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Lampiran 1: *Code* Sistem Inspeksi Kerusakan Jaringan Pipa Bawah Laut

Code* untuk mengklasifikasikan data input untuk *Training:

```
import numpy as np
import matplotlib.pyplot as plt
import os
import cv2 as cv
DATADIR = r'E:\SPECTA_1\training data'
CATEGORIES = ["Corrosion", "Crack"]
for category in CATEGORIES:
    path = os.path.join(DATADIR, category) # path to CATEGORIES
    for img in os.listdir(path):
        img_array = cv.imread(os.path.join(path,img), cv.IMREAD_COLOR)
        plt.imshow(img_array)
        plt.show()
        break
    break
training_data =[]
def create_training_data():
    for category in CATEGORIES:
        path = os.path.join(DATADIR, category) # path to CATEGORIES
        class_num = CATEGORIES.index(category)
        for img in os.listdir(path):
            try:
```

```
            img_array = cv.imread(os.path.join(path,img),
          cv.IMREAD_GRAYSCALE)
            new_array = cv.resize(img_array, (IMG_SIZE, IMG_SIZE))
            training_data.append([new_array, class_num])
        except Exception as e:
            pass
create_training_data()
import random
random.shuffle(training_data)
X = []
y = []
for features, label in training_data:
    X.append(features)
    y.append(label)

X = np.array(X).reshape(-1, IMG_SIZE, IMG_SIZE, 1)
import pickle
pickle_out =open("X.pickle", "wb")
pickle.dump(X,pickle_out)
pickle_out.close()
pickle_out =open("y.pickle", "wb")
pickle.dump(y,pickle_out)
pickle_out.close()
```

***Code* untuk melakukan proses *Training Data*:**

```
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Activation, Flatten, Conv2D,
        MaxPooling2D
from tensorflow.keras.callbacks import TensorBoard
import pickle
import time
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.optimizers import RMSprop

gpu_options =
        tf.compat.v1.GPUOptions(per_process_gpu_memory_fraction=0.333)
sess =
        tf.compat.v1.Session(config=tf.compat.v1.ConfigProto(gpu_options=gpu
        _options))

pickle_in = open("X.pickle", "rb")
X = pickle.load(pickle_in)
pickle_in = open("y.pickle", "rb")
y = pickle.load(pickle_in)

X = X / 255.0
```

```
dense_layers = [0]
layer_sizes = [32]
conv_layers = [2]

for dense_layer in dense_layers:
  for layer_size in layer_sizes:
    for conv_layer in conv_layers:
      NAME = "{}-conv-{}-nodes-{}-dense-{}".format(conv_layer, layer_size,
        dense_layer, int(time.time()))
      tensorboard = TensorBoard(log_dir=
        r'E:\SPECTA_1\logs\{}'.format(NAME))
      print(NAME)
      model = Sequential()

      model.add(Conv2D(layer_size, (3, 3), input_shape=X.shape[1:]))
      model.add(Activation('relu'))
      model.add(MaxPooling2D(pool_size=(2, 2)))

      for l in range(conv_layer-1):
        model.add(Conv2D(layer_size, (3, 3)))
        model.add(Activation('relu'))
        model.add(MaxPooling2D(pool_size=(2, 2)))
```

```
            model.add(Dropout(0.2))

        model.add(Flatten())
        for j in range(dense_layer):
            model.add(Dense(layer_size))
            model.add(Activation('relu'))
            model.add(Dropout(0.2))

        model.add(Dense(1))
        model.add(Activation('sigmoid'))

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

        model.fit(X, y, batch_size=32, epochs=10, validation_split=0.2,
          callbacks=[tensorboard])

model.save('32x2-CNN2.model')
```

***Code* untuk melakukan pengujian *Data Test*:**

```
import cv2
import tensorflow as tf
import matplotlib.pyplot as plt
import numpy as np

CATEGORIES = ["Corrosion", "Crack"]
def prepare(filepath):
    IMG_SIZE = 400
    img_array = cv2.imread(filepath, cv2.IMREAD_GRAYSCALE)
    new_array = cv2.resize(img_array, (IMG_SIZE, IMG_SIZE))
    return new_array.reshape(-1, IMG_SIZE, IMG_SIZE, 1)

model = tf.keras.models.load_model("32x2-CNN2.model")
img_array = cv2.imread('25.jpg', cv2.IMREAD_COLOR)
img_array = cv2.resize(img_array, (1000,1000))

prediction = model.predict([prepare('25.jpg')])
label = str(CATEGORIES[int(prediction[0][0])])
cv2.putText(img_array, "Masalah : " + label, (50,250),
            cv2.FONT_HERSHEY_SIMPLEX, 2, (255,255,0), 3, cv2.LINE_AA)
if label == 'Corrosion':
```

```
    cv2.putText(img_array, "Solusi : Penambahan lapisan anti-corrosion", (50,300),
            cv2.FONT_HERSHEY_SIMPLEX, 1, (255,255,0), 3, cv2.LINE_AA)
else:
    cv2.putText(img_array, "Solusi : Diperlukan pergantian pada pipa", (50,300),
            cv2.FONT_HERSHEY_SIMPLEX, 1, (255,255,0), 3, cv2.LINE_AA)

plt.imshow(img_array)
plt.show()
cv2.waitKey(0)
cv2.destroyAllWindows()
```

Code* untuk pengujian *Data Test* secara *real-time

```
import cv2
import tensorflow as tf
import matplotlib.pyplot as plt
import numpy as np

CATEGORIES = ["Corrosion", "Crack"]
model = tf.keras.models.load_model("32x2-CNN2.model")
def prepare():
    cap = cv2.VideoCapture(0)
    while(True):
        ret, frame = cap.read()
        rgb = cv2.cvtColor(frame, cv2.IMREAD_COLOR)
        cv2.imshow('frame',rgb)
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break
    cap.release()
    cv2.destroyAllWindows()

prediction = model.predict([prepare()])
label = str(CATEGORIES[int(prediction[0][0])])
cv2.putText(frame, "Masalah : " + label, (50,100),
            cv2.FONT_HERSHEY_SIMPLEX, 2, (255,255,0), 3, cv2.LINE_AA)
```

```
if label == 'Corrosion':
    cv2.putText(frame, "Solusi : Penambahan lapisan anti-corrosion", (50,150),
            cv2.FONT_HERSHEY_SIMPLEX, 1, (255,255,0), 3, cv2.LINE_AA)
else:
    cv2.putText(frame, "Solusi : Diperlukan pergantian pada pipa", (50,150),
            cv2.FONT_HERSHEY_SIMPLEX, 1, (255,255,0), 3, cv2.LINE_AA)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

***Code* Interface aplikasi**

```
from tkinter import *
from PIL import Image
from PIL import ImageTk
from tkinter import filedialog
import cv2
import tensorflow as tf
import numpy as np

def select_image():
    global panelA, panelB
    path = filedialog.askopenfilename()

    if len(path) > 0:
        CATEGORIES = ["Corrosion", "Crack"]
        def prepare(path):
            IMG_SIZE = 400
            image = cv2.imread(path, cv2.IMREAD_GRAYSCALE)
            new_array = cv2.resize(image, (IMG_SIZE, IMG_SIZE))
            return new_array.reshape(-1, IMG_SIZE, IMG_SIZE, 1)

        model = tf.keras.models.load_model("32x2-CNN2.model")
```

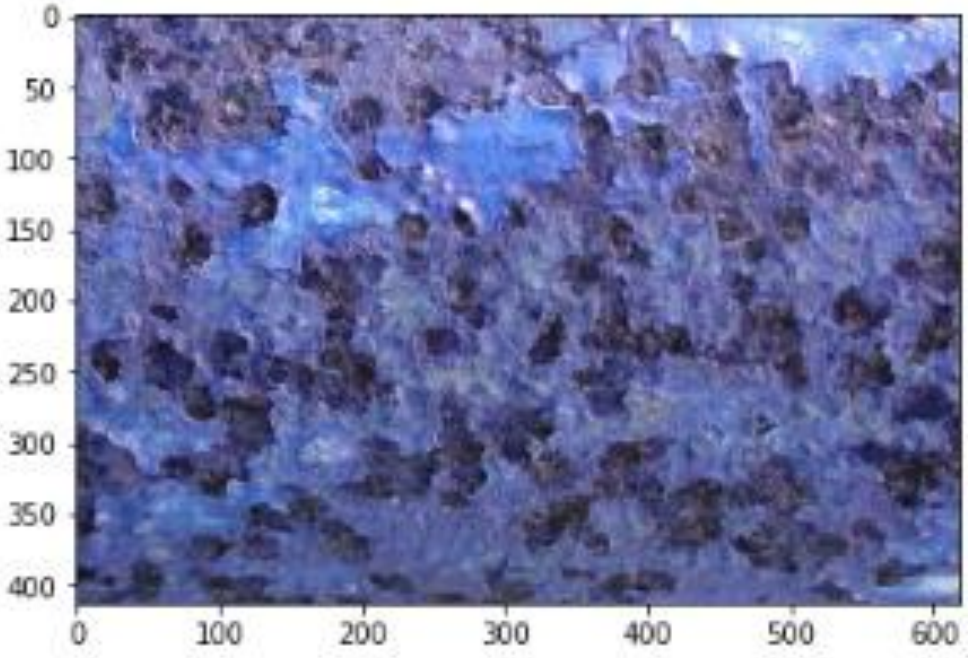
```
image = cv2.imread(path)
prediction = model.predict([prepare(path)])
new_array = cv2.resize(image, (500, 500))
label = str(CATEGORIES[int(prediction[0][0])])

cv2.putText(new_array, "Masalah : " + label, (100,250), cv2.FONT_HERSHEY_SIMPLEX, 1, (0,255,0), 2, cv2.LINE_AA)
if label == 'Corrosion':
  cv2.putText(new_array, "Solusi : Penambahan lapisan anti-corrosion", (80,270),  cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0,255,0), 1, cv2.LINE_AA)
else:
  cv2.putText(new_array, "Solusi : Diperlukan pengelasan pada bagian retak", (60,270), cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0,255,0), 1, cv2.LINE_AA)

image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
new_array = cv2.cvtColor(new_array, cv2.COLOR_BGR2RGB)

image = cv2.resize(image, (500, 500))

image = Image.fromarray(image)
new_array = Image.fromarray(new_array)
image = ImageTk.PhotoImage(image)
```

```
        new_array = ImageTk.PhotoImage(new_array)
        if panelA is None or panelB is None:
            panelA = Label(image=image)
            panelA.image = image
            panelA.pack(side="left", padx=60, pady=10)
            panelB = Label(image=new_array)
            panelB.image = new_array
            panelB.pack(side="right", padx=60, pady=10)
        else:
            panelA.configure(image=image)
            panelB.configure(image=new_array)
            panelA.image = image
            panelB.image = new_array


def show_frame():
        width, height = 800, 600
        cap = cv2.VideoCapture(0)
        cap.set(cv2.CAP_PROP_FRAME_WIDTH, width)
        cap.set(cv2.CAP_PROP_FRAME_HEIGHT, height)
        root.bind('<Escape>', lambda e: root.quit())
        lmain = tk.Label(root)
        lmain.pack()
```

```
        _, frame = cap.read()
        frame = cv2.flip(frame, 1)
        cv2image = cv2.cvtColor(frame, cv2.COLOR_BGR2RGBA)
        img = Image.fromarray(cv2image)
        imgtk = ImageTk.PhotoImage(image=img)
        lmain.imgtk = imgtk
        lmain.configure(image=imgtk)
        lmain.after(10, show_frame)
        show_frame()

root = Tk()
panelA = None
panelB = None
Label(root, text = 'Surface Inspector', font =('Lucida Console', 40)).pack(side = TOP, pady = 10, padx=50)
Label(root, text = 'Created by Alan Fhajoeng Ramadhan', font =('Lucida Console', 10)).pack(side = TOP, pady = 0, padx=50)

btncamera = Button(root, text="Select an Image", command=select_image, bg='blue', fg='white')
btncamera.pack(side="bottom", fill="both", expand="yes", padx="10", pady="10")
```

```
btnvideo = Button(root, text="Start Real-Time Camera", command=show_frame, bg='blue', fg='white')

btnvideo.pack(side="bottom", fill="both", expand="yes", padx="10", pady="10")


root.title('SPECTA')

root.mainloop()
```

Lampiran 2: Proses Kerja Sistem Inspeksi Kerusakan Jaringan Pipa Bawah Laut



Gambar 1 Hasil citra RGB pada permukaan pipa

```
training_data =[]

def create_training_data():
    for category in CATEGORIES:
        path = os.path.join(DATADIR, category) # path to CATEGORIES
        class_num = CATEGORIES.index(category)
        for img in os.listdir(path):
            try:
                img_array = cv.imread(os.path.join(path,img), cv.IMREAD_GRAYSCALE)
                new_array = cv.resize(img_array, (IMG_SIZE, IMG_SIZE))
                training_data.append([new_array, class_num])
            except Exception as e:
                pass

create_training_data()
```

```
print(len(training_data))
```

```
2400
```

```
import random

random.shuffle(training_data)
```

```
for sample in training_data[:10]:
    print(sample[1])
```

```
0
1
0
0
0
0
0
1
0
0
```

```
X = []
y = []
```

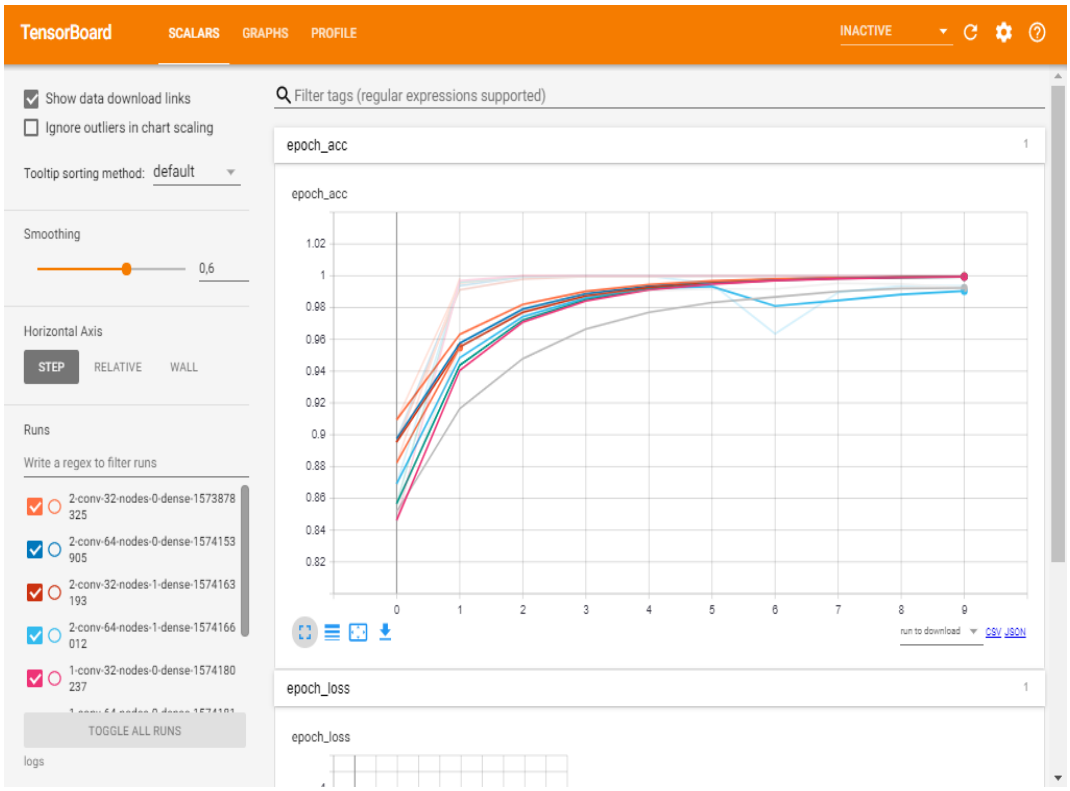
```
for features, label in training_data:
    X.append(features)
    y.append(label)

