br>G=0.943<br>B=1.909    | ... | R=1.749<br>G=1.671<br>B= 0.982   |

hasil average pooling 3x3 stride 2

## BAB 3

ANALISIS DAN

PERANCANGAN SISTEM

# PEMODELAN DENSENET 121

## AVERAGE POOLING 3X3 STRIDE 2

LANGKAH AVERAGE POOLING DILAKUKAN SELAMA 3X HINGGA MENGHASILKAN OUTPUT SEBESAR 7X7 UNTUK DILAKUKAN PROSES GLOBAL AVERAGE POOLING

|   | 0                                | 1                                | 2                                | 3                                | 4                                | 5                                | 6                                |
|---|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 0 | R=1.253<br>G=1.027<br>B= 1.016   | R=1.757<br>G=1.686<br>B= 1.896   | R=1.688<br>G=0.943<br>B= 1.909   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 0.956<br>G= 1.026<br>B= 1.184 | R=1.749<br>G=1.671<br>B= 0.982   |
| 1 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R=1.733<br>G=0.655<br>B= 0.987   | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.749<br>G=1.671<br>B= 0.982  | R=1.749<br>G=0.981<br>B= 1.125   |
| 2 | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.749<br>G= 1.671<br>B= 0.982 | R= 1.688<br>G= 1.643<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.688<br>G=0.943<br>B= 1.909   |
| 3 | R=1.688<br>G=0.943<br>B=1.909    | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.688<br>G=1.643<br>B= 0.987   | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 4 | R=1.749<br>G=1.671<br>B= 0.982   | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.749<br>G= 1.671<br>B= 0.982 | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 1.749<br>G=1.671<br>B= 0.982  | R= 0.956<br>G= 1.026<br>B= 1.184 |
| 5 | R= 0.694<br>G= 0.616<br>B= 1.709 | R= 0.956<br>G= 1.026<br>B= 1.184 | R= 0.956<br>G= 1.026<br>B= 1.184 | R=1.733<br>G=0.655<br>B= 0.987   | R= 1.749<br>G=1.671<br>B= 0.982  | R= 1.749<br>G=1.671<br>B= 0.982  | R= 1.122<br>G= 1.012<br>B= 0.987 |
| 6 | R=1.749<br>G=1.671<br>B= 0.982   | R=1.688<br>G=0.943<br>B=1.909    | R=1.749<br>G=1.671<br>B= 0.982   | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.688<br>G=0.943<br>B=1.909    | R= 1.122<br>G= 1.012<br>B= 0.987 | R=1.749<br>G=1.671<br>B= 0.982   |

## BAB 3

ANALISIS DAN

PERANCANGAN SISTEM

# PEMODELAN DENSENET 121

## PENGGABUNGAN RGB

MATRIKS HASIL PROSES AVERAGE POOLING DIJUMLAHKAN YANG SUDAH MELALUI TAHAPAN PERHITUNGAN DIJUMLAHKAN SEHINGGA MENGHASILKAN OUTPUT 1 CHANNEL SEBAGAI CHANNEL GABUNGAN RGB

|   | 0     | 1     | 2     | 3     | 4     | 5     | 6     |
|---|-------|-------|-------|-------|-------|-------|-------|
| 0 | 3.296 | 5.339 | 4.54  | 4.402 | 3.121 | 3.166 | 4.402 |
| 1 | 3.166 | 4.515 | 3.166 | 3.375 | 3.121 | 4.402 | 3.855 |
| 2 | 4.402 | 3.121 | 4.402 | 4.515 | 3.166 | 3.121 | 4.54  |
| 3 | 4.54  | 4.402 | 3.121 | 3.121 | 4.202 | 3.019 | 3.166 |
| 4 | 4.402 | 4.402 | 4.402 | 3.019 | 3.166 | 4.402 | 3.166 |
| 5 | 3.019 | 3.166 | 3.166 | 3.375 | 4.402 | 4.402 | 3.121 |
| 6 | 4.402 | 4.54  | 4.402 | 3.121 | 4.54  | 3.121 | 4.402 |

## BAB 3

ANALISIS DAN

PERANCANGAN SISTEM

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

RATA-RATA Matriks Depth KE-1: 3.8131020  
RATA-RATA Matriks Depth KE-2: 1.9650167  
RATA-RATA Matriks Depth KE-3: 1.1138386  
RATA-RATA Matriks Depth KE-4: 0.5953090

SEHINGGA HASIL AKHIR DARI GLOBAL AVERAGE POOLING YAITU:  
AVGPOOL = [ 3.8131020 1.9650167 1.1138386 0.5953090 ]

## PEMODELAN DENSENET 121

### GLOBAL AVERAGE POOLING

GLOBAL AVERAGE POOLING MENERIMA INPUT DARI LAYER SEBELUMNYA DALAM BENTUK TENSOR TIGA DIMENSI: TINGGI (HEIGHT), LEBAR (WIDTH), DAN KEDALAMAN (DEPTH), DI MANA KEDALAMAN BIASANYA MEREPRESENTASIKAN JUMLAH FITUR DARI LAYER KONVOLUSIONAL TERAKHIR.

|   | 0     | 1     | 2     | 3     | 4     | 5     | 6     |
|---|-------|-------|-------|-------|-------|-------|-------|
| 0 | 3.296 | 5.339 | 4.54  | 4.402 | 3.121 | 3.166 | 4.402 |
| 1 | 3.166 | 4.515 | 3.166 | 3.375 | 3.121 | 4.402 | 3.855 |
| 2 | 4.402 | 3.121 | 4.402 | 4.515 | 3.166 | 3.121 | 4.54  |
| 3 | 4.54  | 4.402 | 3.121 | 3.121 | 4.202 | 3.019 | 3.166 |
| 4 | 4.402 | 4.402 | 4.402 | 3.019 | 3.166 | 4.402 | 3.166 |
| 5 | 3.019 | 3.166 | 3.166 | 3.375 | 4.402 | 4.402 | 3.121 |
| 6 | 4.402 | 4.54  | 4.402 | 3.121 | 4.54  | 3.121 | 4.402 |

MATRIKS DEPTH KE-1

|   | 0         | 1         | 2         | 3        | 4        | 5        | 6        |
|---|-----------|-----------|-----------|----------|----------|----------|----------|
| 0 | 0.3123068 | 0.2566034 | 0.3310717 | 0.584289 | 0.38414  | 0.118639 | 0.033414 |
| 1 | 0.7452625 | 0.128656  | 0.315082  | 0.209081 | 0.459879 | 0.200774 | 0.043624 |
| 2 | 0.1345116 | 0.2187247 | 0.2520268 | 0.087098 | 0.417744 | 0.255531 | 0.065901 |
| 3 | 0.100553  | 0.194032  | 0.309808  | 0.672858 | 0.315028 | 0.228153 | 0.077039 |
| 4 | 0.205511  | 0.288344  | 0.068523  | 0.702123 | 0.253016 | 0.157425 | 0.065901 |
| 5 | 0.301139  | 0.109685  | 0.070251  | 0.355313 | 0.38414  | 0.282909 | 0.094674 |
| 6 | 0.3123068 | 0.2566034 | 0.3310717 | 0.584289 | 0.38414  | 0.118639 | 0.033414 |

MATRIKS DEPTH KE-2

|   | 0         | 1         | 2         | 3        | 4        | 5        | 6        |
|---|-----------|-----------|-----------|----------|----------|----------|----------|
| 0 | 1.325568  | 0.9566034 | 0.3310717 | 1.584289 | 0.38414  | 0.118639 | 0.033414 |
| 1 | 2.3242625 | 0.128656  | 0.315082  | 0.209081 | 0.459879 | 0.200774 | 0.043624 |
| 2 | 4.1425216 | 0.5187247 | 0.2520268 | 1.087098 | 1.411744 | 0.255531 | 0.065901 |
| 3 | 0.3205253 | 0.894032  | 0.109808  | 2.672858 | 0.315028 | 0.228153 | 0.077039 |
| 4 | 0.2551211 | 0.318344  | 1.068523  | 1.702123 | 0.253016 | 0.157425 | 0.065901 |
| 5 | 0.3314439 | 0.809685  | 0.070251  | 4.355313 | 0.38414  | 0.282909 | 0.094674 |
| 6 | 0.3412447 | 15.74777  | 0.261335  | 2.942110 | 1.631712 | 0.310288 | 0.033414 |

MATRIKS DEPTH KE-3

|   | 0        | 1        | 2        | 3        | 4         | 5        | 6        |
|---|----------|----------|----------|----------|-----------|----------|----------|
| 0 | 1.584289 | 0.38414  | 0.118639 | 0.118639 | 0.2310717 | 1.484289 | 0.18414  |
| 1 | 0.209081 | 0.459879 | 0.200774 | 0.200774 | 0.115082  | 0.309081 | 0.259879 |
| 2 | 1.087098 | 1.411744 | 0.255531 | 0.255531 | 0.5520268 | 2.23098  | 1.347744 |
| 3 | 2.672858 | 0.315028 | 0.228153 | 0.228153 | 0.109808  | 1.452858 | 0.355028 |
| 4 | 1.702123 | 0.253016 | 0.157425 | 0.157425 | 2.128523  | 0.672123 | 0.553016 |
| 5 | 4.355313 | 0.38414  | 0.282909 | 0.282909 | 1.320251  | 0.765313 | 0.68414  |
| 6 | 2.942110 | 1.631712 | 0.310288 | 0.310288 | 0.2310717 | 1.484289 | 0.18414  |

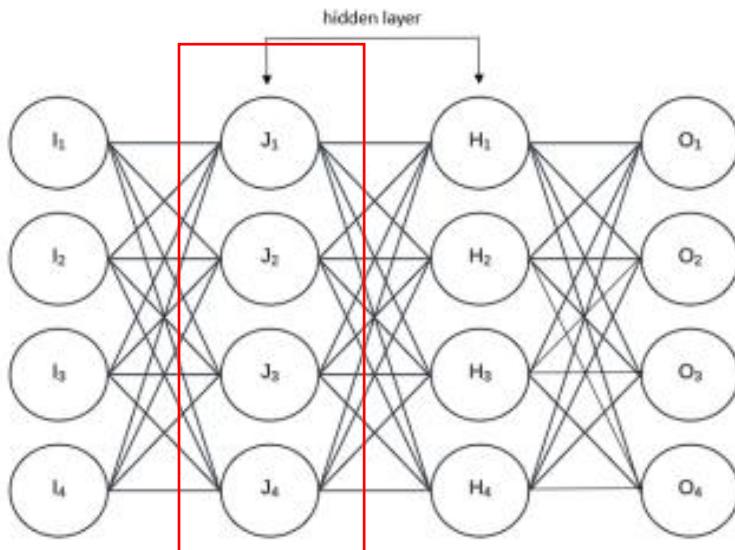
MATRIKS DEPTH KE-4

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 FULLY CONNECTED LAYER

TAHAPAN AKHIR DARI MODEL CNN YANG DIBANGUN INI ADALAH DENSE DENGAN FUNGSI AKTIVASI SOFTMAX DIMANA I YANG ADA PADA GAMBAR MERUPAKAN OUTPUT DARI GLOBAL AVERAGE POOLING.



DIMISALKAN BOBOT UNTUK PERHITUNGAN ADALAH 0.1, 0.4, 0.5, 0.3 DAN BERIKUT MERUPAKAN PERHITUNGAN PADA SETIAP HIDDEN LAYER

$$\begin{aligned} J_1 &= (3.8131020 * 0.1) + (1.9650167 * 0.1) + (1.1138386 * 0.1) + (0.5953090 * 0.1) \\ &= 0.74872663 \end{aligned}$$

$$\begin{aligned} J_2 &= (3.8131020 * 0.4) + (1.9650167 * 0.4) + (1.1138386 * 0.4) + (0.5953090 * 0.4) \\ &= 2.99490652 \end{aligned}$$

$$\begin{aligned} J_3 &= (3.8131020 * 0.2) + (1.9650167 * 0.2) + (1.1138386 * 0.2) + (0.5953090 * 0.2) \\ &= 1.49745326 \end{aligned}$$

$$\begin{aligned} J_4 &= (3.8131020 * 0.3) + (1.9650167 * 0.3) + (1.1138386 * 0.3) + (0.5953090 * 0.3) \\ &= 2.24617989 \end{aligned}$$

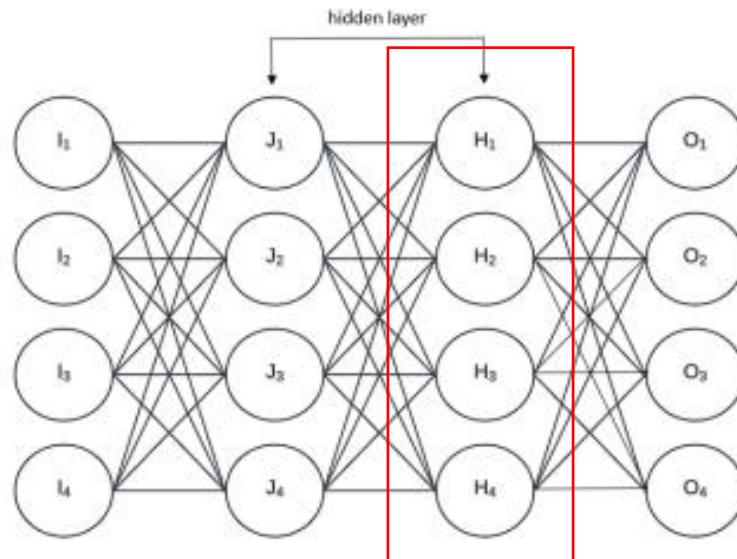
# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

# PEMODELAN DENSENET 121

## FULLY CONNECTED LAYER

HIDDEN LAYER PERTAMA DI ILUSTRASIKAN DENGAN J<sub>1</sub>,J<sub>2</sub>,J<sub>3</sub>,J<sub>4</sub> DIMANA SETIAP NEURON DARI J<sub>1</sub>-J<sub>4</sub> INI AKAN DIKALIKAN LAGI DENGAN BOBOT YANG BERBEDA BEDA UNTUK MENGHASILKAN NILAI H<sub>1</sub>-H<sub>4</sub> SEBAGAI HIDDEN LAYER SELANJUTNYA.



$$H_1 = (0.74872663 * 0.3) + (2.99490652 * 0.3) + (1.49745326 * 0.3) + (2.24617989 * 0.3) \\ = 2.24617990$$

$$H_2 = (0.74872663 * 0.5) + (2.99490652 * 0.5) + (1.49745326 * 0.5) + (2.24617989 * 0.5) \\ = 3.74363316$$

$$H_3 = (0.74872663 * 0.2) + (2.99490652 * 0.2) + (1.49745326 * 0.2) + (2.24617989 * 0.2) \\ = 1.49745326$$

$$H_4 = (0.74872663 * 0.4) + (2.99490652 * 0.4) + (1.49745326 * 0.4) + (2.24617989 * 0.4) \\ = 2.99490652$$

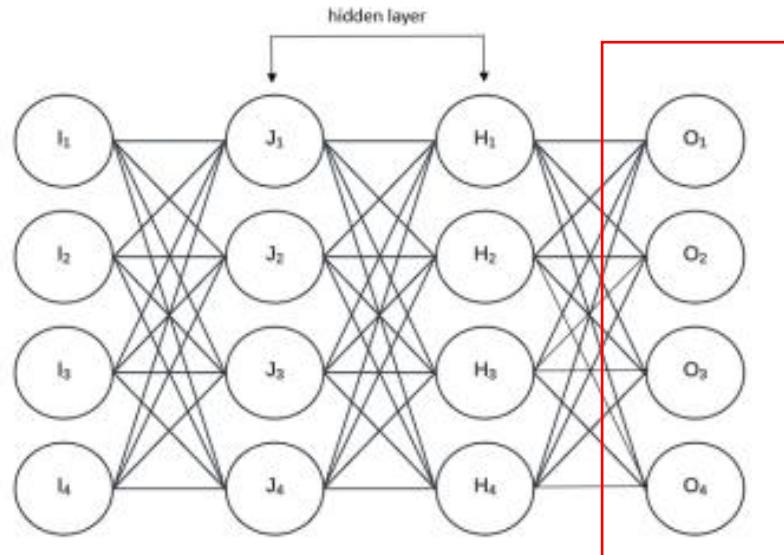
# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121

#### FULLY CONNECTED LAYER

DARI HASIL HIDDEN LAYER H AKAN DIKALIKAN LAGI DENGAN BOBOT YANG BERBEDA LAGI DAN MENGHASILKAN NILAI O1-O4



$$O_1 = (2.24617990 * 0.1) + (3.74363316 * 0.1) + (1.49745326 * 0.1) + (2.99490652 * 0.1) = 0.5615$$

$$O_2 = (2.24617990 * 0.2) + (3.74363316 * 0.2) + (1.49745326 * 0.2) + (2.99490652 * 0.2) = 0.1142$$

$$O_3 = (2.24617990 * 0.3) + (3.74363316 * 0.3) + (1.49745326 * 0.3) + (2.99490652 * 0.3) = 0.0917$$

$$O_4 = (2.24617990 * 0.4) + (3.74363316 * 0.4) + (1.49745326 * 0.4) + (2.99490652 * 0.4) = 0.0917$$

# PEMODELAN DENSENET 121

## SOFTMAX ACTIVATION

PADA STUDI KASUS INI MEMILIKI 4 KELAS. SETIAP KELAS DILAKUKAN ONE-HOT ENCODING UNTUK MENGHASILKAN OUTPUT SEPERTI BERIKUT :

- KELAS GREEN : [1, 0, 0, 0]
- KELAS LIGHT : [0, 1, 0, 0]
- KELAS MEDIUM: [0, 0, 1, 0]
- KELAS DARK : [0, 0, 0, 1]

DIASUMSIKAN BAHWA NILAI DARI PERHITUNGAN MENGGUNAKAN INPUT DARI FULLY CONNECTED LAYER DENGAN OUTPUT 0.561500, 0.1142, 0.0917, 0.0917

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### 1. MENGHITUNG DENOMINATOR

$$\text{denominator} = e^{0.561500} + e^{0.1142} + e^{0.0917} + e^{0.0917} = 5.692584$$

### 2. MELAKUKAN PERHITUNGAN SESUAI DENGAN RUMUS

$$\text{Softmax}(x_1) = \frac{e^{0.561500}}{5.692584} = 0.36511747$$

$$\text{Softmax}(x_2) = \frac{e^{0.1142}}{5.692584} = 0.19198633$$

$$\text{Softmax}(x_3) = \frac{e^{0.0917}}{5.692584} = 0.16978345$$

$$\text{Softmax}(x_4) = \frac{e^{0.0917}}{5.692584} = 0.23212713$$

DARI HASIL PROBABILITAS TERSEBUT DICARI NILAI TERTINGGI MENJADI ANGKA 1 SEPERTI BERIKUT :

[0.36511747 0.19198633 0.16978345 0.16978345]

[1 0 0 0]

Sehingga hasil akhirnya dari citra inputan awal pada model DenseNet121 menghasilkan probabilitas kelas **Green bean**.

# PEMODELAN DENSENET 121

## LOSS FUNTION CROSS ENTROPY

FUNGSI LOSS MENGUKUR PERBEDAAN ANTARA PROBABILITAS YANG DIPREDIKSI OLEH MODEL DAN LABEL YANG SEBENARNYA. FUNGSI LOSS INI MEMBERIKAN NILAI YANG MENUNJUKAN SEBERAPA BAIK ATAU BURUK MODEL DALAM MEMPREDIKSI LABEL YANG BENAR.

ASUMSI LABEL SEBENARNYA ADALAH GREEN BEAN YAITU

$Y_1 = 1, Y_2 = 0, Y_3 = 0, Y_4 = 0, Y_5 = 0$

[1 0 0 0].

MENGHITUNG LOSS CROSS ENTROPY PADA KELAS PERTAMA  
MENGGUNAKAN PERSAMAAN

$$Loss = - \sum_{i=0}^n y_i \log(p_i)$$

n = jumlah kelas

$y_i$  = nilai 1 jika kelas sebenarnya adalah kelas ke- $i$ , dan 0 jika bukan.

$P_i$  = probabilitas prediksi untuk kelas ke- $i$ .

KARENA  $Y_1 = 1$  MAKA RUMUS CROSS ENTROPY LOSS  
DISEDERHANAKAN MENJADI:  $Loss = -\log(\text{softmax}(x_1))$

$$Loss = -\log(0.36511747)$$

$$Loss \approx 1.0075$$

DAPAT DISIMPULKAN BAHWA MODEL INI MEMPREDIKSI BIJI KOPI DENGAN INPUTAN GAMBAR TERSEBUT MENGHASILKAN OUTPUT “**GREEN BEAN**” DENGAN LOSS SEBESAR **1.0075**

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 BACKPROPAGATION

Setelah loss dihitung, backpropagation digunakan untuk menghitung gradien dari loss terhadap setiap parameter dalam model. Kemudian gradien digunakan untuk memperbarui parameter model melalui algoritma optimisasi seperti Adam.

Untuk cross-entropy loss dengan softmax, derivatifnya adalah:

$$\frac{\partial L}{\partial f_{C0i}} = y_i - t_i \quad \text{dimana } Y_i \text{ adalah output dari softmax dan } T_i \text{ adalah target } [1,0,0,0] \text{ untuk kelas pertama}$$

SEHINGGA

$$\frac{\partial L}{\partial f_{C01}} = 0.36511747 - 1 = -0.63488253$$

$$\frac{\partial L}{\partial f_{C02}} = 0.19198633 - 0 = 0.19198633$$

$$\frac{\partial L}{\partial f_{C03}} = 0.16978345 - 0 = 0.16978345$$

$$\frac{\partial L}{\partial f_{C04}} = 0.16978345 - 0 = 0.16978345$$

## PEMODELAN DENSENET 121

### BACKPROPAGATION

Langkah kedua adalah menghitung turunan output dari FCL setelah melalui fungsi softmax menggunakan persamaan

$$\frac{\partial f_{C01}}{\partial f_{C11}} = y_i(1 - y_i)$$

SEHINGGA

$$\frac{\partial f_{C01}}{\partial f_{C11}} = 0.36511747(1 - 0.36511747) = 0.231476$$

$$\frac{\partial f_{C02}}{\partial f_{C12}} = 0.19198633(1 - 0.19198633) = 0.155282$$

$$\frac{\partial f_{C03}}{\partial f_{C13}} = 0.16978345(1 - 0.16978345) = 0.141128$$

$$\frac{\partial f_{C04}}{\partial f_{C14}} = 0.16978345(1 - 0.16978345) = 0.141128$$

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 BACKPROPAGATION

Langkah ketiga adalah menghitung turunan bobot dari Fully Connected Layer menggunakan persamaan

$$\frac{\partial L}{\partial w_{i,j}} = \frac{\partial L}{\partial fco_i} \times \frac{\partial fco_i}{\partial fcli} \times \frac{\partial fcli}{\partial w_{i,j}}$$

#### SEHINGGA

Untuk  $i = 1$

$$\frac{\partial L}{\partial w_{1,1}} = -0.63488253 \times 0.231476 \times 0.36511747$$

$$\frac{\partial L}{\partial w_{1,1}} \approx \mathbf{-0.053564}$$

Untuk  $i = 2$

$$\frac{\partial L}{\partial w_{2,1}} = 0.19198633 \cdot 0.155282 \cdot 0.36511747$$

$$\frac{\partial L}{\partial w_{2,1}} \approx \mathbf{0.010899}$$

Untuk  $i = 3$

$$\frac{\partial L}{\partial w_{3,1}} = 0.16978345 \cdot 0.141128 \cdot 0.36511747$$

$$\frac{\partial L}{\partial w_{3,1}} \approx \mathbf{0.008746}$$

Untuk  $i = 4$

$$\frac{\partial L}{\partial w_{3,1}} = 0.16978345 \cdot 0.141128 \cdot 0.36511747$$

$$\frac{\partial L}{\partial w_{3,1}} \approx \mathbf{0.008746}$$

Langkah tersebut dilakukan untuk dilanjutkan ke adam optimizer dengan inputan gradien yang baru

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 ADAM OPTIMIZER

Diasumsikan bahwa :

$$\text{Gradien } (G_t) = -0.053564 \quad \beta_1 = 0.9$$

$$\text{Parameter awal } (\theta) = 0.36511747 \quad \beta_2 = 0.999$$

$$\text{Learning rate } (\alpha) = 0.001 \quad \epsilon = 1 \times 10^{-8}$$

menghitung untuk satu iterasi, sehingga  $t=1$

#### 1. memperbarui bias momen pertama menggunakan persamaan

$$m_t = \beta_1 \cdot m_{t-1} + (1 - \beta_1) \cdot G_t$$

$$m_1 = 0.9 \cdot 0 + (1 - 0.9) \cdot (-0.053564)$$

$$m_1 = 0.1 \cdot (-0.053564) = -0.0053564$$

#### 2. memperbarui bias momen kedua menggunakan persamaan

$$v_t = \beta_2 \cdot v_{t-1} + (1 - \beta_2) \cdot G_t^2$$

$$v_1 = 0.999 \cdot 0 + (1 - 0.999) \cdot (-0.053564)^2$$

$$v_1 = 0.001 \cdot (0.053564^2) = 0.001 \cdot 0.002867 = 0.000002867$$

# BAB 3

## ANALISIS DAN PERANCANGAN SISTEM

### PEMODELAN DENSENET 121 ADAM OPTIMIZER

3. menghitung koreksi bias momen pertama menggunakan persamaan

$$mt = \frac{mt}{(1-\beta_1^t)}$$

$$m1 = \frac{m1}{(1-\beta_1^t)} = \frac{-0.0053564}{1-0.9} = \frac{-0.0053564}{0.1} = -0.053564$$

4. menghitung koreksi bias momen kedua menggunakan persamaan

$$vt = \frac{vt}{(1-b^t_2)}$$

$$v1 = \frac{v1}{(1-b^t_1)} = \frac{0.000002867}{1-0.999} = \frac{0.000002867}{0.001} = 0.002867$$

5. memperbarui parameter menggunakan persamaan

$$\theta_1 = \theta_{t-1} - \alpha \frac{mt}{\sqrt{vt + \epsilon}}$$

$$\theta_1 = 0.36511747 - 0.001 \cdot \frac{-0.053564}{\sqrt{0.002867 + 10^{-8}}}$$

$$\theta_1 = 0.36511747 - 0.001 \cdot \frac{-0.053564}{\sqrt{0.002867 + 10^{-8}}}$$

$$\theta_1 = 0.36511747 + 0.001 \cdot 1.0006$$

$$\theta_1 = 0.36511747 + 0.0010006 = 0.36611807$$

Dengan gradien  $-0.053564$  dan parameter awal  $0.36511747$ , kita melakukan perhitungan untuk satu iterasi dari algoritma Adam. Hasilnya adalah parameter yang diperbarui menjadi  $0.36611807$ . Hal ini menunjukkan bahwa proses optimasi bergerak ke arah yang tepat, yaitu mengurangi nilai parameter secara bertahap untuk mendekati minimum dari fungsi loss.