X = np.array(X).reshape(-1, IMG_SIZE, IMG_SIZE, 1)
```

```
import pickle

pickle_out =open("X.pickle", "wb")
pickle.dump(X,pickle_out)
pickle_out.close()

pickle_out =open("y.pickle", "wb")
pickle.dump(y,pickle_out)
pickle_out.close()
```

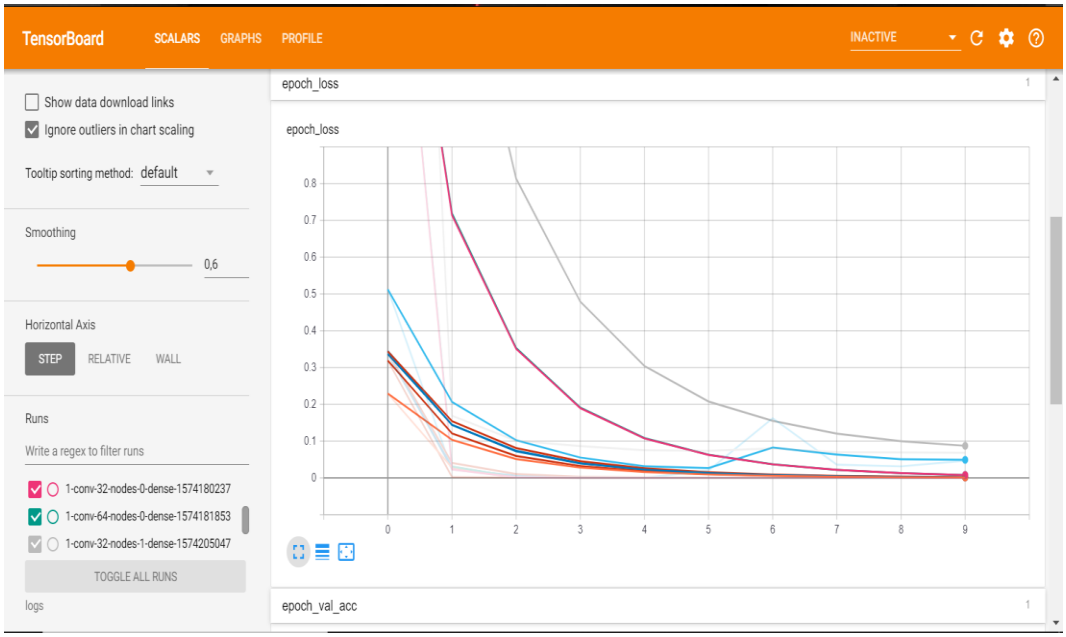
Gambar 2 Proses pengelompokan data input untuk proses *Training*