## ANALISIS KEBUTUHAN PERANGKAT

### BAB 4 IMPLEMENTASI DAN PENGUJIAN

| Kebutuhan Perangkat Keras |                |                                       |
|---------------------------|----------------|---------------------------------------|
| No                        | Item           | Spesifikasi                           |
| 1                         | CPU            | <i>Ryzen 7 5700x 8-core processor</i> |
| 2                         | RAM            | 32 GB DDR4                            |
| 3                         | <i>Storage</i> | 512 GB SSD NVME gen 3                 |

| Kebutuhan Perangkat Lunak |                             |                                    |
|---------------------------|-----------------------------|------------------------------------|
| 1                         | Sistem Operasi              | Windows 11                         |
| 2                         | <i>Compiler</i>             | <i>Google Colaboratory</i>         |
| 3                         | <i>Programming Language</i> | <i>Python Programming Language</i> |

# PENGUJIAN SISTEM

## RENCANA PENGUJIAN

### RENCANA PENGUJIAN AUGMENTASI

| No | Augmentasi      | Epoch | Learning Rate |
|----|-----------------|-------|---------------|
| 1  | Horizontal Flip | 25    | 0.001         |
| 2  |                 |       | 0.0001        |
| 3  |                 |       | 0.001         |
| 4  |                 |       | 0.0001        |

### RENCANA PENGUJIAN HYPERPARAMETER

| No | Epoch | Batch size | Learning Rate |
|----|-------|------------|---------------|
| 5  | 25    | 16         | 0.001         |
| 6  |       |            | 0.0001        |
| 7  |       | 32         | 0.001         |
| 8  |       |            | 0.0001        |
| 9  | 50    | 16         | 0.001         |
| 10 |       |            | 0.0001        |
| 11 |       | 32         | 0.001         |
| 12 |       |            | 0.0001        |

## BAB 4

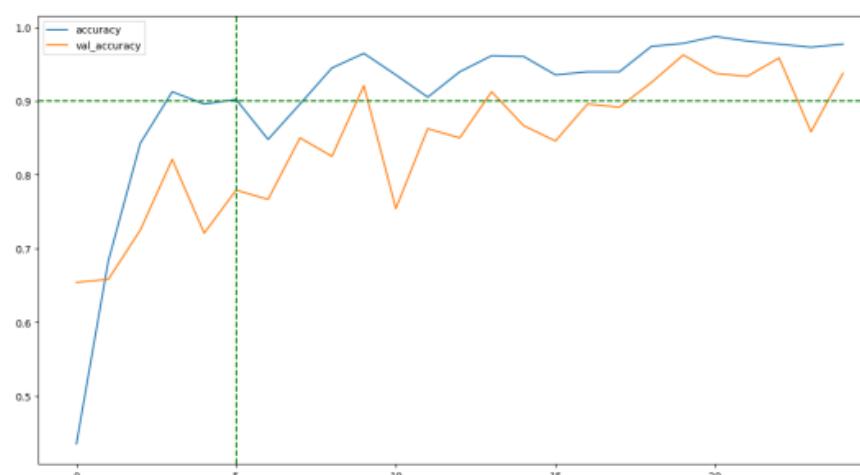
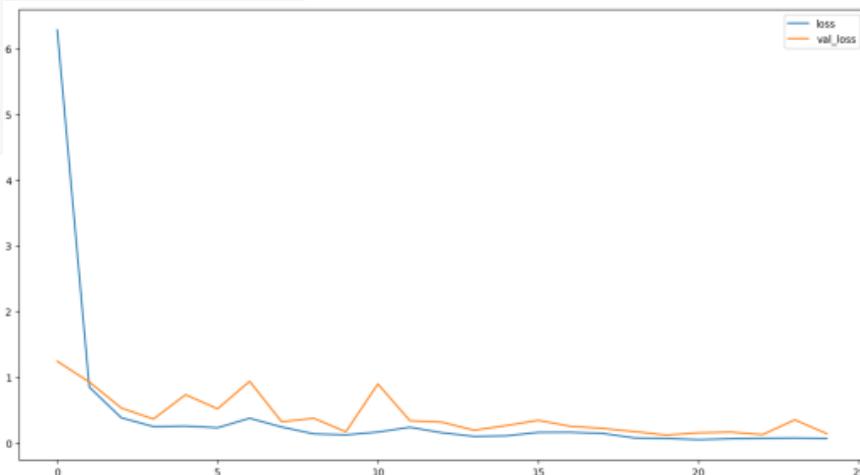
### IMPLEMENTASI DAN PENGUJIAN



# PENGUJIAN SISTEM

## PENGUJIAN 1

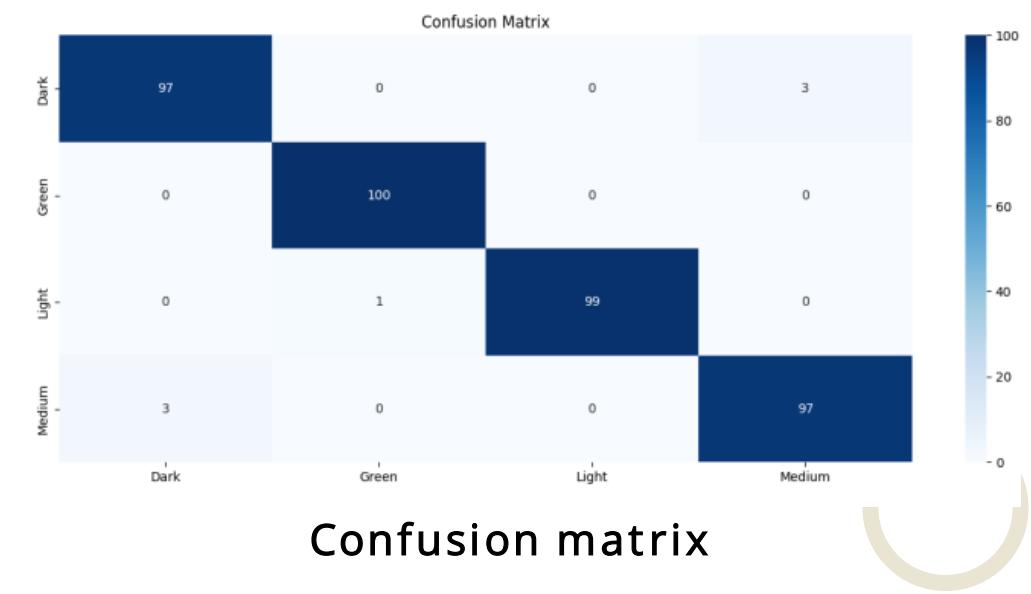
Pengujian pertama melibatkan augmentasi citra berupa Horizontal Flip dengan epoch 25, dan learning rate sebesar 0.001



Plot Akurasi & Loss

|                  | Precision     | Recall | F1-Score |
|------------------|---------------|--------|----------|
| Dark Roast       | 0.97          | 0.97   | 0.97     |
| Green Bean       | 0.99          | 1      | 1        |
| Light Roast      | 1             | 0.99   | 0.99     |
| Medium Roast     | 0.97          | 0.97   | 0.97     |
| Accuracy         | <b>0.98</b>   |        |          |
| Average F1-Score | <b>0.9825</b> |        |          |

Classification Report

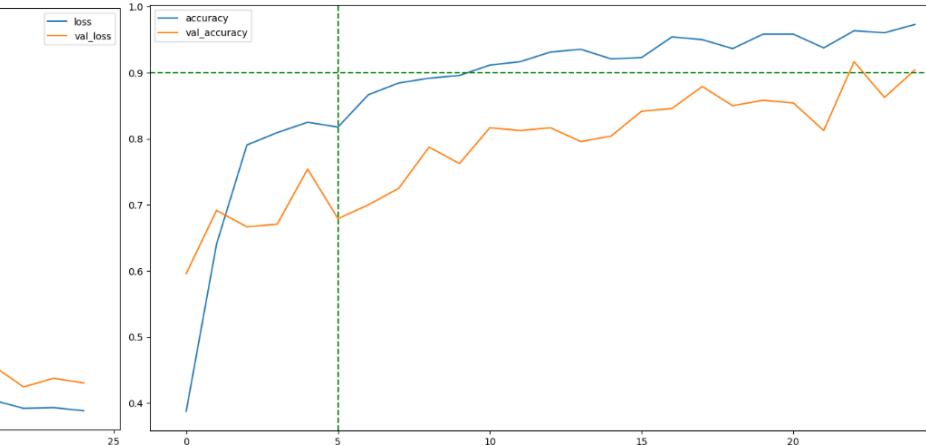
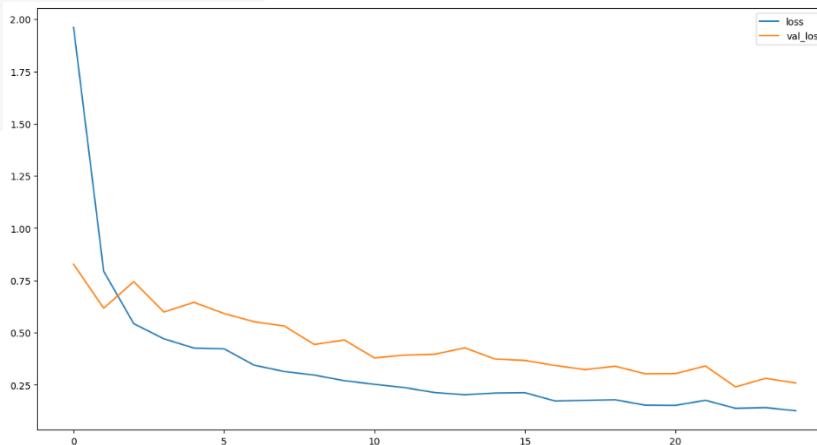


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 2

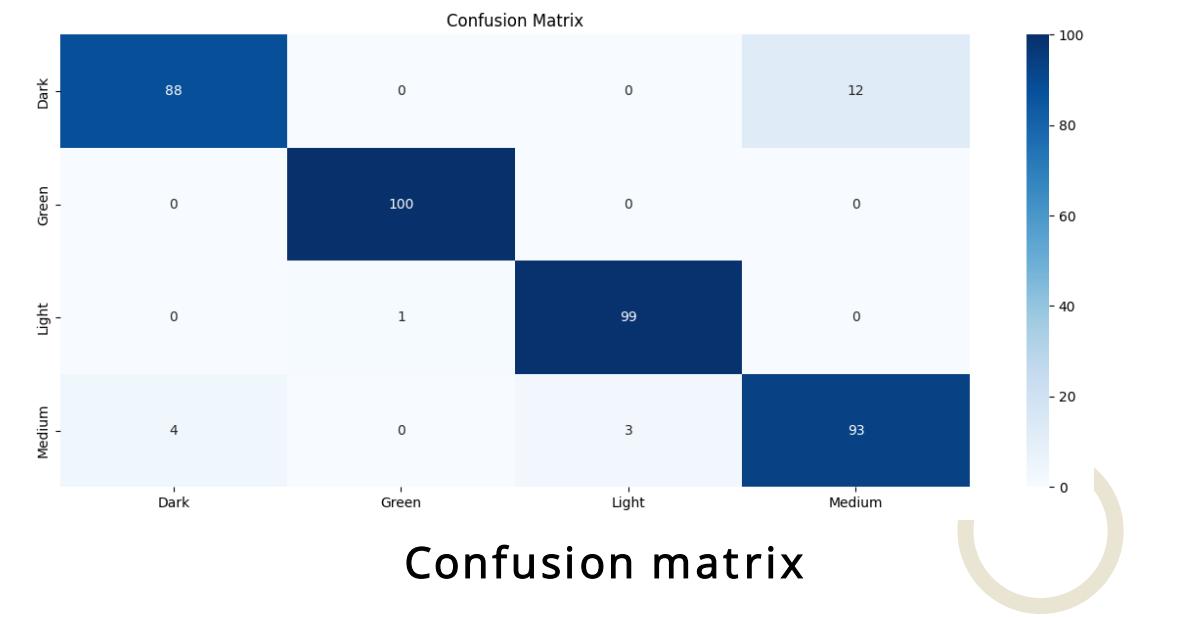
Pengujian kedua melibatkan augmentasi citra berupa Horizontal Flip dengan epoch 25, dan learning rate sebesar 0.0001



Plot Akurasi & Loss

|                  | Precision | Recall      | F1-Score |
|------------------|-----------|-------------|----------|
| Dark Roast       | 0.96      | 0.88        | 0.92     |
| Green Bean       | 0.99      | 1           | 1        |
| Light Roast      | 0.97      | 0.99        | 0.98     |
| Medium Roast     | 0.89      | 0.93        | 0.91     |
| Accuracy         |           | <b>0.95</b> |          |
| Average F1-Score |           | <b>0.95</b> |          |

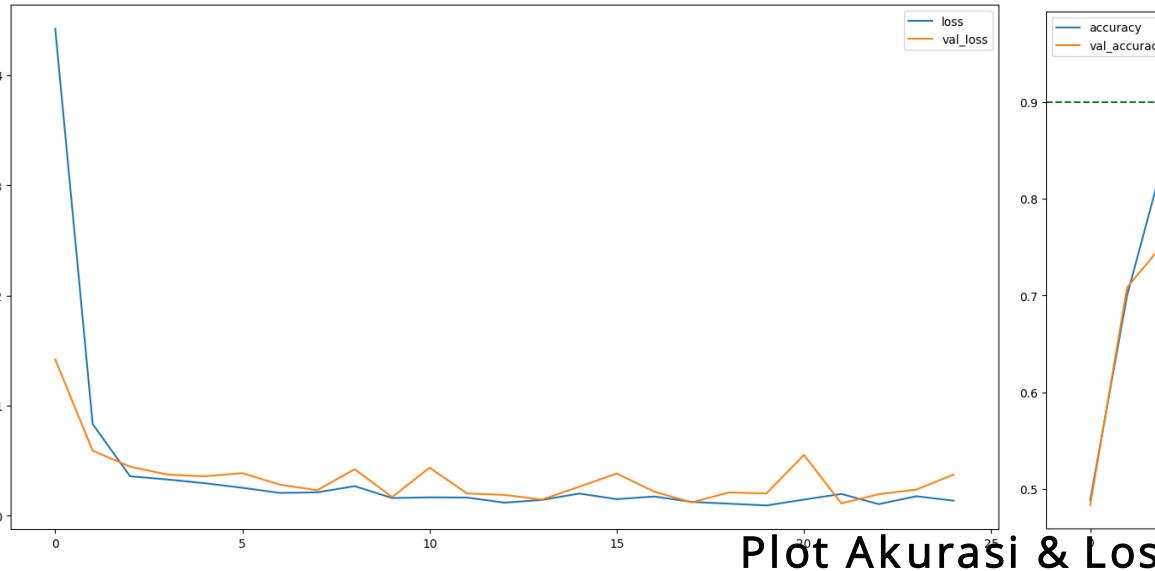
Classification Report



# PENGUJIAN SISTEM

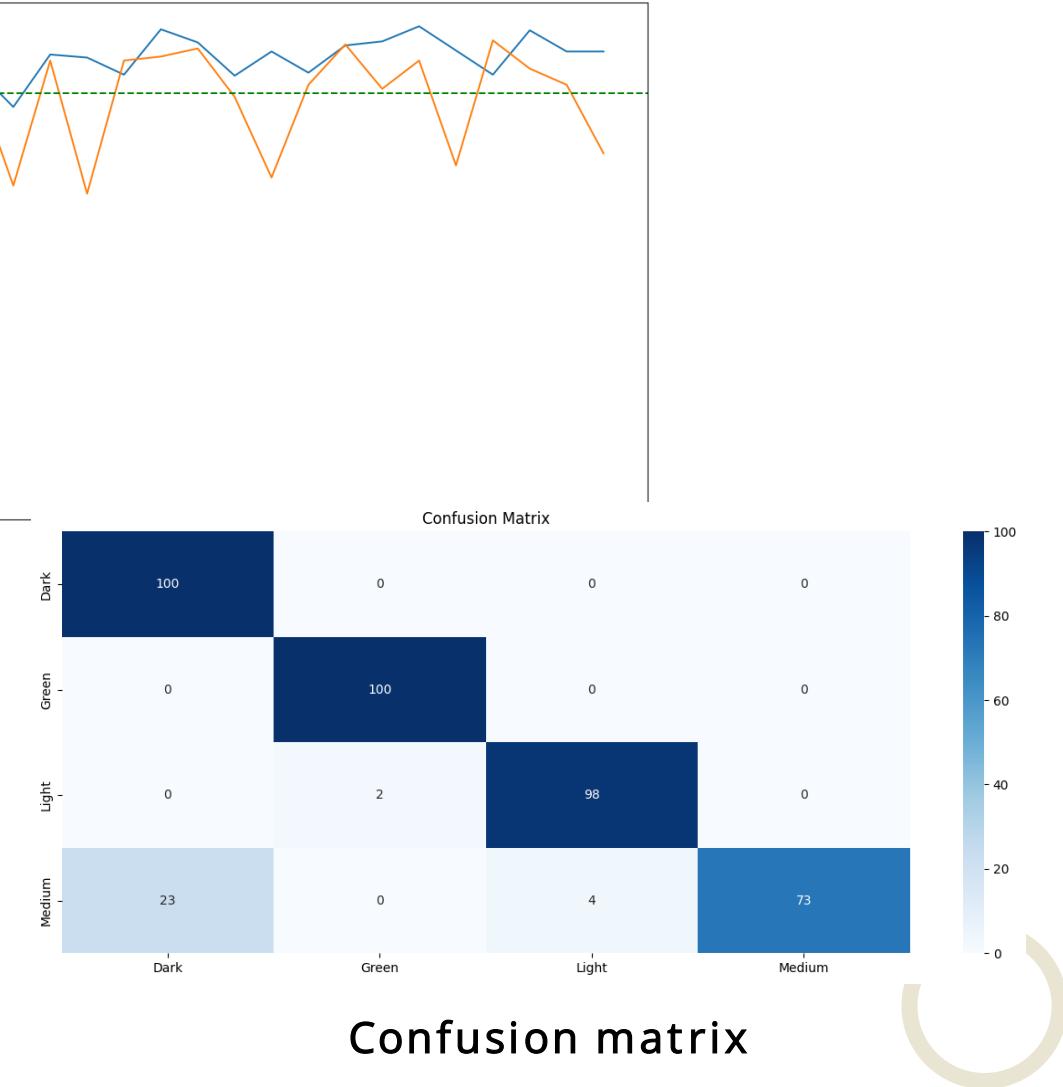
## PENGUJIAN 3

Pengujian ketiga melibatkan augmentasi citra berupa Horizontal Flip,shear,rotation dengan epoch 25, dan learning rate sebesar 0.001



|                  | Precision | Recall | F1-Score    |
|------------------|-----------|--------|-------------|
| Dark Roast       | 0.81      | 1      | 0.9         |
| Green Bean       | 0.98      | 1      | 0.99        |
| Light Roast      | 0.96      | 0.98   | 0.97        |
| Medium Roast     | 1         | 0.73   | 0.84        |
| Accuracy         |           |        | <b>0.93</b> |
| Average F1-Score |           |        | <b>0.93</b> |

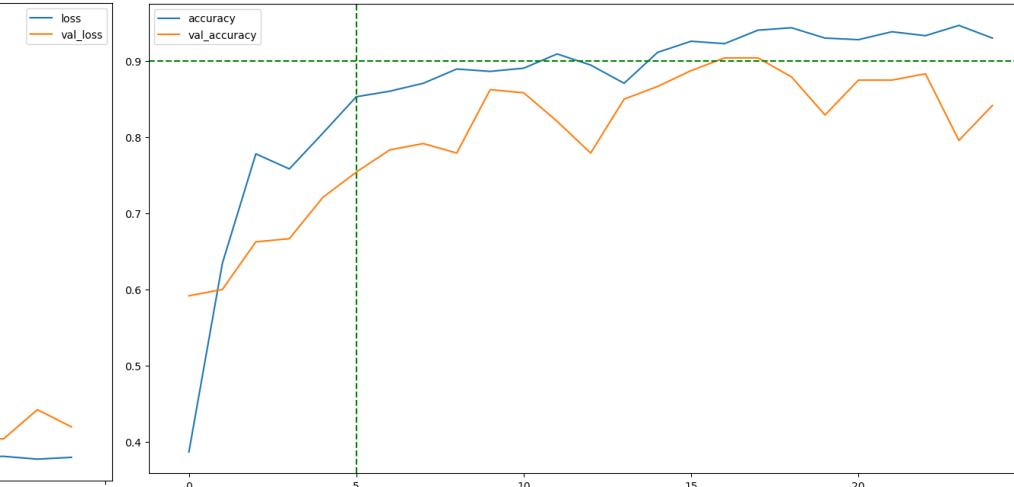
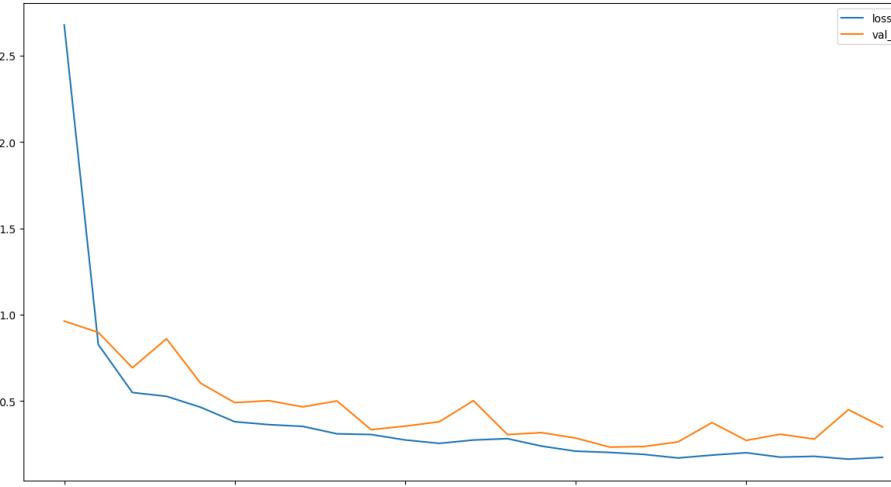
Classification Report



# PENGUJIAN SISTEM

## PENGUJIAN 4

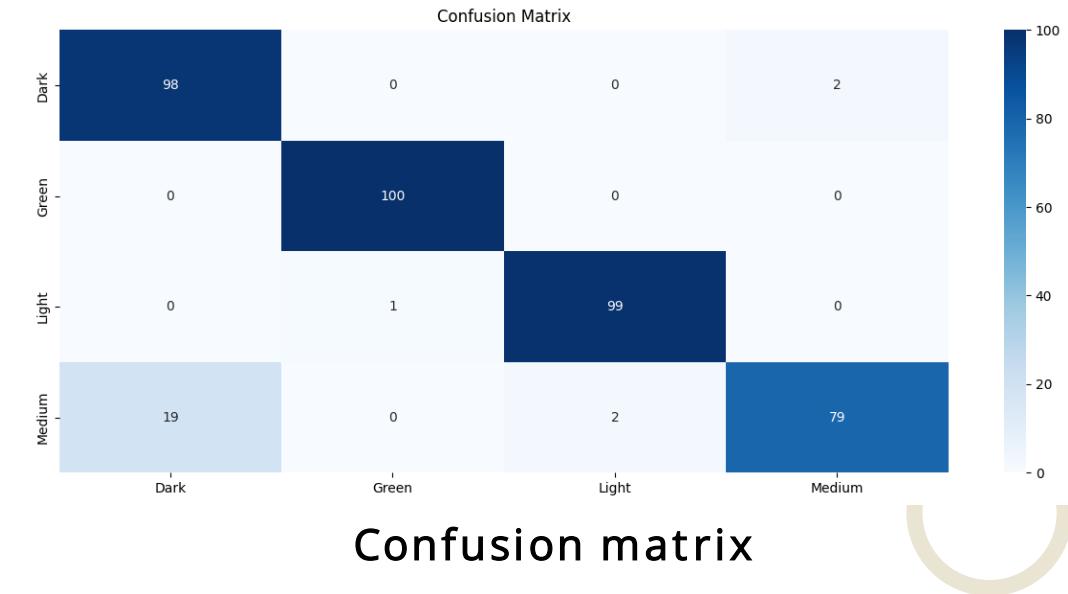
Pengujian keempat melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 25, dan learning rate sebesar 0.0001



Plot Akurasi & Loss

|                  | Precision | Recall      | F1-Score |
|------------------|-----------|-------------|----------|
| Dark Roast       | 0.84      | 0.98        | 0.9      |
| Green Bean       | 0.99      | 1           | 1        |
| Light Roast      | 0.98      | 0.99        | 0.99     |
| Medium Roast     | 0.98      | 0.79        | 0.87     |
| Accuracy         |           | <b>0.99</b> |          |
| Average F1-Score |           | <b>0.94</b> |          |

Classification Report

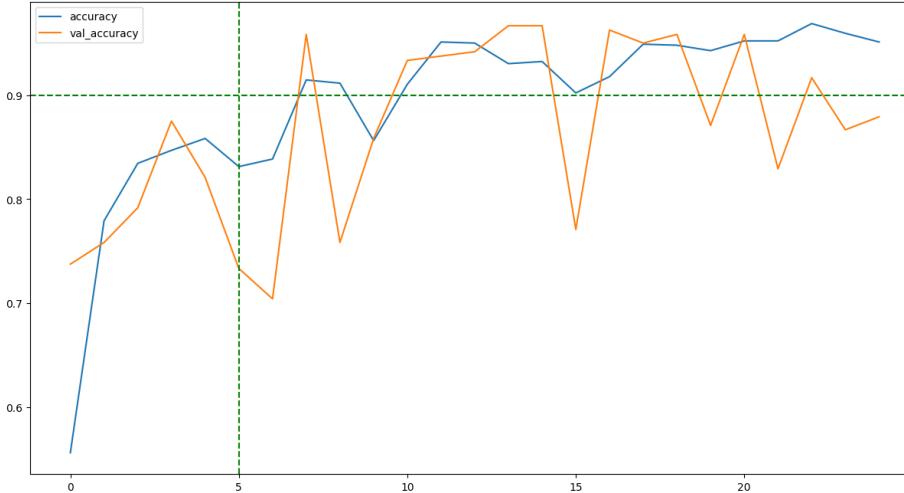
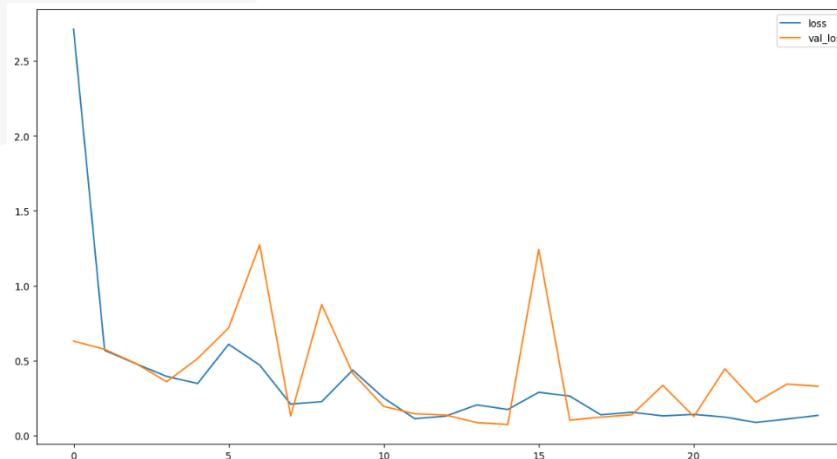