```
2-conv-32-nodes-0-dense-1573878325
WARNING:tensorflow:From c:\python36.8\lib\site-packages\tensorflow\python\ops\init_ops.py:1251: calling VarianceScaling.__init_
_ (from tensorflow.python.ops.init_ops) with dtype is deprecated and will be removed in a future version.
Instructions for updating:
Call initializer instance with the dtype argument instead of passing it to the constructor
WARNING:tensorflow:From c:\python36.8\lib\site-packages\tensorflow\python\ops\nn_impl.py:180: add_dispatch_support.<locals>.wra
pper (from tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
Train on 1920 samples, validate on 480 samples
Epoch 1/10
  64/1920 [>.............................] - ETA: 40:20 - loss: 1.1983 - acc: 0.3750  WARNING:tensorflow:Method (on_train_batch
_end) is slow compared to the batch update (4.119401). Check your callbacks.
1920/1920 [==============================] - 334s 174ms/sample - loss: 0.2293 - acc: 0.9094 - val_loss: 0.0608 - val_acc: 0.991
7
Epoch 2/10
1920/1920 [==============================] - 370s 193ms/sample - loss: 0.0279 - acc: 0.9953 - val_loss: 0.0026 - val_acc: 1.000
018:
Epoch 3/10
1920/1920 [==============================] - 269s 140ms/sample - loss: 0.0012 - acc: 1.0000 - val_loss: 5.9336e-04 - val_acc:
1.0000
Epoch 4/10
1920/1920 [==============================] - 263s 137ms/sample - loss: 3.9156e-04 - acc: 1.0000 - val_loss: 3.0362e-04 - val_ac
c: 1.0000
Epoch 5/10
1920/1920 [==============================] - 267s 139ms/sample - loss: 2.3749e-04 - acc: 1.0000 - val_loss: 1.7045e-04 - val_ac
c: 1.0000
Epoch 6/10
1920/1920 [==============================] - 274s 143ms/sample - loss: 1.5650e-04 - acc: 1.0000 - val_loss: 1.1812e-04 - val_ac
c: 1.0000
Epoch 7/10
1920/1920 [==============================] - 282s 147ms/sample - loss: 1.0838e-04 - acc: 1.0000 - val_loss: 9.3159e-05 - val_ac
c: 1.0000
Epoch 8/10
1920/1920 [==============================] - 283s 148ms/sample - loss: 8.2581e-05 - acc: 1.0000 - val_loss: 6.7311e-05 - val_ac
c: 1.0000
Epoch 9/10
1920/1920 [==============================] - 271s 141ms/sample - loss: 6.3440e-05 - acc: 1.0000 - val_loss: 5.4819e-05 - val_ac
c: 1.0000
Epoch 10/10
1920/1920 [==============================] - 272s 142ms/sample - loss: 5.2097e-05 - acc: 1.0000 - val_loss: 4.2883e-05 - val_ac
c: 1.0000
```

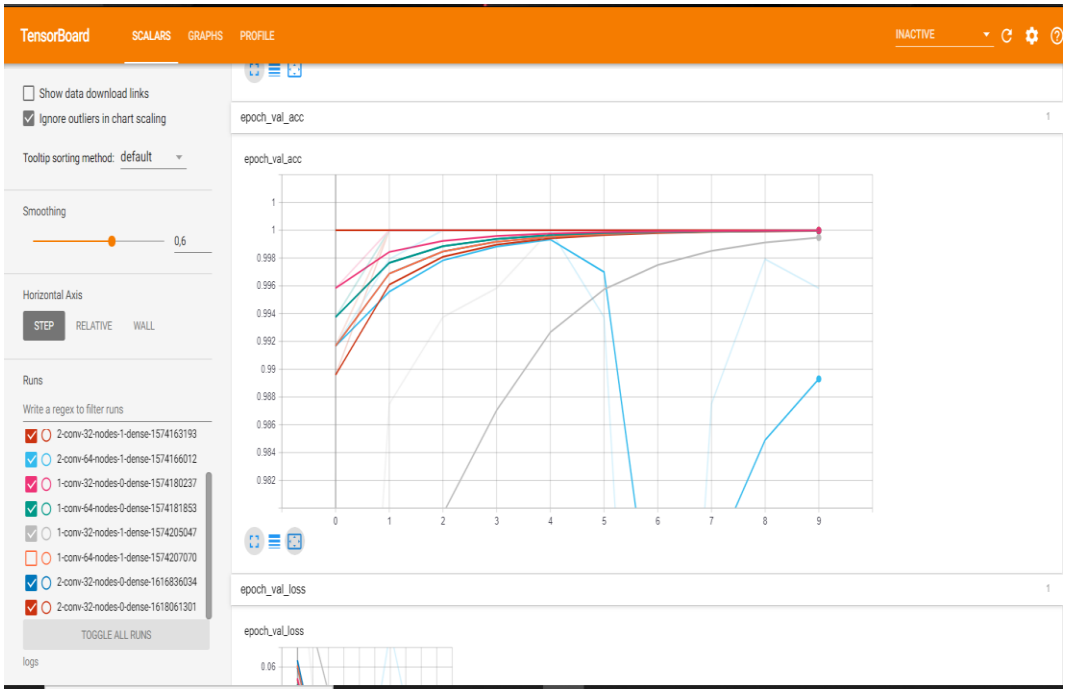
Gambar 3. Proses *Training Data* menggunakan model CNN



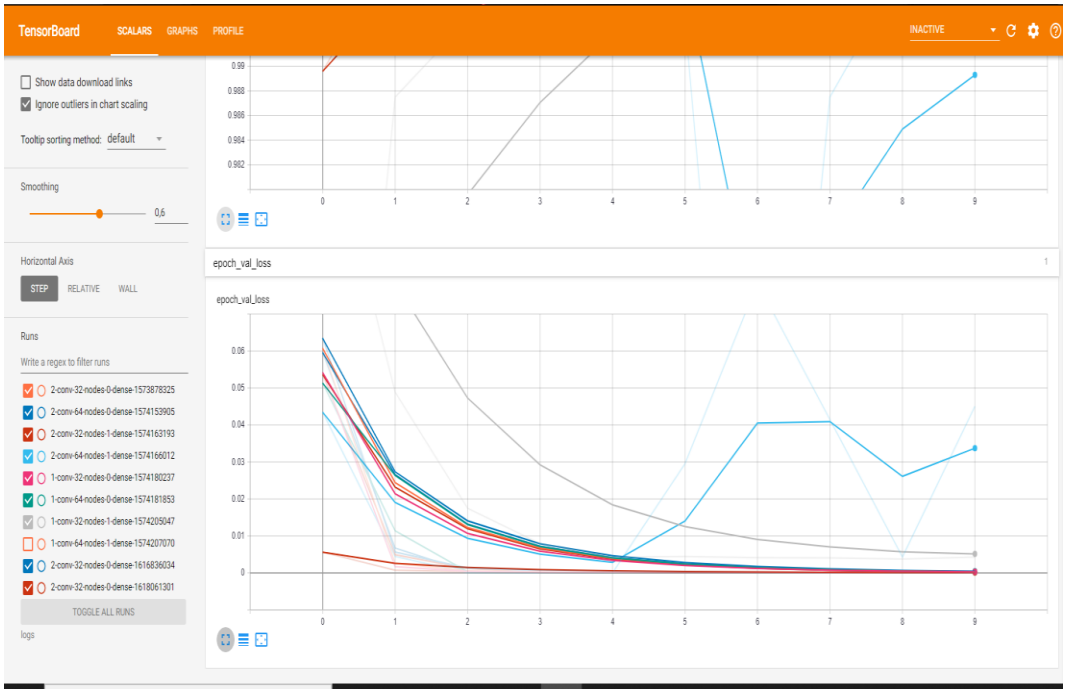
Gambar 4. Tampilan grafik hasil *Accuracy* pada proses *Data Training* beberapa Model CNN pada *Tensorboard Package*



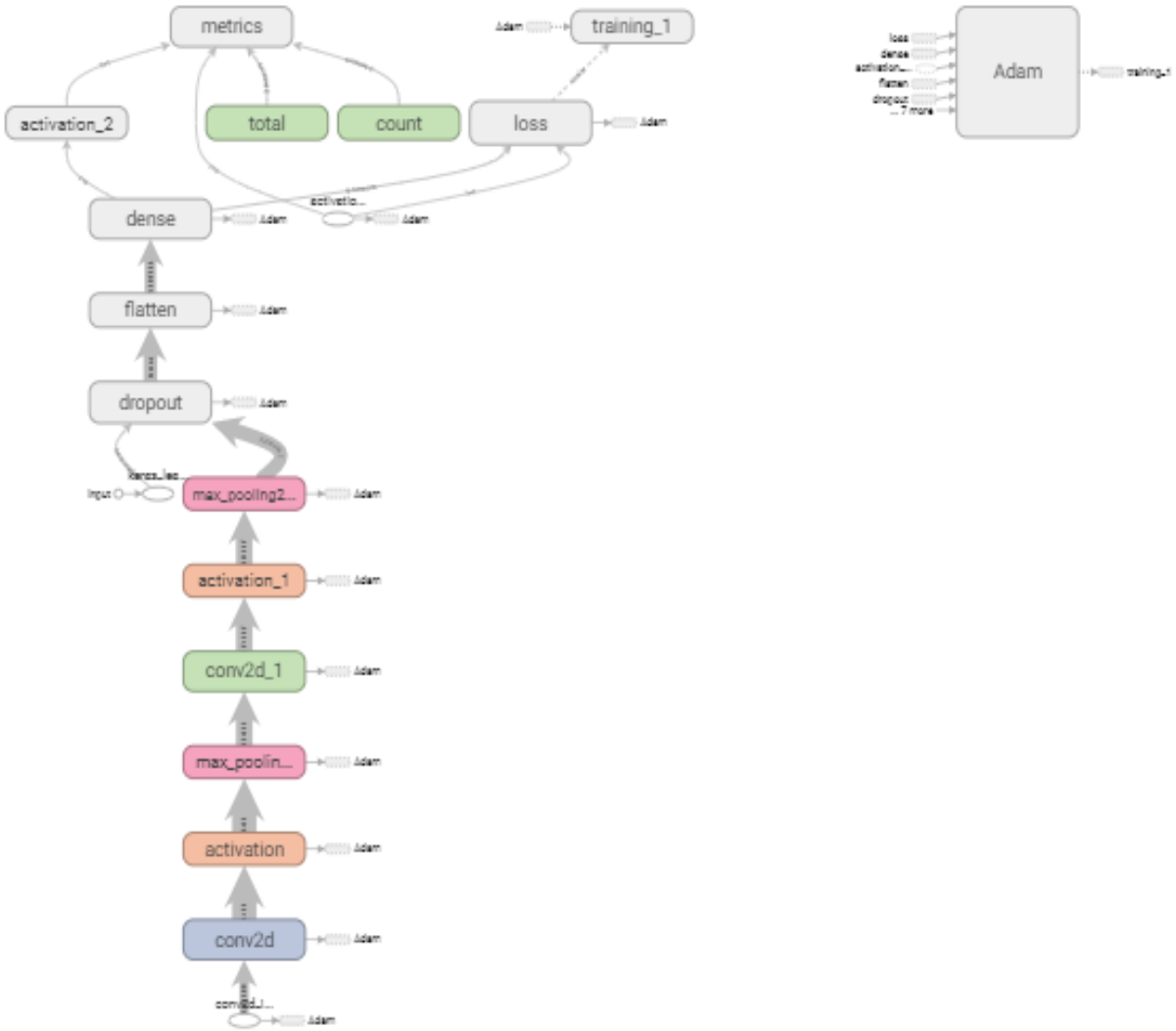
Gambar 5. Tampilan grafik hasil *Loss (Error)* pada proses *Data Training* beberapa Model CNN pada *Tensorboard Package*



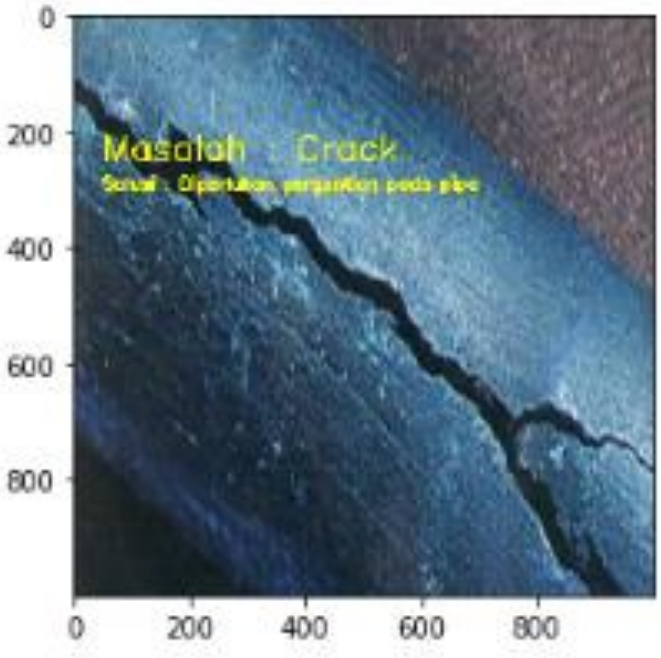
Gambar 6. Tampilan grafik hasil *Accuracy Validation* pada proses *Data Training* beberapa Model CNN pada *Tensorboard Package*



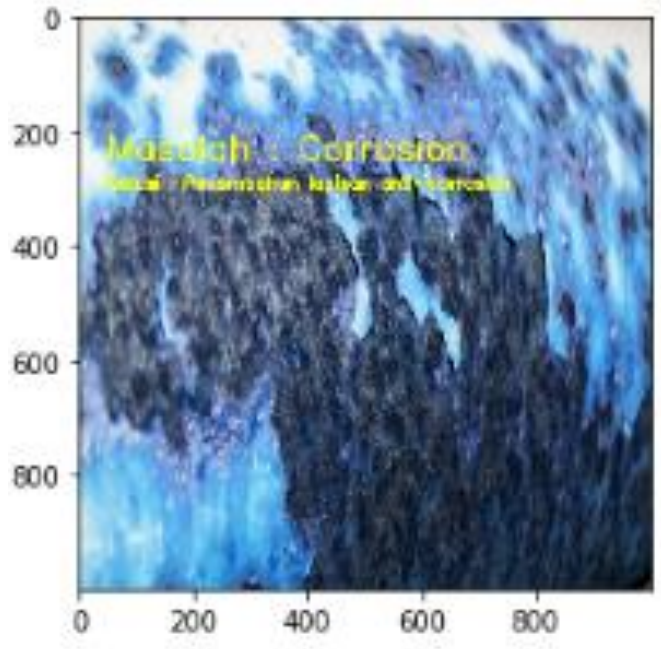
Gambar 7. Tampilan grafik hasil *Loss (Error) Validation* pada proses *Data Training* beberapa Model CNN pada *Tensorboard Package*



Gambar 5. Tampilan arsitektur model CNN 2 *Convulational Layer*, *32 Filter,* dan 1 *Full-Connected Layer* pada *Tensorboard Package*

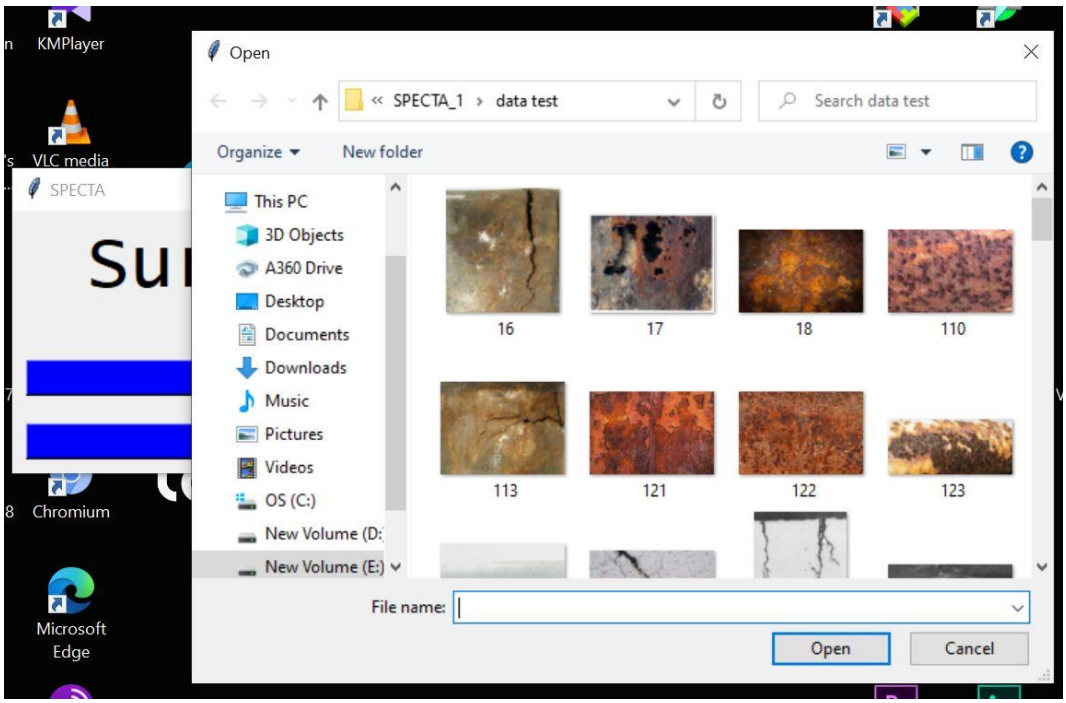


Gambar 6. Hasil dari pengujian *Data Test* menunjukkan gambar pipa pada kelas *Crack*

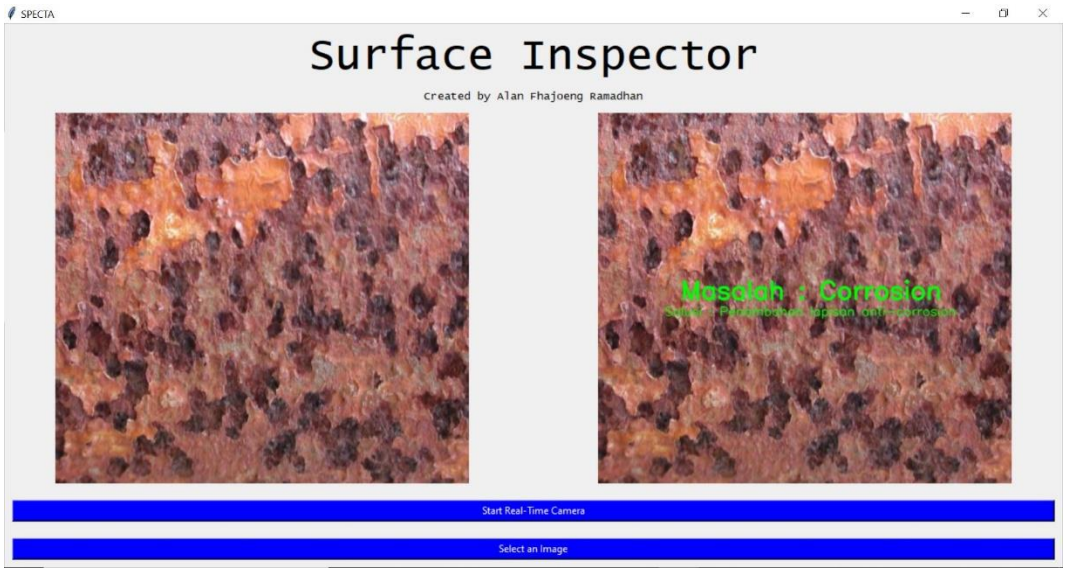


Gambar 7. Hasil dari pengujian *Data Test* menunjukkan gambar pipa pada kelas *Corrosion*

Gambar 8. Tampilan interface awal Aplikasi



Gambar 9. Tampilan interface untuk mengambil gambar yang akan diolah oleh Aplikasi



Gambar 10. Tampilan interface hasil olahan gambar yang mengidentifikasikan gambar kasus Corrosion

Gambar 10. Tampilan interface hasil olahan gambar yang mengidentifikasikan gambar kasus Crack

Lampiran 3: Perhitungan Matematik

Sistem Inspeksi Kerusakan Jaringan

Pipa Bawah Laut

1. Perhitungan matematik kasus kerusakan *Corrosion*

Gambar 1. Tampilan Image input untuk perhitungan matematik kasus *Corrosion* dengan ukuran 10 x 10 px

A. Tahap Pre-Processing

50	50	51	52	52	52	51	52	53	50
45	48	48	49	47	46	46	47	44	50
30	32	48	49	50	60	68	70	79	85
28	26	32	34	68	94	95	102	103	114
27	29	30	50	67	88	101	110	115	120
16	28	25	34	21	40	52	61	32	21
28	24	20	32	34	28	28	27	19	18
25	22	24	27	28	27	26	25	20	19
16	17	19	22	28	28	27	28	22	20
132	135	129	121	101	100	95	91	90	85

Tabel ~~Gambar~~ 1.1. Nilai range scale untuk data input yang akan diolah pada tahap ~~proses~~ pre-processing, dengan urutan sebagai berikut :

1. Gambar (image) diklasifikasikan berdasarkan kelasnya yaitu Corrosion dan Crack, dengan masing-masing gam sebanyak 1200 buah
2. Image kemudian dikonversi menjadi uk 400 x 400 pixel
3. Image input yang merupakan tipe RGB (3 channel) kemudian dikonversi me jadi Grayscale (1 channel)
4. Mengekstrak fitur Image berdasarka kelas, dan skala nilai warnanya.

B. Tahap Data Training

Pada tahap ini dilakukan proses training data input menggunakan struktur Convolutional Neural Network yang telah ditentukan berdasarkan nilai efisiensi yang dihasilkan pada struktur tersebut. Dalam hal ini, struktur yang digunakan adalah 2 Convolutional layer, 32 layer, dan 1 dense layer.

Pada tahap data training diawali dengan :

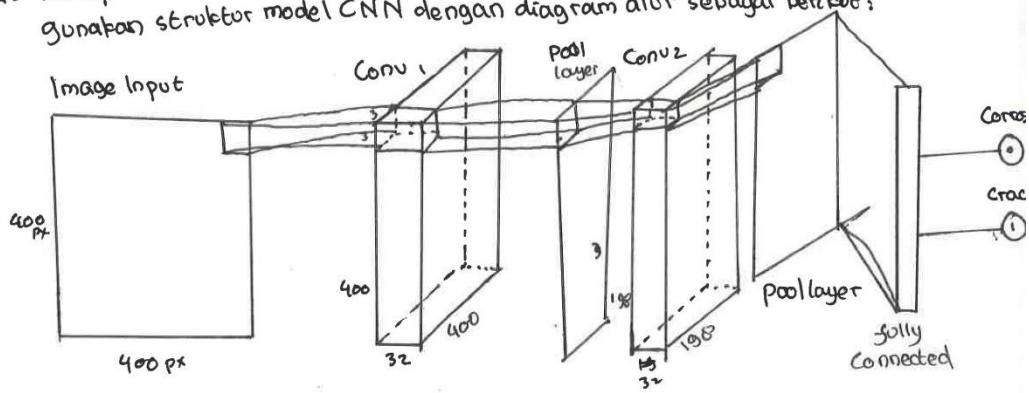
1. Membagi / mengkonversi nilai input (x) bertujuan untuk menyederhanakan nilai input (x) pada proses konvulasi menggunakan rumus :

$$x = \frac{x}{255}$$

	a	b	c	d	e	f	g	h	i	j
1	0,19	0,19	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,19
2	0,17	0,18	0,18	0,19	0,18	0,18	0,18	0,18	0,17	0,19
3	0,11	0,12	0,18	0,19	0,19	0,23	0,26	0,27	0,30	0,33
4	0,10	0,10	0,12	0,13	0,26	0,36	0,37	0,14	0,4	0,44
5	0,10	0,11	0,11	0,19	0,26	0,34	0,39	0,43	0,45	0,47
6	0,06	0,10	0,09	0,13	0,08	0,15	0,20	0,24	0,12	0,08
7	0,10	0,09	0,07	0,12	0,13	0,10	0,10	0,10	0,07	0,07
8	0,09	0,08	0,09	0,10	0,10	0,10	0,10	0,09	0,07	0,07
9	0,06	0,06	0,07	0,08	0,10	0,10	0,10	0,10	0,08	0,07
10	0,51	0,52	0,50	0,47	0,39	0,39	0,37	0,35	0,35	0,33

Tabel 1.1.2. Hasil penyederha nilai input (x)

2. Tahap Convolational, pada tahap ini data input (x) akan diolah ~~pada~~ menggunakan struktur model CNN dengan diagram alur sebagai berikut:



- Convolational layer 1
  1. Menggunakan filter kernel untuk $\sum_{i=32} w_i$:

1	0	-1	b=0
1	0	-1	
1	0	-1	

Maka proses sebagai berikut:

$C_{a1} = 0,19.1 + 0,19.0 + 0,2.-1 + 0,17.1 + 0,18.0 + 0,18.-1 + 0,11.1 + 0,12.0 + 0,18.-1 = -0,09$

$C_{b1} = 0,19.1 + 0,2.0 + 0,2.-1 + 0,18.1 + 0,18.0 + 0,19.-1 + 0,12.1 + 0,18.0 + 0,19.-1 = -0,09$

$C_{c1} = 0,2.1 + 0,2.0 + 0,2.-1 + 0,18.1 + 0,19.0 + 0,18.-1 + 0,18.1 + 0,19.0 + 0,19.-1 = -0,01$

$C_{d1} = 0,2.1 + 0,2.0 + 0,2.-1 + 0,19.1 + 0,18.0 + 0,18.-1 + 0,19.1 + 0,19.0 + 0,23.-1 = -0,03$

$C_{e1} = 0,2.1 + 0,2.0 + 0,2.-1 + 0,18.1 + 0,18.0 + 0,18.-1 + 0,19.1 + 0,23.0 + 0,26.-1 = -0,07$

$C_{f1} = 0,2.1 + 0,2.0 + 0,2.-1 + 0,18.1 + 0,18.0 + 0,18.-1 + 0,23.1 + 0,26.0 + 0,27.-1 = -0,04$

$C_{g1} = 0,2.1 + 0,2.0 + 0,2.-1 + 0,18.1 + 0,18.0 + 0,18.-1 + 0,26.1 + 0,27.0 + 0,30.-1 = -0,03$

$C_{h1} = 0,2.1 + 0,2.0 + 0,19.-1 + 0,18.1 + 0,17.0 + 0,19.-1 + 0,27.1 + 0,30.0 + 0,33.-1 = -0,06$

$C_{a2} = 0,17.1 + 0,18.0 + 0,18.1 + 0,11.1 + 0,12.0 + 0,18.-1 + 0,10.1 + 0,10.0 + 0,12.-1 = -0,$

$C_{b2} = 0,18.1 + 0,18.0 + 0,19.-1 + 0,12.1 + 0,18.0 + 0,19.-1 + 0,10.1 + 0,12.0 + 0,13.-1 = -0,11$

$C_{c2} = 0,18.1 + 0,19.0 + 0,18.-1 + 0,18.1 + 0,19.0 + 0,19.-1 + 0,12.1 + 0,13.0 + 0,26.-1 = -0,15$

$C_{d2} = 0,19.1 + 0,18.0 + 0,18.-1 + 0,19.1 + 0,19.0 + 0,23.-1 + 0,13.1 + 0,26.0 + 0,36.-1 = -0,2$

$C_{e2} = 0,18.1 + 0,18.0 + 0,18.-1 + 0,19.1 + 0,23.0 + 0,26.-1 + 0,26.1 + 0,36.0 + 0,37.-1 =$

$C_{f2} = 0,18.1 + 0,18.0 + 0,18.-1 + 0,23.1 + 0,26.0 + 0,27.-1 + 0,36.1 + 0,37.0 + 0,4.-1 = -0,0$

$C_{g2} = 0,18.1 + 0,18.0 + 0,17.-1 + 0,26.1 + 0,27.0 + 0,30.-1 + 0,37.1 + 0,4.0 + 0,4.-1 = -0,06$

$C_{h2} = 0,18.1 + 0,17.0 + 0,19.-1 + 0,27.1 + 0,30.0 + 0,33.-1 + 0,4.1 + 0,4.0 + 0,44.-1 = -0,1$

$C_{a3} = 0,11.1 + 0,12.0 + 0,18.-1 + 0,10.-1 + 0,10.0 + 0,12.-1 + 0,10.1 + 0,11.0 + 0,11.-1 = -0,1$

$C_{b3} = 0,12.1 + 0,18.0 + 0,19.-1 + 0,10.1 + 0,12.0 + 0,13.-1 + 0,11.1 + 0,11.0 + 0,19.-1 = -0,18$

$C_{c3} = 0,18.1 + 0,19.0 + 0,19.-1 + 0,12.1 + 0,13.0 + 0,26.-1 + 0,11.1 + 0,19.0 + 0,26.-1 = -0,3$

$C_{d3} = 0,19.1 + 0,19.0 + 0,23.-1 + 0,13.1 + 0,26.0 + 0,36.-1 + 0,19.1 + 0,26.0 + 0,34.-1 = -0,42$

$C_{e3} = 0,19.1 + 0,23.0 + 0,26.-1 + 0,26.1 + 0,36.0 + 0,37.-1 + 0,26.1 + 0,34.0 + 0,39.-1 = -0,31$

$C_{f3} = 0,23.1 + 0,26.0 + 0,27.-1 + 0,36.1 + 0,37.0 + 0,4.-1 + 0,34.1 + 0,39.0 + 0,43.-1 = -0,17$

$C_{g3} = 0,26.1 + 0,27.0 + 0,30.-1 + 0,37.1 + 0,4.0 + 0,4.-1 + 0,39.1 + 0,43.0 + 0,45.-1 = -0,13$

$C_{h3} = 0,27.1 + 0,30.0 + 0,33.-1 + 0,4.1 + 0,4.0 + 0,44.-1 + 0,43.1 + 0,45.0 + 0,47.-1 = -0,14$

$C_{a4} = 0,10.1 + 0,10.0 + 0,12.-1 + 0,10.1 + 0,11.0 + 0,11.-1 + 0,06.1 + 0,10.0 + 0,09.-1 = -0,06$

$C_{b4} = 0,10.1 + 0,12.0 + 0,13.-1 + 0,11.1 + 0,11.0 + 0,19.-1 + 0,10.1 + 0,09.0 + 0,13.-1 = -0,14$

$C_{c4} = 0,12.1 + 0,13.0 + 0,26.-1 + 0,11.1 + 0,19.0 + 0,26.-1 + 0,09.1 + 0,13.0 + 0,08.-1 = -0,28$

$C_{d4} = 0,13.1 + 0,26.0 + 0,36.-1 + 0,19.1 + 0,26.0 + 0,34.-1 + 0,13.1 + 0,08.0 + 0,15.-1 = -0,4$

$C_{e4} = 0,26.1 + 0,36.0 + 0,37.-1 + 0,26.1 + 0,34.0 + 0,39.-1 + 0,08.1 + 0,15.0 + 0,20.-1 = -0,36$

$C_{f4} = 0,36.1 + 0,37.0 + 0,4.-1 + 0,34.1 + 0,39.0 + 0,43.-1 + 0,15.1 + 0,20.0 + 0,24.-1 = -0,22$

$C_{g4} = 0,37.1 + 0,4.0 + 0,4.-1 + 0,39.1 + 0,43.0 + 0,45.-1 + 0,20.1 + 0,24.0 + 0,12.-1 = -0,01$

$C_{h4} = 0,4.1 + 0,4.0 + 0,44.-1 + 0,43.1 + 0,45.0 + 0,47.-1 + 0,24.1 + 0,12.0 + 0,08.-1 = 0,08$

$C_{a5} = 0,10.1 + 0,11.0 + 0,11.-1 + 0,06.1 + 0,10.0 + 0,09.-1 + 0,10.1 + 0,09.0 + 0,07.-1 = -0,01$

$C_{b5} = 0,11.1 + 0,11.0 + 0,19.-1 + 0,10.1 + 0,09.0 + 0,13.-1 + 0,09.1 + 0,07.0 + 0,12.-1 = -0,14$

$C_{c5} = 0,11.1 + 0,19.0 + 0,26.-1 + 0,09.1 + 0,13.0 + 0,08.-1 + 0,07.1 + 0,12.0 + 0,13.-1 = -0,2$

$C_{d5} = 0,19.1 + 0,26.0 + 0,34.-1 + 0,13.1 + 0,08.0 + 0,15.-1 + 0,12.1 + 0,13.0 + 0,10.-1 = -0,15$

$C_{e5} = 0,26.1 + 0,34.0 + 0,39.-1 + 0,08.1 + 0,15.0 + 0,20.-1 + 0,13.1 + 0,10.0 + 0,10.-1 = -0,22$

$C_{f5} = 0,34.1 + 0,39.0 + 0,43.-1 + 0,15.1 + 0,20.0 + 0,24.-1 + 0,10.1 + 0,10.0 + 0,10.-1 = -0,18$

$C_{g5} = 0,39.1 + 0,43.0 + 0,45.-1 + 0,20.1 + 0,24.0 + 0,12.-1 + 0,10.1 + 0,10.0 + 0,07.-1 = 0,05$

$C_{h5} = 0,43.1 + 0,43.0 + 0,47.0 - 1 + 0,24.1 + 0,12.0 + 0,08.-1 + 0,10.1 + 0,07.0 + 0,07.-1 = 0,15$

$C_{a6} = 0,06.1 + 0,10.0 + 0,09.-1 + 0,10.1 + 0,09.0 + 0,07.-1 + 0,09.1 + 0,08.0 + 0,09.-1 = 0$

$C_{b6} = 0,10.1 + 0,09.0 + 0,13.-1 + 0,09.1 + 0,07.0 + 0,12.-1 + 0,08.1 + 0,09.0 + 0,10.-1 = -0,08$

$C_{c6} = 0,09.1 + 0,13.0 + 0,08.-1 + 0,07.1 + 0,12.0 + 0,13.-1 + 0,09.1 + 0,10.0 + 0,10.-1 = -0,06$

$C_{d6} = 0,13.1 + 0,08.0 + 0,15.-1 + 0,12.1 + 0,13.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 = 0$

$C_{e6} = 0,08.1 + 0,15.0 + 0,20.-1 + 0,13.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 = -0,09$

$C_{f6} = 0,15.1 + 0,20.0 + 0,24.-1 + 0,10.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,09.-1 = -0,08$

$C_{g6} = 0,20.1 + 0,24.0 + 0,12.-1 + 0,10.1 + 0,10.0 + 0,07.-1 + 0,10.1 + 0,09.0 + 0,07.-1 = 0,14$

$C_{h6} = 0,24.1 + 0,12.0 + 0,08.-1 + 0,10.1 + 0,07.0 + 0,07.-1 + 0,09.1 + 0,07.0 + 0,07.-1 = 0,21$

$C_{a7} = 0,10.1 + 0,09.0 + 0,07.-1 + 0,09.1 + 0,08.0 + 0,09.-1 + 0,06.1 + 0,06.0 + 0,07.-1 = 0,02$

$C_{b7} = 0,09.1 + 0,07.0 + 0,12.-1 + 0,08.1 + 0,09.0 + 0,10.-1 + 0,06.1 + 0,07.0 + 0,08.-1 = -0,07$

$C_{c7} = 0,07.1 + 0,12.0 + 0,13.-1 + 0,09.1 + 0,10.0 + 0,10.-1 + 0,07.1 + 0,08.0 + 0,10.-1 = -0,1$

$C_{d7} = 0,12.1 + 0,13.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 + 0,08.1 + 0,10.0 + 0,10.-1 = 0$

$C_{e7} = 0,13.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 = 0,03$

$C_{f7} = 0,10.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,09(-1) + 0,10.1 + 0,10.0 + 0,10.-1 = 0,01$

$C_{g7} = 0,10.1 + 0,10.0 + 0,07.-1 + 0,10.1 + 0,09.0 + 0,07(-1) + 0,10.1 + 0,10.0 + 0,08.-1 = 0,08$

$C_{h7} = 0,10.1 + 0,07.0 + 0,07.-1 + 0,09.1 + 0,07.0 + 0,07.-1 + 0,10.1 + 0,08.0 + 0,07.-1 = 0,08$

$C_{a8} = 0,09.1 + 0,08.0 + 0,09.-1 + 0,06.1 + 0,06.0 + 0,07.-1 + 0,51.1 + 0,52.0 + 0,50.-1 = 0$

$C_{b8} = 0,08.1 + 0,09.0 + 0,10.-1 + 0,06.1 + 0,07.0 + 0,08.-1 + 0,52.1 + 0,50.0 + 0,47.-1 = 0,01$

$C_{c8} = 0,09.1 + 0,10.0 + 0,10.-1 + 0,07.1 + 0,08.0 + 0,10.-1 + 0,50.1 + 0,47.0 + 0,39.-1 = 0,07$

$C_{d8} = 0,10.1 + 0,10.0 + 0,10.-1 + 0,08.1 + 0,10.0 + 0,10.-1 + 0,47.1 + 0,39.0 + 0,39.-1 = 0,06$

$C_{e8} = 0,10.1 + 0,10.0 + 0,10.-1 + 0,10.1 + 0,10.0 + 0,10.-1 + 0,39.1 + 0,39.0 + 0,37.-1 = 0,02$

$C_{f8} = 0,10.1 + 0,10.0 + 0,09.-1 + 0,10.1 + 0,10.0 + 0,10.-1 + 0,39.1 + 0,37.0 + 0,35.-1 = 0,05$

$C_{g8} = 0,10.1 + 0,09.0 + 0,07.-1 + 0,10.1 + 0,10.0 + 0,08.-1 + 0,37.1 + 0,35.0 + 0,35.-1 = 0,07$

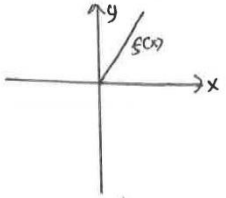
$C_{h8} = 0,09.1 + 0,07.0 + 0,07.-1 + 0,10.1 + 0,08.0 + 0,07.-1 + 0,35.1 + 0,35.0 + 0,33.-1 = 0,07$

2. Activation layer

-0,09	-0,09	-0,01	-0,03	-0,07	-0,04	-0,03	-0,06
-0,1	-0,11	-0,15	-0,26	-0,18	-0,08	-0,06	-0,11
-0,1	-0,18	-0,3	-0,42	-0,31	-0,17	-0,13	-0,14
-0,06	-0,14	-0,28	-0,4	-0,36	-0,22	-0,01	0,08
-0,01	-0,14	-0,2	-0,15	-0,22	-0,18	0,05	0,15
0	-0,08	-0,06	0	-0,09	-0,08	0,14	0,21
0,02	-0,07	-0,1	0	0,03	0,01	0,08	0,08
0	0,01	0,07	0,06	0,02	0,05	0,07	0,07

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	0,08
0	0	0	0	0	0	0,05	0,15
0	0	0	0	0	0	0,14	0,21
0,02	0	0	0	0,03	0,01	0,08	0,08
0	0,01	0,07	0,06	0,02	0,05	0,07	0,07

Padatahap ini hasil convulasi kemudian diolah menggunakan fungsi aktivasi ReLu



$$f(x) = \begin{cases} 0 & , x < 0 \\ x & , x \geq 0 \end{cases}$$

3. Max Pooling

Pada tahap ini dilakukan proses pooling bertujuan untuk mengurangi jumlah input data pada proses selanjutnya dengan memilih nilai diantara kelompok data. Jenis Pooling yang digunakan adalah Max Pooling dengan indeks 2x2.

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	0,08
0	0	0	0	0	0	0,05	0,15
0	0	0	0	0	0	0,14	0,21
0,02	0	0	0	0,03	0,01	0,08	0,08
0	0,01	0,07	0,06	0,02	0,05	0,07	0,07

	a	b	c	d	e	f	g
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0,08
4	0	0	0	0	0	0,05	0,15
5	0	0	0	0	0	0,14	0,21
6	0,02	0	0	0,03	0,03	0,14	0,21
7	0,02	0,07	0,07	0,06	0,05	0,08	0,08

- Convolutional layer 2.

1. Pada tahap ini menggunakan filter kernel untuk $\sum_{j=32} w_j$

0	0	-1
1	1	0
1	1	0

b=0

Maka proses konvolasinya sebagai berikut.

$C_{a1} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{b1} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{c1} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{d1} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0,08 = 0$

$C_{e1} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{a2} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{b2} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{c2} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0105 = 0$

$C_{d2} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0,0,15 = 0,105$

$C_{e2} = 0.0+0.0+-1.0+1.0+0.0+0.0,08+1.0+1.0,105+0,0,15 = 0,105$

$C_{a3} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{b3} = 0.0+0.0+-1.0+1.0+0.0+0.0+1.0+1.0+0.0 = 0$

$C_{c3} = 0.0 + 0.0 + -1.0 + 0.1 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$C_{d3} = 0.0 + 0.0 + -1.0 + 0.1 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$C_{e3} = 0.0 + 0.0 + 0,08 \cdot -1 + 0.0 + 0.0,05 + 0.0,15 + 1.0 + 1.0,14 + 0.0,21 = 0,06$

$C_{a4} = 0.0 + 0.0 + 0.0 + 1.0 + 0.0 + 0.0 + 0,02 \cdot 1 + 0.1 + 0.0 = 0,02$

$C_{b4} = 0.0 + 0.0 + -1.0 + 1.0 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0,03 = 0$

$C_{c4} = 0.0 + 0.0 + -1.0 + 1.0 + 0.0 + 0.0 + 1.0 + 1.0,03 + 0.0,03 = 0,03$

$C_{d4} = 0.0 + 0.0 + -1.0,05 + 1.0 + 0.0 + 0.0,14 + 1.0,03 + 1.0,03 + 0.0,14 = 0,01$

$C_{e4} = 0.0 + 0.05 + -1.0,15 + 1.0 + 0,14.0 + 0.0,21 + 0,03 \cdot 1 + 0,14 \cdot 1 + 0,21 \cdot 0 = 0,02$

$C_{a5} = 0.0 + 0.0 + 0.0 \cdot -1 + 0,02 \cdot 1 + 0.0 + 0.0 + 1.0,02 + 1.0,07 + 0.0,07 = 0,11$

$C_{b5} = 0.0 + 0.0 + 0. -1 + 0. 1 + 0.0 + 0,0,03 + 1.0,07 + 1.0,07 + 0.0,06 = 0,14$

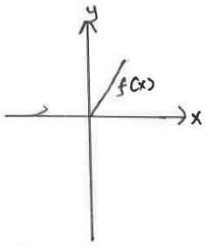
$C_{c5} = 0.0 + 0.0 + -1.0 + 0.1 + 0.0,03 + 0.0,03 + 1.0,07 + 1.0,06 + 0.0,05 = 0,13$

$C_{d5} = 0.0 + 0.0 + -1.0,14 + 1.0,03 + 0.0,03 + 0.0,14 + 1.0,06 + 1.0,05 + 0.0,08 = 0$

$C_{e5} = 0.0 + 0.0,14 + -1.0,21 + 1.0,03 + 0.0,14 + 0.0,21 + 1.0,05 + 1.0,08 + 0.0,08 = -0,05$

2. Activation layer

Pada tahap ini hasil konvulasi ke-2 kemudian diolah menggunakan fungsi aktivasi Relu :



0	0	0	0	0
0	0	0	0	0,05
0	0	0	0	0,06
0,02	0	0,03	0,01	0,02
0,11	0,14	0,13	0	-0,05

0	0	0	0	0
0	0	0	0	0,05
0	0	0	0	0,06
0,02	0	0,03	0,01	0,02
0,11	0,14	0,13	0	0

3. Max Pooling

Pada tahap ini dilakukan proses pooling bertujuan untuk mengurangi jumlah input data pada proses selanjutnya dengan memilih nilai diantara kelompok data Jenis pooling yang digunakan adalah Max Pooling dengan indeks 2x2.

0	0	0	0	0
0	0	0	0	0,105
0	0	0	0	0,106
0,02	0	0,103	0,101	0,102
0,11	0,114	0,113	0	0

0	0	0	0,105
0	0	0	0,106
0,102	0,103	0,103	0,106
0,114	0,114	0,113	0,102

- Fully Connected layer

1. Flattening

Pada tahap ini output dari konvulasi ke-2 yang berupa matriks 4x4 diubah menjadi bentuk vektor

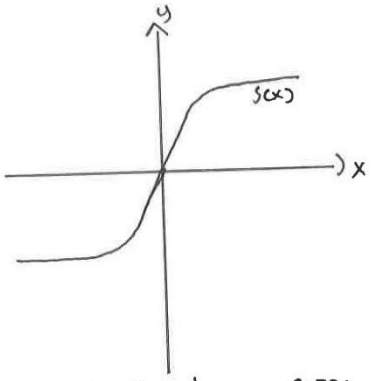
0	0	0	0,105
0	0	0	0,106
0,102	0,103	0,103	0,106
0,114	0,114	0,113	0,102

0
0
0
0,105
0
0
0
0,06
0,102
0,103
0,103
0,106
0,114
0,114
0,113
0,102

2. Activation Layer

Pada ~~lapisan~~ tahap ini, input yang berupa vektor akan ditransform menjadi data input menjadi dimensi yang lebih tinggi sehingga memungkinkan dilakukan klasifikasi. Pada tahap ini digunakan fungsi aktivasi jenis sigmoid.

$$S(x) = \frac{1}{1+e^{-x}}$$



$S(x_1) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_2) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_3) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_4) = \frac{1}{1+e^{-0{,}05}} = 0{,}512$

$S(x_5) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_6) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_7) = \frac{1}{1+e^{-0}} = 0{,}5$

$S(x_8) = \frac{1}{1+e^{-0{,}106}} = 0{,}514$

$S(x_9) = \frac{1}{1+e^{-0{,}02}} = 0{,}504$

$S(x_{10}) = \frac{1}{1+e^{-0{,}03}} = 0{,}507$

$S(x_{11}) = \frac{1}{1+e^{-0{,}03}} = 0{,}507$

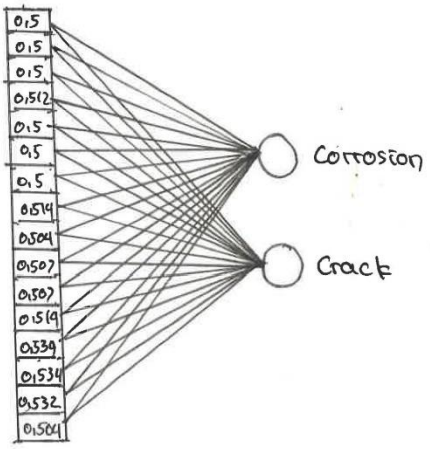
$S(x_{12}) = \frac{1}{1+e^{-0{,}106}} = 0{,}514$

$S(x_{13}) = \frac{1}{1+e^{-0{,}14}} = 0{,}534$

$S(x_{14}) = \frac{1}{1+e^{-0{,}14}} = 0{,}534$

$S(x_{15}) = \frac{1}{1+e^{-0{,}13}} = 0{,}532$

$S(x_{16}) = \frac{1}{1+e^{-0{,}02}} = 0{,}504$



• Loss Function

Menggunakan Binary Cross Entropy

$$L = -\frac{1}{N}\sum_{i=1}^{N} y_i \cdot \log(\bar{y_i}) + (1-y_i) \cdot \log(1-\bar{y_i})$$

Maka didapatkan nilai :

$L_1 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_2 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_3 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_4 = -\frac{1}{2} \cdot 0 \cdot \log(0,512) + (1-0) \cdot \log(1-0,512) = 0,155 \cdot -2 = -0,31$