Confusion matrix

# PENGUJIAN SISTEM

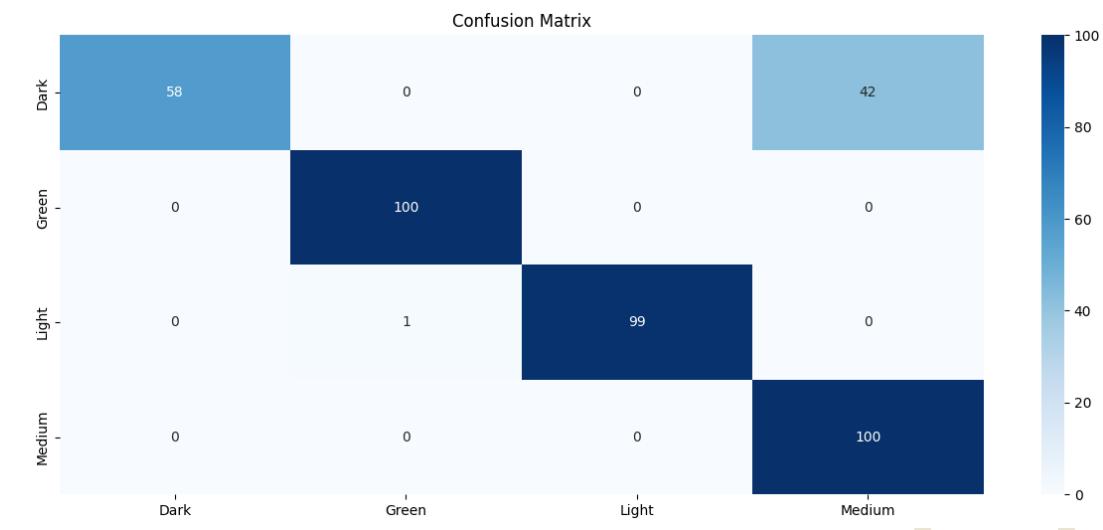
## PENGUJIAN 5

Pengujian kelima melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 25, batch size 16 dan learning rate sebesar 0.001



|                  | Precision   | Recall | F1-Score |
|------------------|-------------|--------|----------|
| Dark Roast       | 1           | 0.58   | 0.73     |
| Green Bean       | 0.99        | 1      | 1        |
| Light Roast      | 1           | 0.99   | 0.99     |
| Medium Roast     | 0.7         | 1      | 0.83     |
| Accuracy         | <b>0.89</b> |        |          |
| Average F1-Score | <b>0.89</b> |        |          |

Classification Report

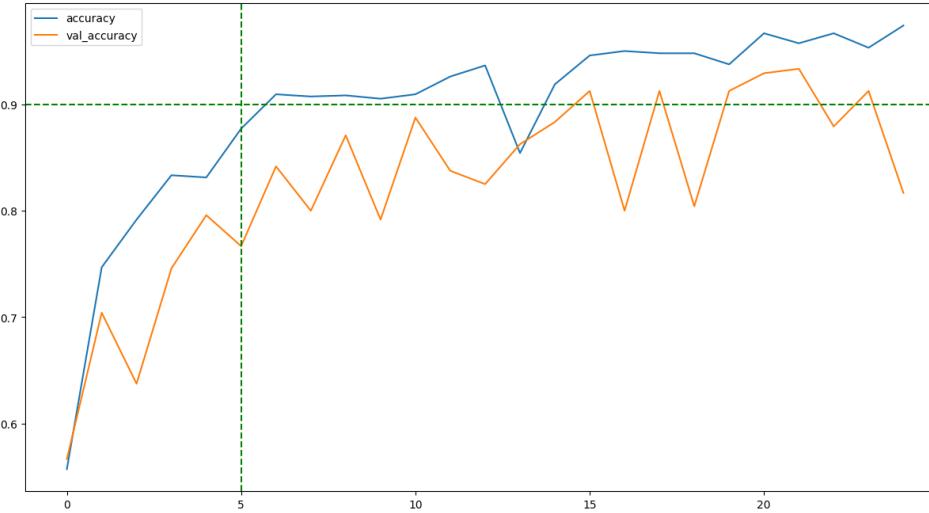
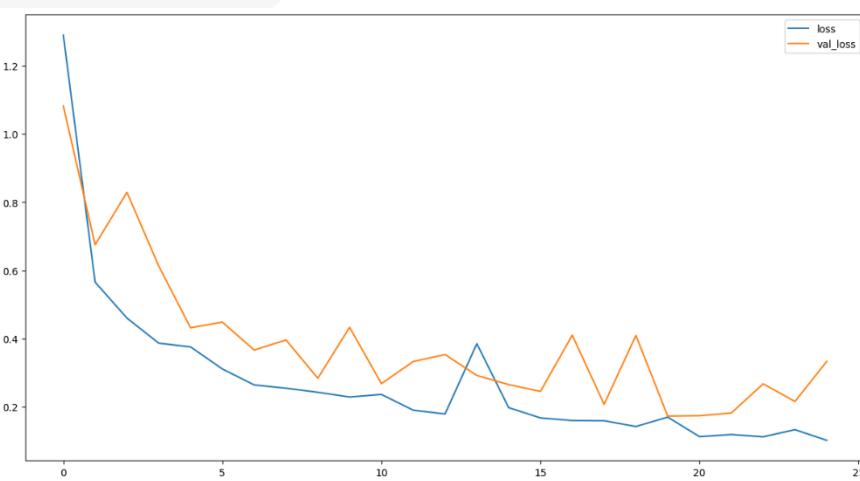


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 6

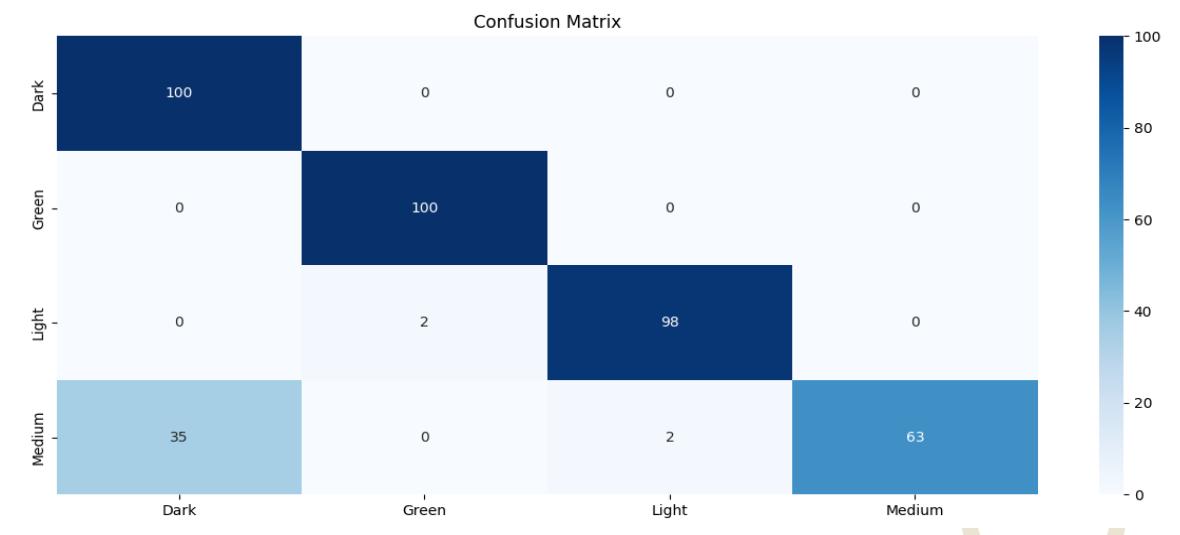
Pengujian keenam melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 25, batch size 16 dan learning rate sebesar 0.0001



Plot Akurasi & Loss

|                  | Precision   | Recall | F1-Score |
|------------------|-------------|--------|----------|
| Dark Roast       | 0.74        | 1      | 0.85     |
| Green Bean       | 0.98        | 1      | 0.98     |
| Light Roast      | 0.98        | 0.98   | 0.98     |
| Medium Roast     | 1           | 0.63   | 0.77     |
| Accuracy         | <b>0.9</b>  |        |          |
| Average F1-Score | <b>0.89</b> |        |          |

Classification Report

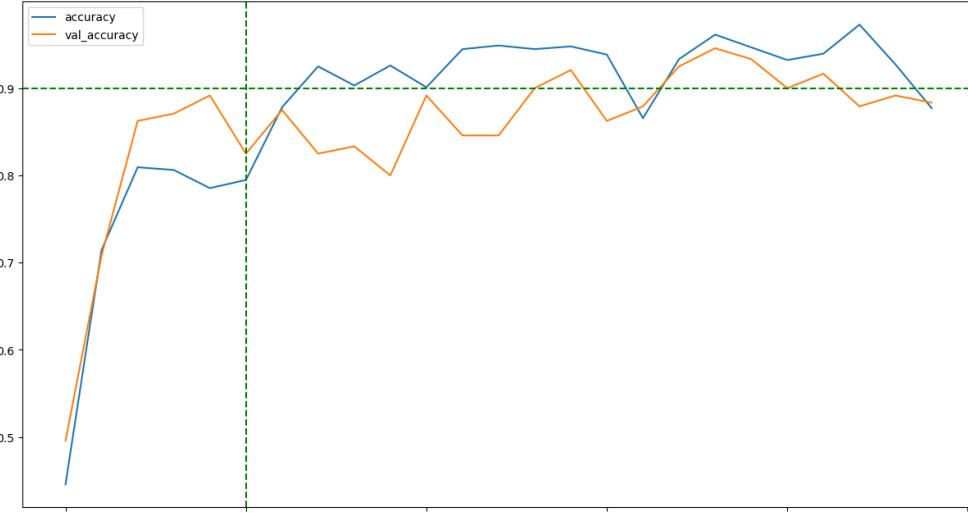
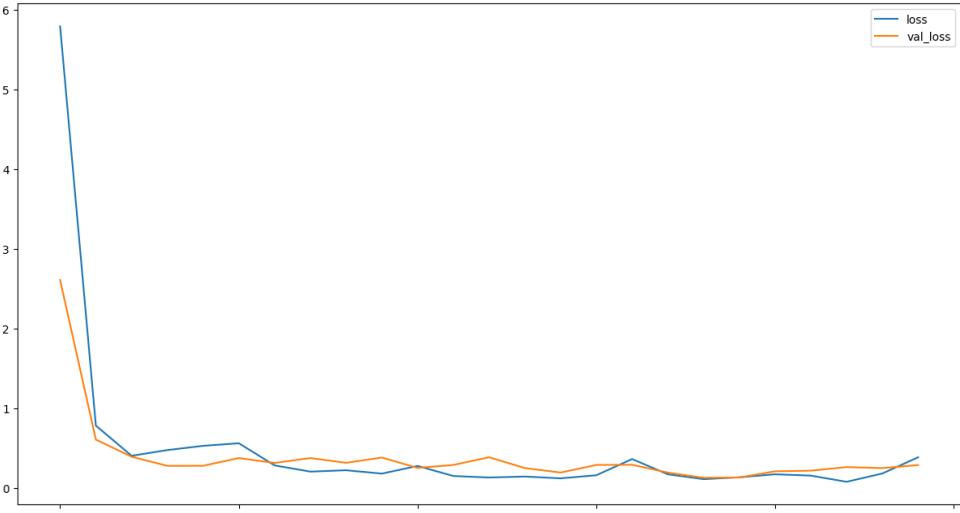