$L_5 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_6 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_7 = -\frac{1}{2} \cdot 0 \cdot \log(0,5) + (1-0) \cdot \log(1-0,5) = 0,150 \cdot -2 = -0,3$

$L_8 = -\frac{1}{2} \cdot 0 \cdot \log(0,514) + (1-0) \cdot \log(1-0,514) = 0,156 \cdot -2 = -0,312$

$L_9 = -\frac{1}{2} \cdot 0 \cdot \log(0,504) + (1-0) \cdot \log(1-0,504) = 0,152 \cdot -2 = -0,304$

$L_{10} = -\frac{1}{2} \cdot 0 \cdot \log(0,507) + (1-0) \cdot \log(1-0,507) = 0,153 \cdot -2 = -0,306$

$L_{11} = -\frac{1}{2} \cdot 0 \cdot \log(0,507) + (1-0) \cdot \log(1-0,507) = 0,153 \cdot -2 = -0,306$

$L_{12} = -\frac{1}{2} \cdot 0 \cdot \log(0,514) + (1-0) \cdot \log(1-0,514) = 0,156 \cdot -2 = -0,312$

$L_{13} = -\frac{1}{2} \cdot 0 \cdot \log(0,534) + (1-0) \cdot \log(1-0,534) = 0,165 \cdot -2 = -0,33$

$L_{14} = -\frac{1}{2} \cdot 0 \cdot \log(0,534) + (1-0) \cdot \log(1-0,534) = 0,165 \cdot -2 = -0,33$

$L_{15} = -\frac{1}{2} \cdot 0 \cdot \log(0,532) + (1-0) \cdot \log(1-0,532) = 0,164 \cdot -2 = -0,328$

$L_{16} = -\frac{1}{2} \cdot 0 \cdot \log(0,504) + (1-0) \cdot \log(1-0,504) = 0,152 \cdot -2 = -0,304$

$L_{total} = -\frac{1}{2} \cdot (-0,3 - 0,3 - 0,3 - 0,31 - 0,3 - 0,3 - 0,3 - 0,312 - 0,304 - 0,306 - 0,306 - 0,312 - 0,33 - 0,33 - 0,328 - 0,304)$

$= 0,308$

Backpropagation

1. Backward Pass (Output -> FC)

$$\frac{\partial loss}{\partial w_{ho}} = \frac{\partial Loss}{\partial o_{out}} \times \frac{\partial o_{out}}{\partial o_{in}} \times \frac{\partial o_{in}}{\partial w_{ho}}$$

$$\rightarrow Loss = -\frac{1}{N}\sum_{i=1}^{N} y_i \cdot \log(\bar{y}_i) + (1-y_i)\cdot \log(1-\bar{y}_i)$$

$$\frac{\partial loss}{\partial o_{out}} = \frac{1}{m}\sum^{m} [\bar{y}_i - y_i] \times_j^i$$

$$\frac{\partial loss}{\partial o_{out}} = \frac{1}{16}[(0,5-0)\cdot 0 + (0,5)\cdot 0 + (0,5)\cdot 0 + (0,5512)\cdot 0,105 + (0,5)\cdot 0 + 0,5\cdot 0 + 0,5\cdot 0 + 0,5514\cdot 0,06 + 0,504\cdot 0,02 + 0,507\cdot 0,03 + 0,507\cdot 0,03 + 0,514\cdot 0,06 + 0,534\cdot 0,14 + 0,534\cdot 0,14 + 0,532\cdot 0,13 + 0,504\cdot 0,02] = 0,022$$

-> Gradient $\bar{y}_i$ terhadap x_i :

$$\bar{y}_i = \frac{1}{1+e^{-x}}$$

$$\frac{\partial \bar{y}_i}{\partial x} = \frac{1}{1+e^{-x}} \cdot \left(1 - \frac{1}{1+e^{-x}}\right)$$

$\frac{\partial \bar{y}_1}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_2}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_3}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_4}{\partial x} = 0,5512\cdot(1-0,5512) = 0,249$

$\frac{\partial \bar{y}_5}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_6}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_7}{\partial x} = 0,5\cdot(1-0,5) = 0,25$

$\frac{\partial \bar{y}_8}{\partial x} = 0,5514(1-0,5514) = 0,249$

$\frac{\partial \bar{y}_9}{\partial x} = 0,504\cdot(1-0,504) = 0,249$

$\frac{\partial \bar{y}_{10}}{\partial x} = 0,507 - (1-0,507) = 0,249$

$\frac{\partial \bar{y}_{11}}{\partial x} = 0,507 - (1-0,507) = 0,249$

$\frac{\partial \bar{y}_{12}}{\partial x} = 0,512 - (1-0,512) = 0,249$

$\frac{\partial \bar{y}_{13}}{\partial x} = 0,534 - (1-0,534) = 0,248$

$\frac{\partial \bar{y}_{14}}{\partial x} = 0,534 - (1-0,534) = 0,248$

$\frac{\partial \bar{y}_{15}}{\partial x} = 0,532 - (1-0,532) = 0,248$

$\frac{\partial \bar{y}_{16}}{\partial x} = 0,504 - (1-0,504) = 0,249$

$\frac{\partial \bar{y}_0}{\partial x} = 0,5 - (1-0,5) = 0,125$

→ Gradient xin terhadap w_{*0}

$x_i = w_i \bar{y}_i + b$

$\frac{\partial x_i}{\partial w_x} = \frac{\partial (y_i w_i + b_0)}{\partial w_{x0}}$

$\frac{\partial x_1}{\partial w_1} = \bar{y}_1 = 0.5$

$\frac{\partial x_2}{\partial w_2} = \bar{y}_2 = 0.5$

$\frac{\partial x_3}{\partial w_3} = \bar{y}_3 = 0.5$

$\frac{\partial x_4}{\partial w_4} = \bar{y}_4 = 0.512$

$\frac{\partial x_5}{\partial w_5} = \bar{y}_5 = 0.5$

$\frac{\partial x_6}{\partial w_6} = \bar{y}_6 = 0.5$

$\frac{\partial x_7}{\partial w_7} = \bar{y}_7 = 0.5$

$\frac{\partial x_8}{\partial w_8} = \bar{y}_8 = 0.514$

$\frac{\partial x_9}{\partial w_9} = \bar{y}_9 = 0.504$

$\frac{\partial x_{10}}{\partial w_{10}} = \bar{y}_{10} = 0.507$

$\frac{\partial x_{11}}{\partial w_{11}} = \bar{y}_{11} = 0.507$

$\frac{\partial x_{12}}{\partial w_{12}} = \bar{y}_{12} = 0.512$

$\frac{\partial x_{13}}{\partial w_{13}} = \bar{y}_{13} = 0.534$

$\frac{\partial x_{14}}{\partial w_{14}} = \bar{y}_{14} = 0.534$

$\frac{\partial x_{15}}{\partial w_{15}} = \bar{y}_{15} = 0.532$

$\frac{\partial x_{16}}{\partial w_{16}} = \bar{y}_{16} = 0.504$

$\frac{\partial b}{\partial w_b} = b = 1$

→ Gradient Loss terhadap weight

$\frac{\partial Loss}{\partial w_i} = \left[\frac{\partial Loss}{\partial y_i} \times \frac{\partial y_i}{\partial x} \times \frac{\partial x}{\partial w_i} \right]$

$\frac{\partial Loss}{\partial w_1} = 0.022 \cdot 0.25 \cdot 0.5 = 0.00275$

$\frac{\partial Loss}{\partial w_2} = 0.022 \cdot 0.25 \cdot 0.5 = 0.00275$

$\frac{\partial Loss}{\partial w_3} = 0.022 \cdot 0.25 \cdot 0.5 = 0.00275$

$\frac{\partial Loss}{\partial w_4} = 0.022 \cdot 0.249 \cdot 0.512 = 0.0028$

$\frac{\partial Loss}{\partial w_5} = 0.022 \cdot 0.5 \cdot 0.25 = 0.00275$

$\frac{\partial Loss}{\partial w_6} = 0.022 \cdot 0.25 \cdot 0.5 = 0.00275$

$\frac{\partial Loss}{\partial w_7} = 0.022 \cdot 0.25 \cdot 0.5 = 0.00275$

$\frac{\partial Loss}{\partial w_8} = 0.022 \cdot 0.249 \cdot 0.514 = 0.0028$

$\frac{\partial Loss}{\partial b} = 0.022 \cdot 1 \cdot 1 = 0.022$

$\frac{\partial Loss}{\partial w_9} = 0,022 . 0,249 . 0,504 = 0,00276$

$\frac{\partial Loss}{\partial w_{10}} = 0,022 . 0,249 . 0,507 = 0,00277$

$\frac{\partial Loss}{\partial w_{11}} = 0,022 . 0,249 . 0,507 = 0,00277$

$\frac{\partial Loss}{\partial w_{12}} = 0,022 . 0,249 . 0,512 = 0,00278$

$\frac{\partial Loss}{\partial w_{13}} = 0,022 . 0,248 . 0,534 = 0,0029$

$\frac{\partial Loss}{\partial w_{14}} = 0,022 . 0,248 . 0,534 = 0,0029$

$\frac{\partial Loss}{\partial w_{15}} = 0,022 . 0,248 . 0,532 = 0,0029$

$\frac{\partial Loss}{\partial w_{16}} = 0,022 . 0,249 . 0,504 = 0,00276$

→ Stochastic Gradient Descent (SGD) update

$w'_x = w_x - \alpha\left(\frac{\partial Loss}{\partial w_x}\right)$

$w'_1 = 1 - 0,001(0,00275) = 0,99999725$

$w'_2 = 1 - 0,001(0,00275) = 0,99999725$

$w'_3 = 1 - 0,001(0,00275) = 0,99999725$

$w'_4 = 1 - 0,001(0,00278) = 0,9999972$

$w'_5 = 1 - 0,001(0,00275) = 0,99999725$

$w'_6 = 1 - 0,001(0,00275) = 0,99999725$

$w'_7 = 1 - 0,001(0,00275) = 0,99999725$

$w'_8 = 1 - 0,001(0,00278) = 0,99999724$

$w'_9 = 1 - 0,001(0,00276) = 0,99999724$

$w'_{10} = 1 - 0,001(0,00277) = 0,99999723$

$w'_{11} = 1 - 0,001(0,00277) = 0,99999723$

$w'_{12} = 1 - 0,001(0,00278) = 0,9999972$

$w'_{13} = 1 - 0,001(0,0029) = 0,99999971$

$w'_{14} = 1 - 0,001(0,0029) = 0,99999971$

$w'_{15} = 1 - 0,001(0,0029) = 0,99999971$

$w'_{16} = 1 - 0,001(0,00276) = 0,99999724$

$w'_b = 0 - 0,001(0,02) = -0,00002$

2. Backward Pass (FC - Conv 2)

$$\frac{\partial Loss}{\partial w_{jxi}} = \frac{\partial Loss}{\partial \bar{y}_i} \times \frac{\partial \bar{y}_i}{\partial x_j} \times \frac{\partial x_j}{\partial w_{jxj}}$$

→ Gradient Loss terhadap w_{jixi}

$$\frac{\partial Loss}{\partial \bar{y}_{iout}} = \left[\frac{\partial Loss}{\partial O_{out}} \times \frac{\partial \bar{y}_i}{\partial x} \times \frac{\partial x}{\partial w_{xi}} \times \frac{\partial w_{xi}}{\partial \bar{y}_{iout}} \right]$$

$$\frac{\partial Loss}{\partial \bar{y}_{iout}} = \frac{\partial Loss}{\partial w_{xi}} \cdot \frac{\partial w_{xi}}{\partial \bar{y}_{iout}}$$

$\frac{\partial Loss}{\partial \bar{y}_{1out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{2out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{3out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{4out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{5out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{6out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{7out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{8out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{9out}} = 0,00276 \cdot 1 = 0,00276$

$\frac{\partial Loss}{\partial b} = \frac{0,0221}{} = 0,022 \cdot 1$

$\frac{\partial Loss}{\partial \bar{y}_{10out}} = 0,00277 \cdot 1 = 0,00277$

$\frac{\partial Loss}{\partial \bar{y}_{11out}} = 0,00277 \cdot 1 = 0,00277$

$\frac{\partial Loss}{\partial \bar{y}_{12out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{13out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{14out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{15out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{16out}} = 0,00276 \cdot 1 = 0,00276$

→ Pooling Backpropagation

0	0	0	0,05
0	0	0	0,06
0,02	0,03	0,03	0,06
0,14	0,14	0,13	0,02

→

0	0	0	0	0
0	0	0	0	0,05
0	0	0	0	0,06
0	0,02	0,03	0	0,02
0	0,14	0,13	0	0

2. Backward Pass (FC - Conv 2)

$$\frac{\partial Loss}{\partial w_{jxi}} = \frac{\partial Loss}{\partial \bar{y}_i} \times \frac{\partial \bar{y}_i}{\partial x_j} \times \frac{\partial x_j}{\partial w_{jxj}}$$

→ Gradient Loss terhadap w_{jixi}

$$\frac{\partial Loss}{\partial \bar{y}_{iout}} = \left[\frac{\partial Loss}{\partial O_{out}} \times \frac{\partial \bar{y}_i}{\partial x} \times \frac{\partial x}{\partial w_{xi}} \times \frac{\partial w_{xi}}{\partial \bar{y}_{iout}} \right]$$

$$\frac{\partial Loss}{\partial \bar{y}_{iout}} = \frac{\partial Loss}{\partial w_{xi}} \cdot \frac{\partial w_{xi}}{\partial \bar{y}_{iout}}$$

$\frac{\partial Loss}{\partial \bar{y}_{0out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{1out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{2out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{3out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{4out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{5out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{6out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{7out}} = 0,00275 \cdot 1 = 0,00275$

$\frac{\partial Loss}{\partial \bar{y}_{8out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{9out}} = 0,00276 \cdot 1 = 0,00276$

$\frac{\partial Loss}{\partial \bar{y}_{10out}} = 0,00277 \cdot 1 = 0,00277$

$\frac{\partial Loss}{\partial \bar{y}_{11out}} = 0,00277 \cdot 1 = 0,00277$

$\frac{\partial Loss}{\partial \bar{y}_{12out}} = 0,0028 \cdot 1 = 0,0028$

$\frac{\partial Loss}{\partial \bar{y}_{13out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{14out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{15out}} = 0,0029 \cdot 1 = 0,0029$

$\frac{\partial Loss}{\partial \bar{y}_{16out}} = 0,00276 \cdot 1 = 0,00276$

$\frac{\partial Loss}{\partial b} = 0,0221 = 0,022 \cdot 1$

→ Pooling Backpropagation

0	0	0	0,05
0	0	0	0,06
0,02	0,03	0,03	0,06
0,14	0,14	0,13	0,02

→

0	0	0	0	0
0	0	0	0	0,05
0	0	0	0	0,06
0	0,02	0,03	0	0,02
0	0,14	0,13	0	0

→ Gradient loss terhadap weight

$$\frac{\partial L}{\partial w} = \sum_{i=1}^{N} \frac{\partial L}{\partial y_i} \cdot x_i$$

Input :

1,92	1,95	2,19	2,33	2,44	2,51	2,59
1,64	1,94	2,19	2,54	2,68	2,91	2,99
1,64	1,88	2,18	2,54	2,68	2,91	2,99
1,54	1,63	1,81	2,21	2,53	2,55	2,55
1,49	1,58	1,63	1,69	1,89	2	2
1,45	1,48	1,58	1,58	1,54	1,56	1,56
2,23	2,18	2,1	2,06	2,06	2	2

$\frac{\partial L}{\partial o}$ =

0	0	0	0	0
0	0,00275	0,00275	0,00275	0,00275
0	0,00276	0,00276	0,00276	0,00276
0	0,00276	0,00276	0	0,00276
0	0,00276	0,00276	0	0

$\frac{\partial L}{\partial w_1}$ = 1,94.0,00275 + 2,19.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 1,88.0,00275 + 2,18.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 1,63.0,00276 + 1,81.0,00277 + 2,53.0,00276 + 1,58.0,00276 + 1,63.0,00276 + 1,89.0,00276 = 0,077

$\frac{\partial L}{\partial w_2}$ = 2,19.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 2,18.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 1,81.0,00276 + 2,21.0,00276 + 2,55.0,00276 + 1,63.0,00276 + 1,69.0,00276 = 0,084

$\frac{\partial L}{\partial w_3}$ = 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 2,99.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 2,99.0,00275 + 2,21.0,00276 + 2,53.0,00277 + 2,55.0,00276 + 1,69.0,00276 + 1,89.0,00276 = 0,092

$\frac{\partial L}{\partial w_4}$ = 1,88.0,00275 + 2,18.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 1,63.0,00275 + 1,81.0,00275 + 2,21.0,00275 + 2,53.0,00275 + 1,58.0,00276 + 1,63.0,00277 + 1,89.0,00276 + 1,48.0,00276 + 1,58.0,00276 = 0,081

$\frac{\partial L}{\partial w_5}$ = 2,18.0,00275 + 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 1,81.0,00275 + 2,21.0,00275 + 2,53.0,00275 + 2,55.0,00276 + 1,63.0,00276 + 1,69.0,00277 + 2.0,00276 + 1,58.0,00276 + 1,58.0,00276 = 0,077

$\frac{\partial L}{\partial w_6}$ = 2,54.0,00275 + 2,68.0,00275 + 2,91.0,00275 + 2,99.0,00275 + 2,21.0,00275 + 2,53.0,00275 + 2,55.0,00275 + 2,55.0,00276 + 1,69.0,00276 + 1,89.0,00277 + 2.0,00276 + 1,58.0,00276 + 1,54.0,00276 = 0,092

$\frac{\partial L}{\partial w_7}$ = 1,63.0,00275 + 1,81.0,00275 + 2,21.0,00275 + 2,53.0,00275 + 1,58.0,00275 + 1,63.0,00275 + 1,69.0,00275 + 1,89.0,00275 + 1,48.0,00276 + 1,58.0,00277 + 1,54.0,00276 + 2,18.0,00276 + 2,1.0,00276 = 0,090

$\frac{\partial L}{\partial w_8}$ = 1,81.0,00275 + 2,21.0,00275 + 2,53.0,00275 + 2,55.0,00275 + 1,63.0,00275 + 1,69.0,00275 + 1,89.0,00275 + 2.0,00275 + 1,58.0,00276 + 1,58.0,00277 + 1,56.0,00276 + 2,1.0,00276 + 2,06.0,00276 = 0,070

$\frac{\partial L}{\partial w_9}$ = 2,21.0,00275 + 2,53.0,00275 + 2,55.0,00275 + 1,69.0,00275 + 1,89.0,00275 + 2.0,00275 + 1,58.0,00276 + 1,54.0,00277 + 1,56.0,00276 + 2,06.0,00276 + 2.0,00276 = 0,073

→ Stochastic Gradient Descent (SGD) update

$$w'_x = w_x - \alpha \left(\frac{\partial Loss}{\partial w_x}\right)$$

$w'_1 = 1 - 0{,}001\,(0{,}077) = 0{,}999923$

$w'_2 = 0 - 0{,}001\,(0{,}084) = -0{,}0000084$

$w'_3 = -1 - 0{,}001\,(0{,}092) = -1{,}000092$

$w'_4 = -1 - 0{,}001\,(0{,}071) = -1{,}000071$

$w'_5 = -1 - 0{,}001\,(0{,}077) = -1{,}000077$

$w'_6 = 0 - 0{,}001\,(0{,}082) = -0{,}0000082$

$w'_7 = 1 - 0{,}001\,(0{,}066) = 0{,}999934$

$w'_8 = 1 - 0{,}001\,(0{,}07) = 0{,}99993$

$w'_9 = 0 - 0{,}001\,(0{,}073) = -0{,}0000073$

$b'_0 = 1 - 0{,}001\,(0{,}022) = 0{,}9999978$

→ Gradient Loss terhadap x_i

$$\frac{\partial L}{\partial x_i} = \sum \frac{\partial L}{\partial \hat{y}_i} \cdot \frac{\partial \hat{y}_i}{\partial x_i}$$

$\frac{\partial L}{\partial \hat{y}_i}$ =

0,00275	0,00275	0,00275	0,0029
0,00275	0,00275	0,00275	0,0029
0,00276	0,00277	0,00277	0,0029
0,0029	0,0029	0,0029	0,00276

$\frac{\partial \hat{y}_i}{\partial x_i}(180°)$ =

0	0	1	1	0
1	0	1	1	0
1	1	1	1	0
1	1	1	1	0
0	0	0	0	0

$\frac{\partial L}{\partial x_{11}} = 0{,}00276 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{12}} = 0{,}0029 \cdot 0 + 0{,}00276 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{13}} = 0{,}0029 \cdot 0 + 0{,}0029 \cdot 0 + 0{,}00276 \cdot 1 = 0{,}00276$

$\frac{\partial L}{\partial x_{14}} = 0{,}0029 \cdot 0 + 0{,}0029 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00566$

$\frac{\partial L}{\partial x_{15}} = 0{,}0029 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}0058$

$\frac{\partial L}{\partial x_{16}} = 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 = 0{,}0058$

$\frac{\partial L}{\partial x_{17}} = 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 = 0{,}0029$

$\frac{\partial L}{\partial x_{18}} = 0{,}0029 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{21}} = 0{,}00028 \cdot 0 + 0{,}00276 \cdot 1 = 0{,}00276$

$\frac{\partial L}{\partial x_{22}} = 0{,}00277 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}0029$

$\frac{\partial L}{\partial x_{23}} = 0{,}00277 \cdot 0 + 0{,}00277 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 + 0{,}00276 \cdot 1 = 0{,}00846$

$\frac{\partial L}{\partial x_{24}} = 0{,}00276 \cdot 0 + 0{,}00277 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}01413$

$\frac{\partial L}{\partial x_{25}} = 0{,}00276 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}0029 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}01134$

$\frac{\partial L}{\partial x_{26}} = 0{,}00276 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 = 0{,}01133$

$\frac{\partial L}{\partial x_{27}} = 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 = 0{,}00566$

$\frac{\partial L}{\partial x_{28}} = 0{,}00276 \cdot 0 + 0{,}0029 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{31}} = 0{,}00028 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00556$

$\frac{\partial L}{\partial x_{32}} = 0{,}00275 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00843$

$\frac{\partial L}{\partial x_{33}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 1$
$= 0{,}01693$

$\frac{\partial L}{\partial x_{34}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 0 + 0{,}00275 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 1 +$
$0{,}0029 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}025346$

$\frac{\partial L}{\partial x_{35}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 1 + 0{,}00275 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00276 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 +$
$0{,}0029 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00 29 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}01974$

$\frac{\partial L}{\partial x_{36}} = 0{,}00275 \cdot 1 + 0{,}00275 \cdot 1 + 0{,}00275 \cdot 0 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}00 28 \cdot 1 +$
$0{,}0029 \cdot 0 = 0{,}01683$

$\frac{\partial L}{\partial x_{37}} = 0{,}00275 \cdot 1 + 0{,}00275 \cdot 0 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}0029 \cdot 1 + 0{,}0029 \cdot 0 = 0{,}00841$

$\frac{\partial L}{\partial x_{38}} = 0{,}00275 \cdot 0 + 0{,}00276 \cdot 0 + 0{,}0029 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{41}} = 0{,}00028 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00836$

$\frac{\partial L}{\partial x_{42}} = 0{,}00275 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}00275 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}0029 \cdot 1 + 0{,}00276 \cdot 0$
$= 0{,}01122$

$\frac{\partial L}{\partial x_{21}} = 0{,}00028 \cdot 0 + 0{,}00276 \cdot 1 = 0{,}00276$

$\frac{\partial L}{\partial x_{22}} = 0{,}00277 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}00029$

$\frac{\partial L}{\partial x_{23}} = 0{,}00277 \cdot 0 + 0{,}00277 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 + 0{,}00276 \cdot 1 = 0{,}00846$

$\frac{\partial L}{\partial x_{24}} = 0{,}00276 \cdot 0 + 0{,}00277 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00845$

$\frac{\partial L}{\partial x_{25}} = 0{,}00276 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00029 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}01134$

$\frac{\partial L}{\partial x_{26}} = 0{,}00276 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 = 0{,}01133$

$\frac{\partial L}{\partial x_{27}} = 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 = 0{,}00566$