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 7

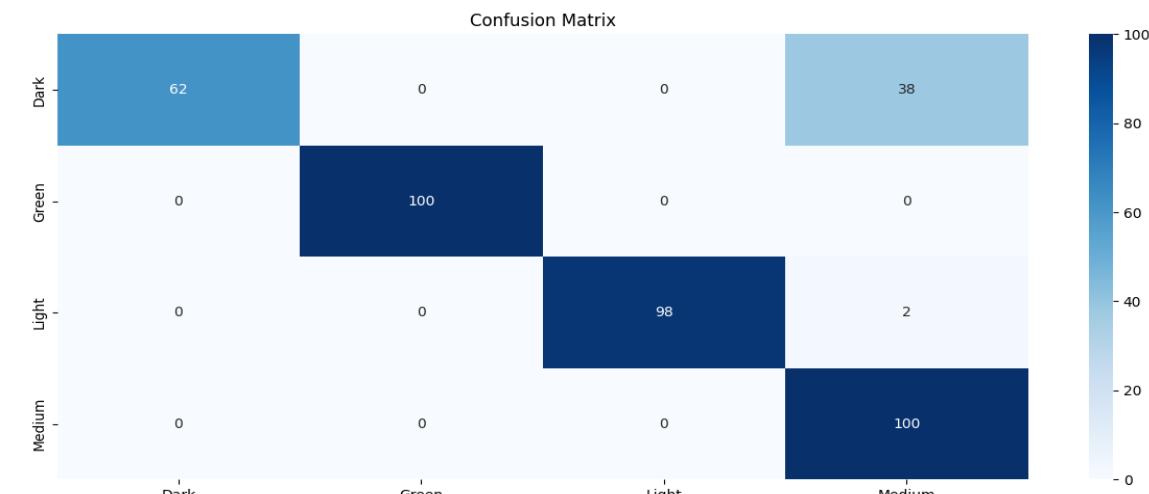
Pengujian keenam melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 25, batch size 32 dan learning rate sebesar 0.001



Plot Akurasi & Loss

|                  | Precision | Recall     | F1-Score |
|------------------|-----------|------------|----------|
| Dark Roast       | 1         | 0.62       | 0.77     |
| Green Bean       | 1         | 1          | 1        |
| Light Roast      | 1         | 0.98       | 0.99     |
| Medium Roast     | 0.71      | 1          | 0.83     |
| Accuracy         |           | <b>0.9</b> |          |
| Average F1-Score |           | <b>0.9</b> |          |

Classification Report

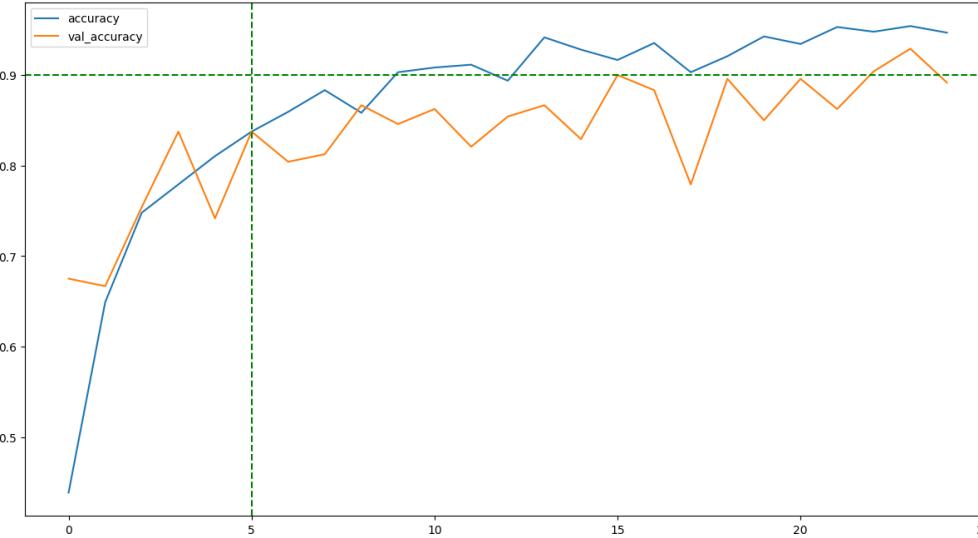
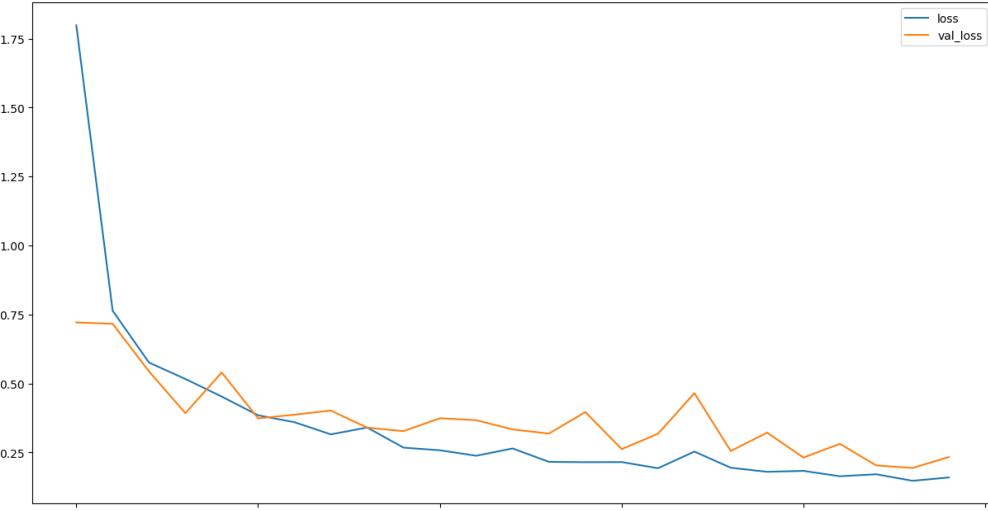


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 8

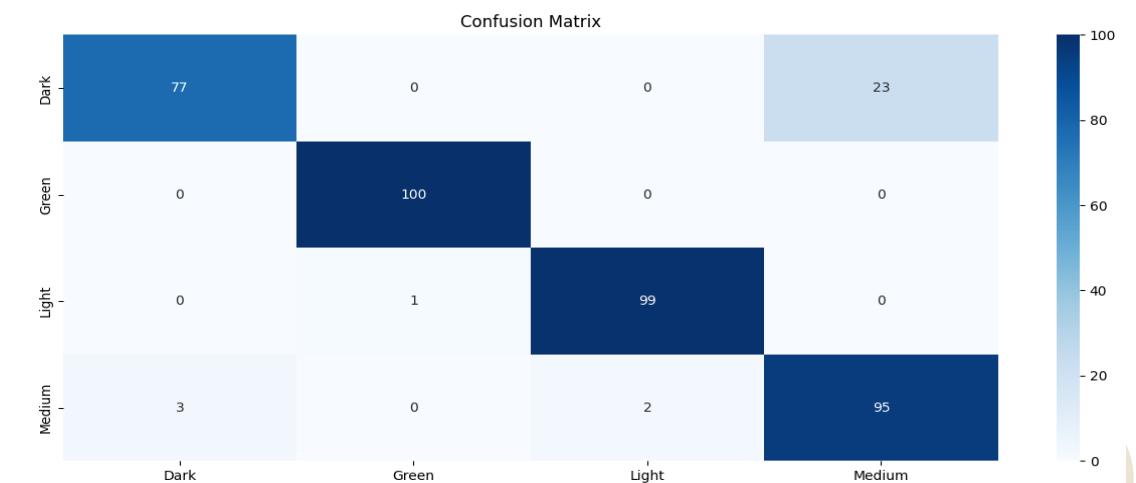
Pengujian kedelapan melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 25, batch size 32 dan learning rate sebesar 0.0001



Plot Akurasi & LOSS

|                  | Precision | Recall      | F1-Score |
|------------------|-----------|-------------|----------|
| Dark Roast       | 0.96      | 0.77        | 0.86     |
| Green Bean       | 0.99      | 1           | 1        |
| Light Roast      | 0.98      | 0.99        | 0.99     |
| Medium Roast     | 0.81      | 0.95        | 0.87     |
| Accuracy         |           | <b>0.93</b> |          |
| Average F1-Score |           | <b>0.93</b> |          |

Classification Report

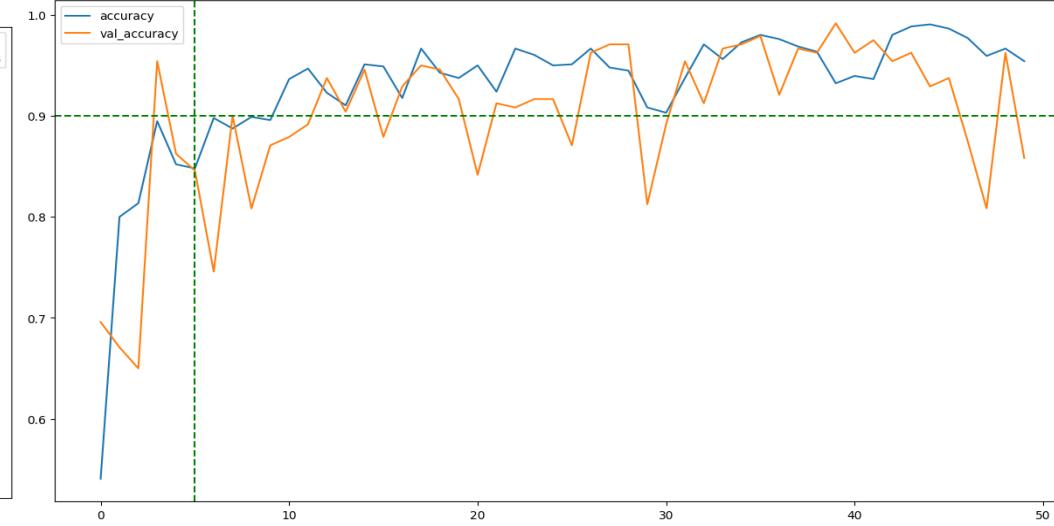
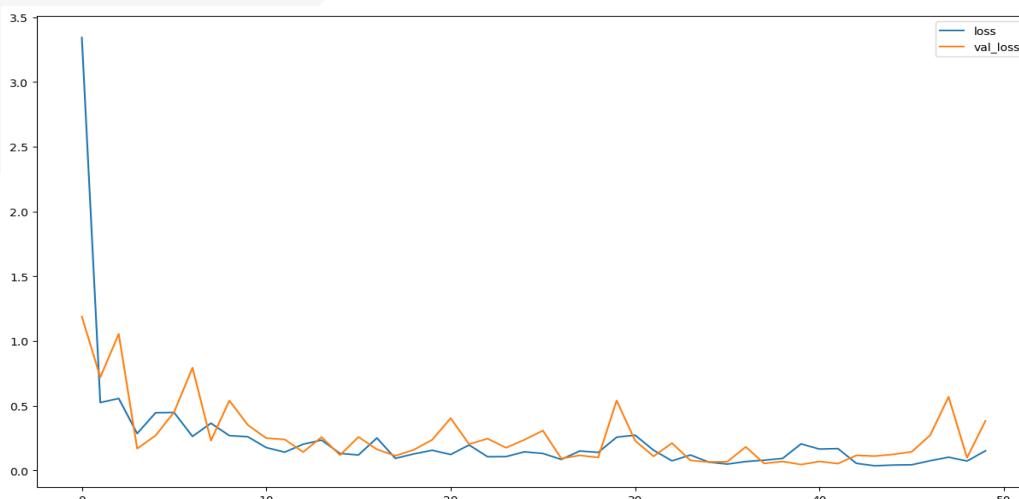


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 9

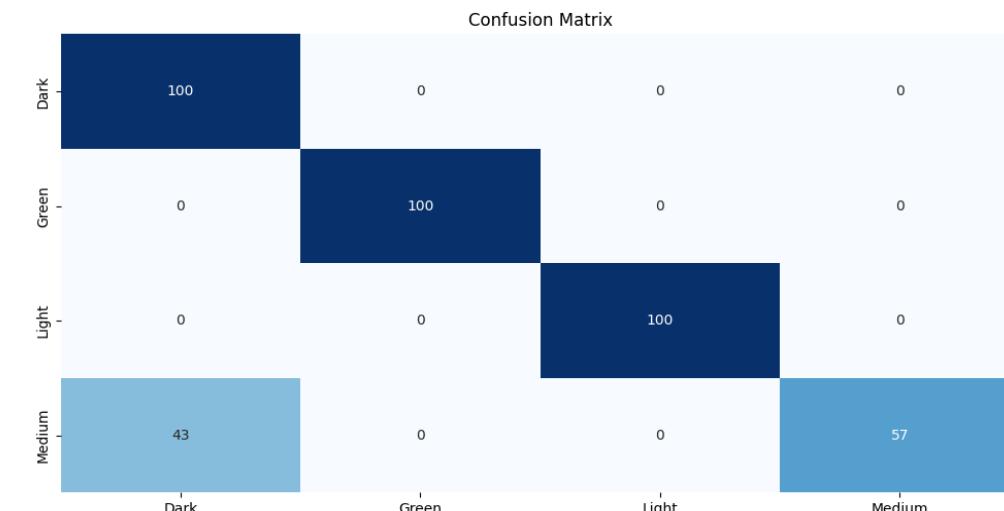
Pengujian kesembilan melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 50, batch size 16 dan learning rate sebesar 0.001



Plot Akurasi & Loss

|                  | Precision   | Recall | F1-Score |
|------------------|-------------|--------|----------|
| Dark Roast       | 0.7         | 1      | 0.82     |
| Green Bean       | 1           | 1      | 1        |
| Light Roast      | 1           | 1      | 1        |
| Medium Roast     | 1           | 0.57   | 0.73     |
| Accuracy         | <b>0.89</b> |        |          |
| Average F1-Score | <b>0.89</b> |        |          |