$\frac{\partial L}{\partial x_{28}} = 0{,}00276 \cdot 0 + 0{,}00029 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{31}} = 0{,}00028 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00556$

$\frac{\partial L}{\partial x_{32}} = 0{,}00275 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00843$

$\frac{\partial L}{\partial x_{33}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}01693$

$\frac{\partial L}{\partial x_{34}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 0 + 0{,}00275 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 1 + 0{,}00029 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}02534$

$\frac{\partial L}{\partial x_{35}} = 0{,}00275 \cdot 0 + 0{,}00275 \cdot 1 + 0{,}00275 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00276 \cdot 0 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00028 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}01974$

$\frac{\partial L}{\partial x_{36}} = 0{,}00275 \cdot 1 + 0{,}00275 \cdot 0 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 = 0{,}01683$

$\frac{\partial L}{\partial x_{37}} = 0{,}00275 \cdot 1 + 0{,}00275 \cdot 0 + 0{,}00276 \cdot 1 + 0{,}00277 \cdot 0 + 0{,}00029 \cdot 1 + 0{,}00029 \cdot 0 = 0{,}00841$

$\frac{\partial L}{\partial x_{38}} = 0{,}00275 \cdot 0 + 0{,}00276 \cdot 0 + 0{,}00029 \cdot 0 = 0$

$\frac{\partial L}{\partial x_{41}} = 0{,}00028 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00276 \cdot 1 = 0{,}00836$

$\frac{\partial L}{\partial x_{42}} = 0{,}00275 \cdot 0 + 0{,}00028 \cdot 0 + 0{,}00277 \cdot 0 + 0{,}00028 \cdot 1 + 0{,}00029 \cdot 1 + 0{,}00276 \cdot 0 = 0{,}01122$

$\frac{\partial L}{\partial x_{21}} = 0{,}00028.0 + 0{,}00276.1 = 0{,}00276$

$\frac{\partial L}{\partial x_{22}} = 0{,}00277.0 + 0{,}00028.0 + 0{,}0029.1 + 0{,}00276.0 = 0{,}0029$

$\frac{\partial L}{\partial x_{23}} = 0{,}00277.0 + 0{,}00277.0 + 0{,}00028.1 + 0{,}0029.1 + 0{,}0029.0 + 0{,}00276.1 = 0{,}00846$

$\frac{\partial L}{\partial x_{24}} = 0{,}00276.0 + 0{,}00277.0 + 0{,}00277.1 + 0{,}00028.1 + 0{,}0029.1 + 0{,}0029.0 + 0{,}0029.1 + 0{,}00276.1 = 0{,}00853$

$\frac{\partial L}{\partial x_{25}} = 0{,}00276.0 + 0{,}00277.1 + 0{,}00277.1 + 0{,}00028.0 + 0{,}0029.0 + 0{,}0029.1 + 0{,}0029.1 + 0{,}00276.0 = 0{,}01134$

$\frac{\partial L}{\partial x_{26}} = 0{,}00276.1 + 0{,}00277.1 + 0{,}00277.0 + 0{,}0029.1 + 0{,}0029.1 + 0{,}0029.0 = 0{,}01133$

$\frac{\partial L}{\partial x_{27}} = 0{,}00276.1 + 0{,}00277.0 + 0{,}0029.1 + 0{,}0029.0 = 0{,}00566$

$\frac{\partial L}{\partial x_{28}} = 0{,}00276.0 + 0{,}0029.0 = 0$

$\frac{\partial L}{\partial x_{31}} = 0{,}00028.0 + 0{,}00028.1 + 0{,}00276.1 = 0{,}00556$

$\frac{\partial L}{\partial x_{32}} = 0{,}00275.0 + 0{,}00028.0 + 0{,}00277.1 + 0{,}00028.0 + 0{,}0029.1 + 0{,}00276.1 = 0{,}00843$

$\frac{\partial L}{\partial x_{33}} = 0{,}00275.0 + 0{,}00275.0 + 0{,}00028.1 + 0{,}00277.1 + 0{,}00277.0 + 0{,}00028.1 + 0{,}0029.1 + 0{,}0029.1 + 0{,}00276.1$
$= 0{,}01693$

$\frac{\partial L}{\partial x_{34}} = 0{,}00275.0 + 0{,}00275.0 + 0{,}00275.1 + 0{,}00028.1 + 0{,}00276.1 + 0{,}00277.0 + 0{,}00277.1 + 0{,}00028.1 +$
$0{,}0029 + 0{,}0029.1 + 0{,}0029.1 + 0{,}00276.1 = 0{,}025346$

$\frac{\partial L}{\partial x_{35}} = 0{,}00275.0 + 0{,}00275.1 + 0{,}00275.1 + 0{,}00028.0 + 0{,}00276.0 + 0{,}00277.1 + 0{,}00277.1 + 0{,}00028.0 +$
$0{,}0029.1 + 0{,}0029.1 + 0{,}00029.1 + 0{,}00276.0 = 0{,}01974$

$\frac{\partial L}{\partial x_{36}} = 0{,}00275.1 + 0{,}00275.1 + 0{,}00275.0 + 0{,}00276.1 + 0{,}00277.1 + 0{,}00277.0 + 0{,}0029.1 + 0{,}00028.1 +$
$0{,}0029.0 = 0{,}01683$

$\frac{\partial L}{\partial x_{37}} = 0{,}00275.1 + 0{,}00275.0 + 0{,}00276.1 + 0{,}00277.0 + 0{,}0029.1 + 0{,}0029.0 = 0{,}00841$

$\frac{\partial L}{\partial x_{38}} = 0{,}00275.0 + 0{,}00276.0 + 0{,}0029.0 = 0$

$\frac{\partial L}{\partial x_{41}} = 0{,}00028.0 + 0{,}00028.1 + 0{,}00028.1 + 0{,}00276.1 = 0{,}00836$

$\frac{\partial L}{\partial x_{42}} = 0{,}00275.0 + 0{,}00028.0 + 0{,}00275.1 + 0{,}00028.0 + 0{,}00277.1 + 0{,}00028.1 + 0{,}0029.1 + 0{,}00276.0$
$= 0{,}01122$

$\frac{\partial L}{\partial x_i} =$

0	0	0,00276	0,00566	0,00558	0,00558	0,00579	0
0,00281	0,00029	0,00894	0,01913	0,01134	0,01133	0,00566	0
0,00556	0,00894	0,00469	0,0225	0,019	0,016	0,00881	0
0,00883	0,01122	0,025	0,036	0,028	0,022	0,01114	0
0,00884	0,01107	0,0221	0,030	0,022	0,016	0,008	0
0,0036	0,0111	0,0166	0,0221	0,0165	0,011	0,0055	0
0,0028	0,0055	0,0083	0,011	0,0082	0,0055	0,0027	0
0	0	0	0	0	0	0	0

3. Backward Pass (Conv2 - Conv1)

$\frac{\partial Loss}{\partial w_{jxi}} = \frac{\partial Loss}{\partial \bar{y}_i} \times \frac{\partial \bar{y}_i}{\partial \bar{x}_i} \times \frac{\partial x_i}{\partial w_{ij}}$

→ Pooling Backpropagation

1,92	1,95	2,19	2,33	2,44	2,51	2,59
1,64	1,84	2,19	2,54	2,68	2,91	2,99
1,64	1,88	2,18	2,54	2,68	2,91	2,99
1,54	1,63	1,81	2,21	2,53	2,55	2,55
1,49	1,58	1,63	1,69	1,69	2	2
1,49	1,48	1,58	1,58	1,54	1,56	1,56
2,23	2,18	2,1	2,06	2,06	2	2

0	1,92	1,95	0	2,33	2,44	2,51	2,59
0	0	1,94	2,19	0	0	0	0
0	1,64	1,88	2,18	2,54	2,68	2,91	2,99
0	1,54	1,63	1,81	2,21	2,53	2,55	0
0	1,49	1,58	1,63	1,69	0	2	0
0	1,45	1,48	1,58	1,54	0	1,56	0
0	0	0	0	0	0	0	0
0	2,23	2,18	2,1	2,06	0	2	0

⇒ Gradient $\bar{y}_{out}$ terhadap x_i :

$\bar{y}_{i\,out} = \max(0, x_{in})$

$$\frac{\partial \bar{y}_{i\,out}}{\partial y_{in}} = \frac{\partial (ReLU)}{\partial y_{in}} = \begin{cases} 1, & \bar{y}_{in} > 0 \\ 0, & \bar{y}_{in} \leq 0 \end{cases}$$

$\frac{\partial \bar{y}_{1\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{2\,out}}{\partial y_{in}} = \max(0,1,82) : 1$

$\frac{\partial \bar{y}_{3\,out}}{\partial y_{in}} = \max(0,1,95) : 1$

$\frac{\partial \bar{y}_{4\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{5\,out}}{\partial y_{in}} = \max(0,2,33) : 0$

$\frac{\partial \bar{y}_{6\,out}}{\partial y_{in}} = \max(0,2,49) : 1$

$\frac{\partial \bar{y}_{7\,out}}{\partial y_{in}} = \max(0,2,51) : 1$

$\frac{\partial \bar{y}_{8\,out}}{\partial y_{in}} = \max(0,2,59) : 1$

$\frac{\partial \bar{y}_{9\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{10\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{11\,out}}{\partial y_{in}} = \max(0,1,94) : 1$

$\frac{\partial \bar{y}_{12\,out}}{\partial y_{in}} = \max(0,2,19) : 1$

$\frac{\partial \bar{y}_{13\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{14\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{15\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{16\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{17\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{18\,out}}{\partial y_{in}} = \max(0,1,64) : 1$

$\frac{\partial \bar{y}_{19\,out}}{\partial y_{in}} = \max(0,1,88) : 1$

$\frac{\partial \bar{y}_{20\,out}}{\partial y_{in}} = \max(0,2,18) : 1$

$\frac{\partial \bar{y}_{21\,out}}{\partial y_{in}} = \max(0,2,54) : 1$

$\frac{\partial \bar{y}_{22\,out}}{\partial y_{in}} = \max(0,2,68) : 1$

$\frac{\partial \bar{y}_{23\,out}}{\partial y_{in}} = \max(0,2,91) : 1$

$\frac{\partial \bar{y}_{24\,out}}{\partial y_{in}} = \max(0,2,98) : 1$

$\frac{\partial \bar{y}_{25\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{26\,out}}{\partial y_{in}} = \max(0,1,54) : 1$

$\frac{\partial \bar{y}_{27\,out}}{\partial y_{in}} = \max(0,1,63) : 1$

$\frac{\partial \bar{y}_{28\,out}}{\partial y_{in}} = \max(0,1,81) : 1$

$\frac{\partial \bar{y}_{29\,out}}{\partial y_{in}} = \max(0,2,21) : 1$

$\frac{\partial \bar{y}_{30\,out}}{\partial y_{in}} = \max(0,2,55) : 1$

$\frac{\partial \bar{y}_{31\,out}}{\partial y_{in}} = \max(0,2,55) : 1$

$\frac{\partial \bar{y}_{32\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{33\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{34\,out}}{\partial y_{in}} = \max(0,1,49) : 1$

$\frac{\partial \bar{y}_{35\,out}}{\partial y_{in}} = \max(0,1,58) : 1$

$\frac{\partial \bar{y}_{36\,out}}{\partial y_{in}} = \max(0,1,63) : 1$

$\frac{\partial \bar{y}_{37\,out}}{\partial y_{in}} = \max(0,1,69) : 1$

$\frac{\partial \bar{y}_{38\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{39\,out}}{\partial y_{in}} = \max(0,2) : 1$

$\frac{\partial \bar{y}_{40\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{41\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{42\,out}}{\partial y_{in}} = \max(0,1,45) : 1$

$\frac{\partial \bar{y}_{43\,out}}{\partial y_{in}} = \max(0,1,48) : 1$

$\frac{\partial \bar{y}_{44\,out}}{\partial y_{in}} = \max(0,1,58) : 1$

$\frac{\partial \bar{y}_{45\,out}}{\partial y_{in}} = \max(0,1,54) : 1$

$\frac{\partial \bar{y}_{46\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{47\,out}}{\partial y_{in}} = \max(0,1,56) : 1$

$\frac{\partial \bar{y}_{48\,out}}{\partial y_{in}} = \max(0,0) : 0$

$\frac{\partial \bar{y}_{49out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{50out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{51out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{52out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{53out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{54out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{55out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{56out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{57out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{58out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{59out}}{\partial y_{in}} = max(0,2{,}23) = 1$