Classification Report

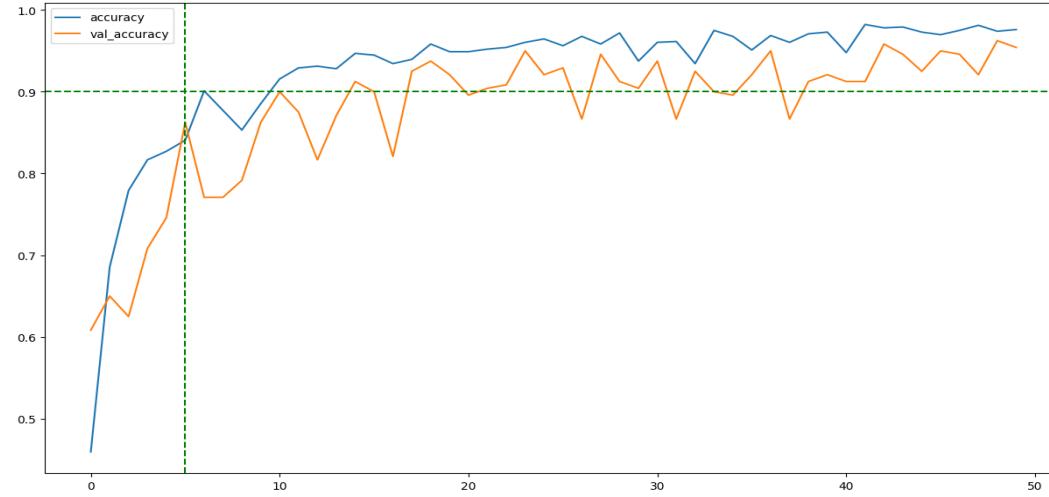
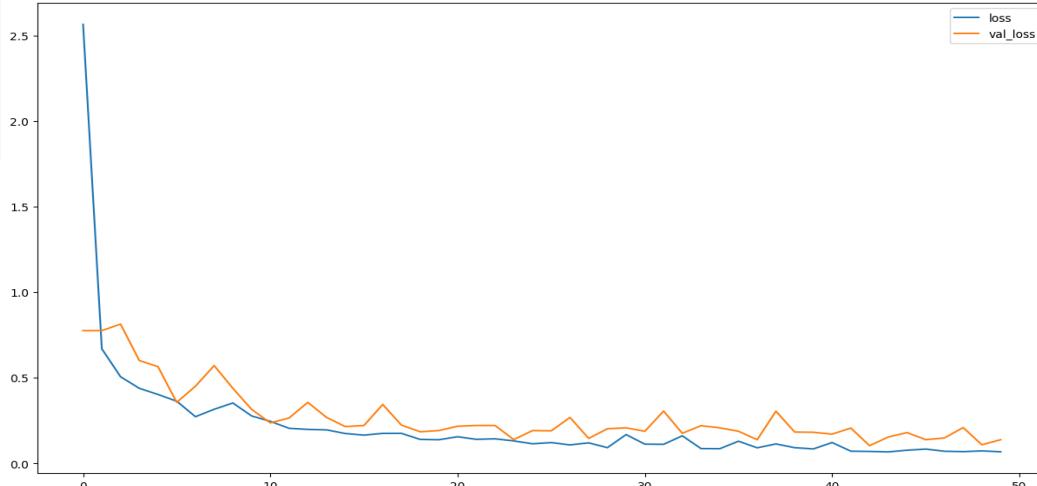


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 10

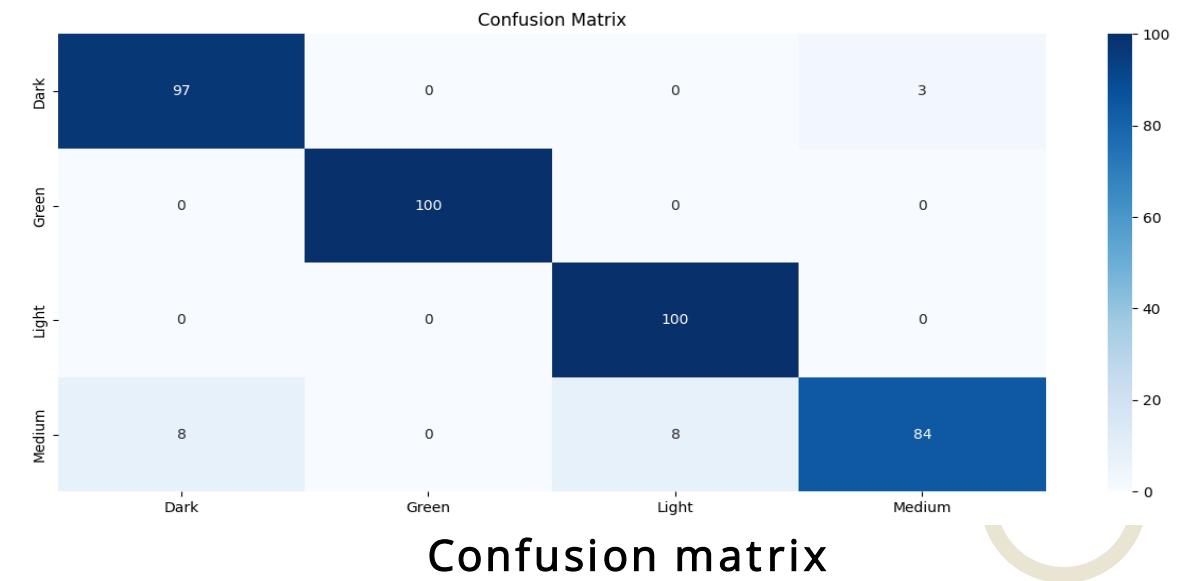
Pengujian kesepuluh melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 50, batch size 16 dan learning rate sebesar 0.0001



Plot Akurasi & Loss

|                  | Precision | Recall      | F1-Score |
|------------------|-----------|-------------|----------|
| Dark Roast       | 0.92      | 0.97        | 0.95     |
| Green Bean       | 1         | 1           | 1        |
| Light Roast      | 0.93      | 1           | 0.96     |
| Medium Roast     | 0.97      | 0.84        | 0.9      |
| Accuracy         |           | <b>0.95</b> |          |
| Average F1-Score |           | <b>0.95</b> |          |

Classification Report

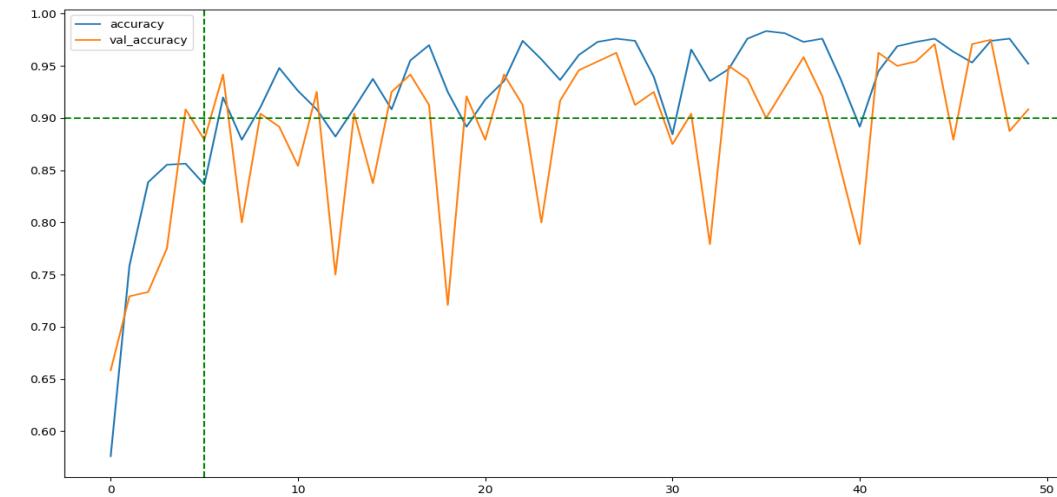
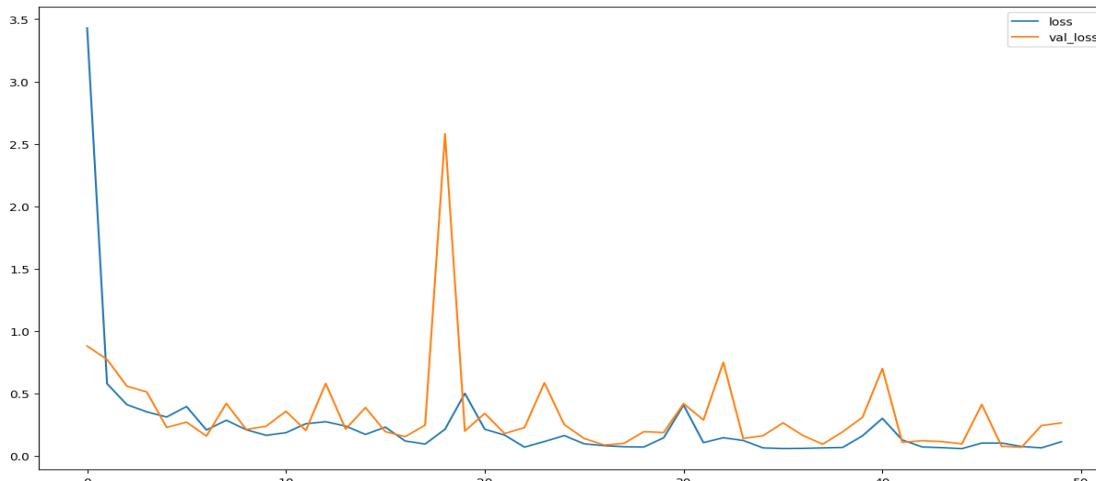


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 11

Pengujian kesebelas melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 50, batch size 32 dan learning rate sebesar 0.001



Plot Akurasi & Loss

|                  | Precision   | Recall | F1-Score |
|------------------|-------------|--------|----------|
| Dark Roast       | 0.99        | 0.7    | 0.95     |
| Green Bean       | 0.97        | 1      | 0.99     |
| Light Roast      | 0.99        | 0.97   | 0.98     |
| Medium Roast     | 0.77        | 0.98   | 0.86     |
| Accuracy         | <b>0.91</b> |        |          |
| Average F1-Score | <b>0.91</b> |        |          |

Classification Report

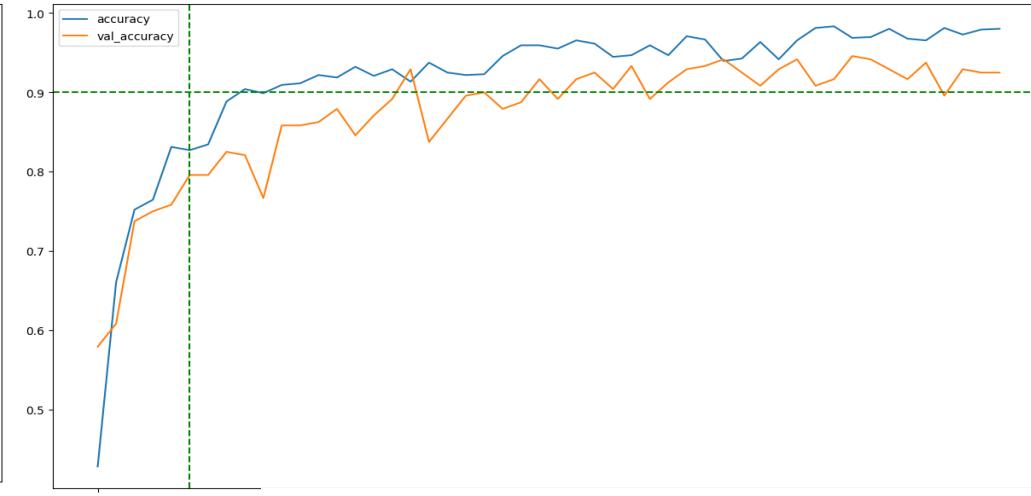
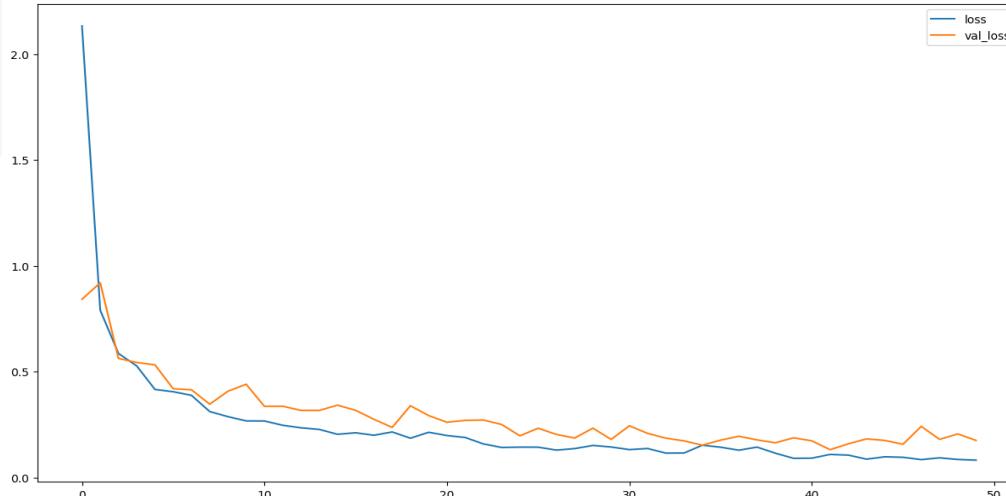


Confusion matrix

# PENGUJIAN SISTEM

## PENGUJIAN 12

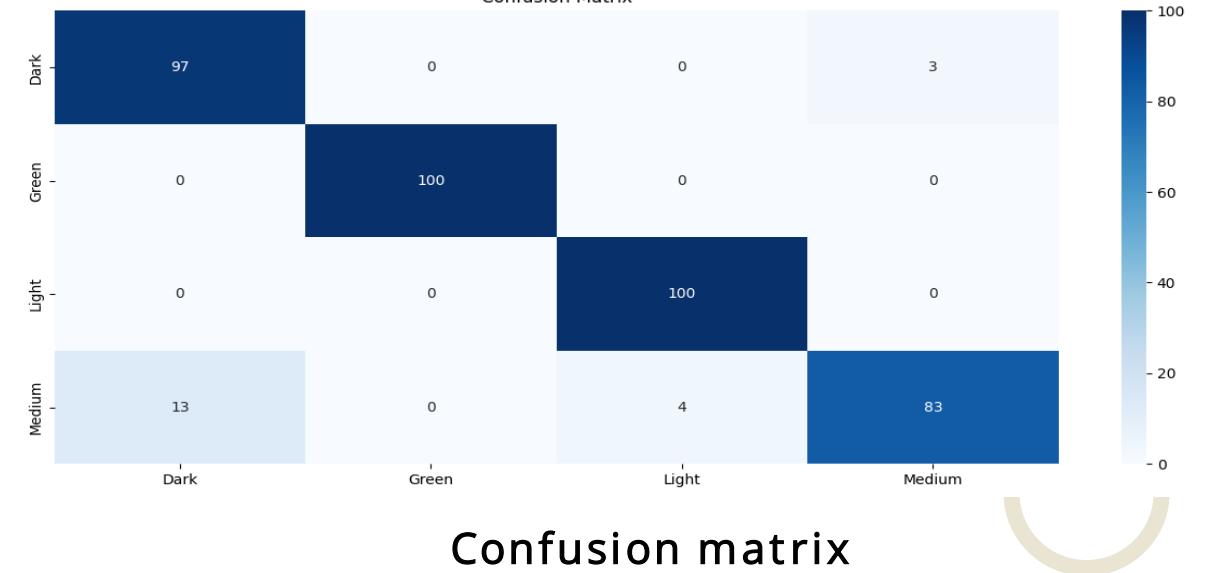
Pengujian keduabelas melibatkan augmentasi citra berupa Horizontal Flip ,shear,rotation dengan epoch 50, batch size 32 dan learning rate sebesar 0.0001



Plot Akurasi & Loss

|                  | Precision | Recall      | F1-Score |
|------------------|-----------|-------------|----------|
| Dark Roast       | 0.88      | 0.97        | 0.92     |
| Green Bean       | 1         | 1           | 1        |
| Light Roast      | 0.96      | 1           | 0.98     |
| Medium Roast     | 0.97      | 0.83        | 0.89     |
| Accuracy         |           | <b>0.95</b> |          |
| Average F1-Score |           | <b>0.95</b> |          |

Classification Report



Confusion matrix

# BAB 4

## IMPLEMENTASI DAN PENGUJIAN

### PEMBAHASAN

| Pengujian    | Akurasi | Precision | F1-Score | Loss   | Epoch | Learning rate |
|--------------|---------|-----------|----------|--------|-------|---------------|
| Pengujian 1  | 0.98    | 0.98      | 0.98     | 0.0702 | 25    | 0.001         |
| Pengujian 2  | 0.95    | 0.95      | 0.95     | 0.1237 | 25    | 0.0001        |
| Pengujian 3  | 0.93    | 0.93      | 0.93     | 0.1849 | 25    | 0.001         |
| Pengujian 4  | 0.94    | 0.95      | 0.94     | 0.1996 | 25    | 0.0001        |
| Pengujian 5  | 0.89    | 0.92      | 0.89     | 0.1780 | 25    | 0.001         |
| Pengujian 6  | 0.9     | 0.93      | 0.9      | 0.1051 | 25    | 0.0001        |
| Pengujian 7  | 0.9     | 0.93      | 0.9      | 0.3245 | 25    | 0.001         |
| Pengujian 8  | 0.93    | 0.93      | 0.93     | 0.1799 | 25    | 0.0001        |
| Pengujian 9  | 0.89    | 0.92      | 0.89     | 0.1131 | 50    | 0.001         |
| Pengujian 10 | 0.94    | 0.93      | 0.94     | 0.0688 | 50    | 0.0001        |
| Pengujian 11 | 0.91    | 0.93      | 0.91     | 0.0941 | 50    | 0.001         |
| Pengujian 12 | 0.95    | 0.95      | 0.95     | 0.0923 | 50    | 0.0001        |

# BAB 4

## IMPLEMENTASI DAN PENGUJIAN

### PEMBAHASAN

#### PENGUJIAN AUGMENTASI

|             |      |      |      |        |    |        |
|-------------|------|------|------|--------|----|--------|
| Pengujian 1 | 0.98 | 0.98 | 0.98 | 0.0702 | 25 | 0.001  |
| Pengujian 2 | 0.95 | 0.95 | 0.95 | 0.1237 | 25 | 0.0001 |
| Pengujian 3 | 0.93 | 0.93 | 0.93 | 0.1849 | 25 | 0.001  |
| Pengujian 4 | 0.94 | 0.95 | 0.94 | 0.1996 | 25 | 0.0001 |

Pada pengujian pertama Hanya menggunakan augmentasi **Horizontal Flip** dan learning rate yang **tidak terlalu kecil (0.001)**. Hal ini menjaga model agar tidak terlalu hati-hati saat belajar (tidak terlalu lambat convergence). Dan Hanya **sedikit misclass** pada “Medium Roast” dan “Dark Roast”, yang bisa dianggap minor error.

Pada pengujian kedua akurasi menurun jadi 95% dan terjadi salah klasifikasi yang cukup banyak pada kelas “dark roast”. Lalu pada pengujian ketiga Kombinasi **augmentasi beragam (flip, shear, rotation)** menyebabkan **overfitting atau noise terlalu besar**, terutama pada “Medium Roast” (Recall hanya 0.73) Dan pada pengujian keempat Meskipun akurasi tinggi (**0.94**), tetapi **F1-Score Medium Roast rendah (0.87)** dan **terjadi salah klasifikasi Medium–Dark yang besar (19 salah)** yang artinya model mungkin terlalu percaya diri pada kelas tertentu (bias).

Pengujian 1 adalah yang paling optimal karena berhasil mencapai akurasi tinggi, distribusi metrik yang seimbang, stabilitas pelatihan yang baik, dan augmentasi yang tidak berlebihan. Ini menunjukkan model mampu generalisasi dengan baik tanpa overfitting atau underfitting.

# BAB 4

## IMPLEMENTASI DAN PENGUJIAN

### PEMBAHASAN

#### PENGUJIAN HYPERPARAMETER

|              |      |      |      |        |    |        |
|--------------|------|------|------|--------|----|--------|
| Pengujian 5  | 0.89 | 0.92 | 0.89 | 0.1780 | 25 | 0.001  |
| Pengujian 6  | 0.9  | 0.93 | 0.9  | 0.1051 | 25 | 0.0001 |
| Pengujian 7  | 0.9  | 0.93 | 0.9  | 0.3245 | 25 | 0.001  |
| Pengujian 8  | 0.93 | 0.93 | 0.93 | 0.1799 | 25 | 0.0001 |
| Pengujian 9  | 0.89 | 0.92 | 0.89 | 0.1131 | 50 | 0.001  |
| Pengujian 10 | 0.94 | 0.93 | 0.94 | 0.0688 | 50 | 0.0001 |
| Pengujian 11 | 0.91 | 0.93 | 0.91 | 0.0941 | 50 | 0.001  |
| Pengujian 12 | 0.95 | 0.95 | 0.95 | 0.0923 | 50 | 0.0001 |

Berdasarkan delapan pengujian yang dilakukan (Pengujian 5 hingga 12), dapat disimpulkan bahwa konfigurasi model dengan **learning rate sebesar 0.0001, epoch sebanyak 50, dan batch size 32** (Pengujian 12) memberikan hasil terbaik secara keseluruhan. Hal ini ditunjukkan oleh **akurasi dan rata-rata F1-Score tertinggi sebesar 0.95**, serta distribusi prediksi yang merata pada confusion matrix, di mana seluruh kelas—termasuk kelas yang sebelumnya sulit seperti "Dark Roast"—mampu dikenali dengan baik. Dibandingkan pengujian lain, konfigurasi ini menunjukkan kestabilan pada grafik akurasi dan loss, serta ketepatan tinggi dalam prediksi semua kelas. Dengan demikian, kombinasi parameter tersebut sangat direkomendasikan untuk digunakan dalam pelatihan model klasifikasi citra kopi ini karena mampu meningkatkan performa generalisasi model secara signifikan.

## BAB 4

### IMPLEMENTASI DAN PENGUJIAN

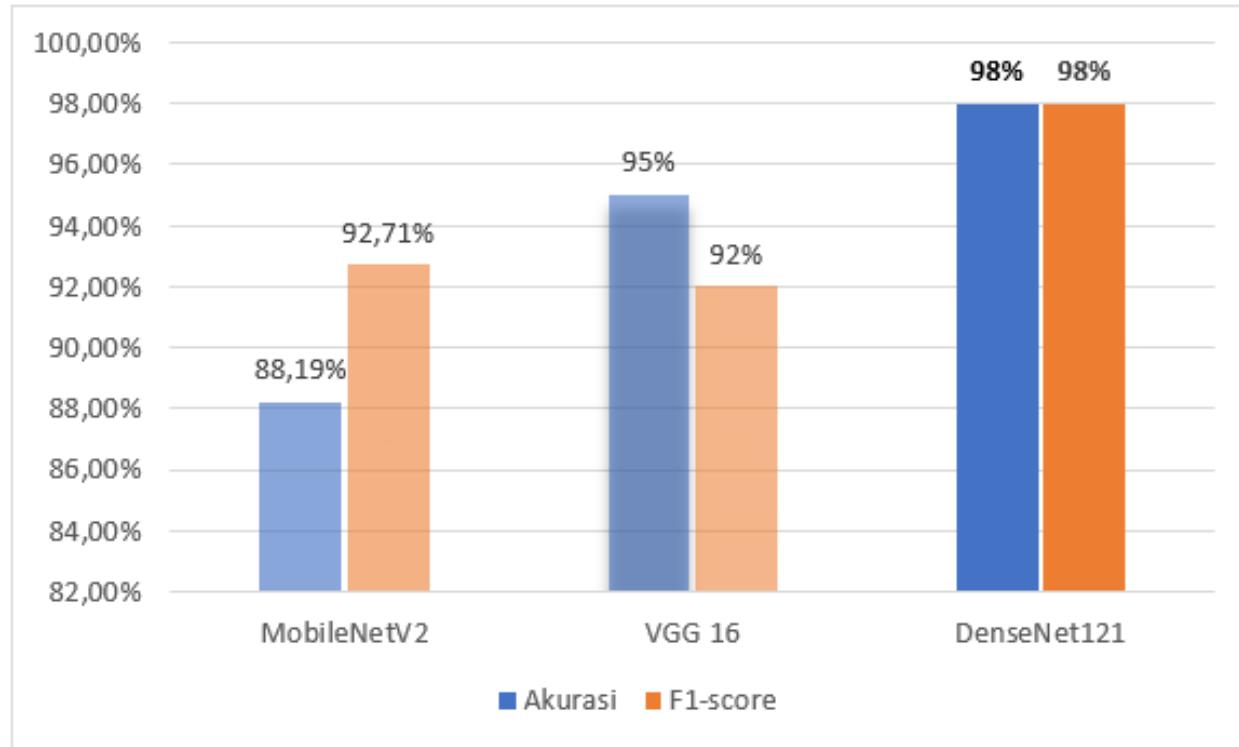
#### KESIMPULAN HASIL PENGUJIAN

Meskipun Pengujian 12 memiliki kombinasi parameter yang optimal untuk kasus umum, **secara metrik performa, Pengujian 1 adalah yang terbaik.** Dengan **akurasi 0.98 dan F1-score 0.9825**, serta distribusi prediksi yang nyaris sempurna, Pengujian 1 lebih unggul secara keseluruhan. Model juga konvergen lebih cepat (epoch hanya 25) dengan learning rate yang lebih besar, menunjukkan bahwa dalam kondisi ini, model dapat belajar dengan cepat dan efektif tanpa overfitting.

## BAB 4

### IMPLEMENTASI DAN PENGUJIAN

## PEMBAHASAN



Pada penelitian yang dilakukan oleh Nailul Fikri Nasution pada *MobileNetV2* Dengan melakukan pengujian hyperparameter, didapatkan performasi model dengan learning rate 0.0001, batch size 16, dan epoch 30. Menghasilkan nilai Akurasi 88,19% dan F1-score 92,71%. Dan penelitian yang dilakukan oleh Murinto Kusno pada *VGG16* dengan menggunakan parameter learning rate 0,0001 dan epoch 25 menghasilkan akurasi sebesar 95% dan F1-score sebesar 92%. Arsitektur DenseNet121 terbukti efisien dalam mengklasifikasikan biji kopi dengan spesifikasi model yang digunakan yaitu learning rate 0.001 batch size 32 dan epoch 25 yang menghasilkan akurasi sebesar 98% dan f1-score 98%.

## BAB 4

### IMPLEMENTASI DAN PENGUJIAN

## KESIMPULAN

Pada penelitian ini telah mengimplementasikan metode convolutional neural

- network (CNN) dengan arsitektur DenseNet121 untuk mengklasifikasi biji kopi berdasarkan tingkat kematangan berhasil di lakukan.
- Performa arsitektur DenseNet121 pada Klasifikasi biji kopi berdasarkan tingkat kematangan menunjukkan kinerja yang baik yang hasil akurasi terbesarnya adalah 98% dengan loss 0.0702 pada model pengujian ke 1