$\frac{\partial \bar{y}_{60out}}{\partial y_{in}} = max(0,2{,}18) = 1$

$\frac{\partial \bar{y}_{61out}}{\partial y_{in}} = max(0,2{,}1) = 1$

$\frac{\partial \bar{y}_{62out}}{\partial y_{in}} = max(0,2{,}06) = 1$

$\frac{\partial \bar{y}_{63out}}{\partial y_{in}} = max(0,0) = 0$

$\frac{\partial \bar{y}_{64out}}{\partial y_{in}} = max(0,2) = 1$

$\frac{\partial \bar{y}_{65out}}{\partial y_{in}} = max(0,0) = 0$

→ Gradient loss terhadap weight

$$\frac{\partial L}{\partial w} = \sum_{i=1}^{N} \frac{\partial L}{\partial y_i} \cdot x_i$$

0,19	0,19	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,19
0,17	0,18	0,18	0,19	0,18	0,18	0,18	0,18	0,17	0,19
0,11	0,12	0,18	0,19	0,19	0,23	0,26	0,27	0,30	0,33
0,10	0,10	0,12	0,13	0,26	0,36	0,37	0,4	0,4	0,44
0,10	0,11	0,11	0,19	0,26	0,34	0,39	0,43	0,45	0,47
0,06	0,10	0,09	0,13	0,08	0,15	0,20	0,24	0,12	0,08
0,10	0,09	0,07	0,12	0,13	0,10	0,10	0,10	0,07	0,07
0,09	0,08	0,09	0,10	0,10	0,10	0,10	0,09	0,07	0,07
0,06	0,06	0,07	0,08	0,10	0,10	0,10	0,10	0,08	0,07
0,51	0,52	0,50	0,47	0,39	0,39	0,37	0,35	0,35	0,33

0	0	0,00276	0,00566	0,0058	0,0058	0,0029	0
0,00276	0,0029	0,00846	0,0191	0,01134	0,0183	0,00566	0
0,00566	0,00840	0,0046	0,0025	0,019	0,016	0,0084	0
0,0083	0,00122	0,025	0,036	0,028	0,022	0,01116	0
0,0089	0,01107	0,0221	0,030	0,028	0,016	0,008	0
0,0056	0,0111	0,0166	0,0221	0,0165	0,011	0,0055	0
0,0028	0,0055	0,0083	0,011	0,0082	0,0055	0,0027	0
0	0	0	0	0	0	0	0

$\frac{\partial L}{\partial w_1}$: 0.19.0+0.19.0+0.2.0.00276+0.2.0.00566+0.2.0.0058+0.2.0.0058+0.2.0.0029+0.2.0+0.17.0.00276+
0.18.0.0029+0.18.0.00846+0.19.0.0141+0.18.0.01134+0.18.0.01133+0.18.0.00566+0.18.0+0.11.0.00566+
0.12.0.00843+0.18.0.00169+0.19.0.0025+0.19.0.19+0.23.0.016+0.26.0.0084+0.27.0+0.10.0.0083+
0.10.0.00112+0.12.0.025+0.13.0.036+0.26.0.028+0.36.0.022+0.37.0.01116+0.4.0+0.10.0.0084+
0.11.0.011+0.11.0.0221+0.19.0.03+0.26.0.022+0.34.0.016+0.39.0.008+0.43.0+0.06.0.00566+
0.10.0.0111+0.09.0.0166+0.13.0.0221+0.08.0.0165+0.15.0.011+0.20.0.0055+0.24.0+0.10.0.00828+
0.09.0.0055+0.07.0.0083+0.12.0.011+0.13.0.0082+0.10.0.0055+0.10.0.0027+0.10.0+0.09.0+
0.08.0+0.09.0+0.10.0+0.10.0+0.10.0+0.09.0 = 0.0745027

$\frac{\partial L}{\partial w_2}$: 0.19.0+0.2.0+0.2.0.00276+0.2.0.00566+0.2.0.0058+0.2.0.0029+0.2.0+0.18.0.00276+
0.18.0.0029+0.19.0.00846+0.18.0.0141+0.18.0.01134+0.18.0.01133+0.18.0.00566+0.17.0+0.12.0.00566+
0.18.0.00843+0.19.0.00169+0.19.0.0025+0.23.0.019+0.26.0.016+0.27.0.0084+0.30.0+0.10.0.0083+
0.12.0.00112+0.13.0.025+0.26.0.036+0.36.0.028+0.37.0.022+0.4.0.01116+0.4.0+0.11.0.00834+
0.11.0.00112+0.19.0.0221+0.26.0.030+0.34.0.022+0.39.0.016+0.43.0.008+0.45.0+0.10.0.00856+
0.09.0.0111+0.13.0.0166+0.08.0.0221+0.15.0.0165+0.20.0.011+0.24.0.0055+0.12.0+0.09.0+
0.07.0.0055+0.12.0.0083+0.13.0.011+0.10.0.0082+0.10.0.0055+0.10.0.0027+0.10.0+0.09.0+
0.10.0+0.10.0+0.10.0+0.09.0 = 0.111399

$\frac{\partial L}{\partial w_3}$: 0.2.0+0.2.0+0.2.0.00276+0.2.0.00566+0.2.0.0058+0.2.0.0058+0.2.0.0029+0.19.0+0.18.0.00276+
0.19.0.0029+0.18.0.00846+0.18.0.0141+0.18.0.01134+0.18.0.01133+0.17.0.00566+0.19.0+0.18.0.00566+
0.19.0.00843+0.19.0.00169+0.23.0.0025+0.26.0.019+0.27.0.016+0.30.0.0084+0.33.0+0.12.0.00843+
0.13.0.00112+0.26.0.025+0.36.0.036+0.37.0.028+0.4.0.022+0.4.0.01116+0.44.0+0.11.0.00834+0.19.0.0111+
0.26.0.0221+0.34.0.03+0.39.0.022+0.43.0.016+0.45.0.008+0.47.0+0.09.0.00566+0.13.0.0111+0.08.0.0166+
0.15.0.0221+0.20.0.0165+0.24.0.011+0.12.0.0055+0.09.0+0.07.0.00283+0.12.0.00855+0.13.0.00827+
0.18.0.011+0.10.0.00827+0.10.0.0055+0.09.0.0027+0.07.0+0.09.0+0.10.0+0.10.0+0.10.0+0.10.0+
0.09.0+0.07.0+0.07.0 = 0.131306

$\frac{\partial L}{\partial w_4}$: 0.17.0+0.18.0+0.18.0.00276+0.19.0.00566+0.18.0.0058+0.18.0.0058+0.18.0.0029+0.18.0+0.11.0.00276+
0.12.0.00283+0.18.0.00846+0.19.0.0141+0.19.0.01134+0.23.0.01133+0.26.0.00566+0.27.0+0.10.0.00566+
0.10.0.00843+0.12.0.00169+0.13.0.0025+0.26.0.019+0.36.0.016+0.37.0.0084+0.4.0+0.00834.0.10+0.11.0.0111+
0.11.0.0221+0.19.0.03+0.26.0.022+0.34.0.016+0.39.0.008+0.43.0+0.06.0.00566+0.10.0.01111+0.08.0.01661+
0.13.0.02214+0.08.0.0165+0.15.0.011+0.20.0.0055+0.24.0+0.10.0.00828+0.09.0.00555+0.07.0.00283+0.12.0.01114+
0.13.0.00827+0.10.0.00555+0.10.0.00276+0.10.0+0.09.0+0.08.0+0.09.0+0.10.0+0.10.0+0.10.0+0.10.0+
0.09.0 = 0.0685502

$\frac{\partial L}{\partial w_5}$: 0.18.0+0.18.0+0.19.0.00276+0.18.0.00566+0.18.0.0058+0.18.0.00558+0.18.0.0029+0.17.0+0.12.0.00276+
0.18.0.00829+0.19.0.00846+0.18.0.0141+0.23.0.01134+0.26.0.01133+0.27.0.00566+0.38.0+0.10.0.00566+
0.12.0.00843+0.13.0.00169+0.26.0.0025+0.36.0.019+0.37.0.016+0.4.0.0084+0.4.0+0.11.0.00843+
0.11.0.00112+0.19.0.025+0.26.0.036+0.34.0.028+0.39.0.022+0.43.0.01116+0.45.0+0.10.0.00834+0.09.0.0111+
0.13.0.0221+0.08.0.03+0.15.0.022+0.20.0.016+0.24.0.008+0.12.0+0.09.0.00556+0.07.0.0111+0.12.0.0166+
0.13.0.0221+0.10.0.0165+0.10.0.011+0.10.0.0055+0.09.0.0027+0.07.0+0.08.0+0.09.0+0.10.0+0.10.0+0.10.0+
0.10.0.00824+0.10.0.0055+0.09.0.0027+0.07.0+0.08.0+0.07.0+0.10.0+0.10.0+0.10.0+0.10.0+0.08.0
= 0.1032145

$\frac{\partial L}{\partial w_6}$: 0.18.0+0.19.0+0.18.0.002276+0.18.0.00566+0.18.0.00558+0.18.0.00558+0.17.0.0029+0.19.0+0.18.0.002276+
0.19.0.0029+0.19.0.00846+0.23.0.00566+0.26.0.00558+0.27.0.0133+0.30.0.00566+0.33.0+0.12.0.002276+
0.13.0.00843+0.26.0.00169+0.36.0.00125+0.37.0.0113+0.4.0.916+0.4.0.00884+0.44.0+0.11.0.00843+0.19.0.001122+
0.18.0.0125+0.34.0.0136+0.39.0.0129+0.43.0.0122+0.43.0.0116+0.47.0+0.09.0.00884+0.13.0.0107+0.08.0.001221+
0.15.0.03+0.20.0.122+0.24.0.016+0.12.0.00884+0.08.0+0.07.0.00556+0.12.0.0111+0.13.0.00169+0.10.0.00122+
0.10.0.0165+0.10.0.0111+0.07.0.00555+0.07.0+0.09.0.00829+0.10.0.00555+0.10.0.00883+0.10.0.0111+0.07.0+0.10.0 = 0.115817

$\frac{\partial L}{\partial w_7}$: 0.11.0+0.12.0+0.18.0.002276+0.18.0.00566+0.18.0.00558+0.23.0.00558+0.26.0.0029+0.27.0+0.10.0.002276+0.19.0.00829+
0.12.0.00846+0.13.0.0141+0.26.0.01134+0.36.0.0113+0.37.0.00566+0.4.0+0.10.0.00883+0.11.0.001122+0.11.0.0125+
0.19.0.036+0.26.0.029+0.34.0.0122+0.39.0.0116+0.43.0+0.06.0.00829+0.10.0.00111+0.09.0.0122+0.13.0.0136+
0.08.0.0129+0.15.0.0729+0.20.0.00829+0.24.0+0.10.0.00883+0.09.0.0122+0.13.0.0107+0.08.0.001221+
0.10.0.00883+0.11.0.00556+0.07.0.00829+0.10.0.00556+0.10.0.00883+0.10.0.0111+0.07.0+0.10.0.002276+0.13.0.00829+
0.07.0+0.06.0.00829+0.10.0.00556+0.10.0.00883+0.10.0.0111+0.10.0.00883+0.10.0.00556+0.10.0.00829+0.07.0+0.08.0+
0.05.0+0.05.0+0.47.0+0.39.0+0.39.0+0.37.0+0.35.0+0.35.0+0.33.0 = 0.0845365

$\frac{\partial L}{\partial w_8}$: 0.10.0+0.13.0+0.19.0.002276+0.23.0.00566+0.26.0.00558+0.27.0.00558+0.30.0.0029+0.33.0+0.12.0.002276+
0.13.0.0029+0.26.0.00846+0.36.0.00141+0.37.0.01134+0.4.0.00566+0.44.0+0.11.0.00566+
0.19.0.00843+0.26.0.00169+0.34.0.00125+0.39.0.0129+0.43.0.00916+0.45.0.00884+0.47.0+0.09.0.00883+0.13.0.001122+
0.08.0.0125+0.15.0.0729+0.20.0.00883+0.24.0.00884+0.12.0.0111+0.13.0.0107+0.08.0.001221+
0.10.0.03+0.10.0.00916+0.07.0.00884+0.12.0.00556+0.10.0.00883+0.10.0.0111+0.10.0.00916+0.07.0+0.09.0.00829+
0.10.0.0165+0.07.0.00556+0.07.0+0.10.0.00883+0.10.0.00556+0.10.0.00829+0.07.0+0.10.0.002276+0.10.0.00829+
0.05.0+0.05.0+0.47.0+0.39.0+0.39.0+0.37.0+0.35.0+0.35.0+0.33.0 = 0.0952681

→Stochastic Gradient Descent (SGD) Update

$w'_x = w_x - \alpha\left(\frac{\partial Loss}{\partial w_x}\right)$

$w'_1 = 1 - 0.001(0.094527) = 0.999905$

$w'_2 = 0 - 0.001(0.11349) = -0.000113$

$w'_3 = 0 - 0.001(0.131306) = -0.000131$

$w'_4 = 1 - 0.001(0.088502) = 0.999911$

$w'_5 = 1 - 0.001(0.115817) = 0.999884$

$w'_6 = 1 - 0.001(0.122) = 0.999878$

$w'_7 = 0 - 0.001(0.073597) = -0.000073597$

$w'_8 = 1 - 0.001(0.084365) = 0.999915635$

$w'_9 = 0 - 0.001(0.115817) = -0.000115817$

Tahap Convulational

· Convolutional layer 1

1. Menggunakan filter kernel untuk $\sum_{i=32} \omega i$:

1	0	0	b: 1
1	1	0	
0	1	1	

Maka proses konvolusinya sebagai berikut:

$C_{a1} = 0,19.1 + 0,19.0 + 0,2.0 + 0,17.1 + 0,18.1 + 0,18.0 + 0,11.0 + 0,12.1 + 0,18.1 + 1 = 1,84$

$C_{b1} = 0,19.1 + 0,2.0 + 0,2.0 + 0,18.1 + 0,18.1 + 0,19.0 + 0,12.0 + 0,18.1 + 0,19.1 + 1 = 1,92$

$C_{c1} = 0,2.1 + 0,2.0 + 0,2.0 + 0,18.1 + 0,19.1 + 0,18.0 + 0,18.0 + 0,19.1 + 0,19.1 + 1 = 1,95$

$C_{d1} = 0,2.1 + 0,2.0 + 0,2.0 + 0,19.1 + 0,18.1 + 0,18.0 + 0,19.0 + 0,19.1 + 0,23.1 + 1 = 1,99$

$C_{e1} = 0,2.1 + 0,2.0 + 0,2.0 + 0,18.1 + 0,18.1 + 0,18.0 + 0,19.0 + 0,23.1 + 0,26.1 + 1 = 2,05$

$C_{f1} = 0,2.1 + 0,2.0 + 0,2.0 + 0,18.1 + 0,18.1 + 0,18.0 + 0,23.0 + 0,26.1 + 0,27.1 + 1 = 2,09$

$C_{g1} = 0,2.1 + 0,2.0 + 0,2.0 + 0,18.1 + 0,18.1 + 0,17.0 + 0,26.0 + 0,27.1 + 0,30.1 + 1 = 2,13$

$C_{h1} = 0,2.1 + 0,2.0 + 0,19.0 + 0,18.1 + 0,17.1 + 0,19.0 + 0,27.0 + 0,30.1 + 0,33.1 + 1 = 2,18$

$C_{a2} = 0,17.1 + 0,18.0 + 0,18.0 + 0,11.1 + 0,12.1 + 0,18.0 + 0,10.0 + 0,10.1 + 0,12.1 + 1 = 1,62$

$C_{b2} = 0,18.1 + 0,18.0 + 0,19.0 + 0,12.1 + 0,18.1 + 0,19.0 + 0,10.0 + 0,12.1 + 0,13.1 + 1 = 1,73$

$C_{c2} = 0,18.1 + 0,19.0 + 0,18.0 + 0,18.1 + 0,19.1 + 0,19.0 + 0,12.0 + 0,13.1 + 0,26.1 + 1 = 1,94$

$C_{d2} = 0,19.1 + 0,18.0 + 0,18.0 + 0,19.1 + 0,19.1 + 0,23.0 + 0,13.0 + 0,26.1 + 0,36.1 + 1 = 2,19$

$C_{e2} = 0,18.1 + 0,18.0 + 0,18.0 + 0,19.1 + 0,23.1 + 0,26.0 + 0,26.0 + 0,36.1 + 0,37.1 + 1 = 2,33$

$C_{f2} = 0,18.1 + 0,18.0 + 0,18.0 + 0,23.1 + 0,26.1 + 0,27.0 + 0,36.0 + 0,37.1 + 0,4.1 + 1 = 2,44$

$C_{g2} = 0,18.1 + 0,18.0 + 0,17.0 + 0,26.1 + 0,27.1 + 0,30.0 + 0,37.0 + 0,4.1 + 0,4.1 + 1 = 2,51$

$C_{h2} = 0,18.1 + 0,17.0 + 0,19.0 + 0,27.1 + 0,30.1 + 0,33.0 + 0,4.0 + 0,4.1 + 0,44.1 + 1 = 2,59$

$C_{a3} = 0,11.1 + 0,12.0 + 0,18.0 + 0,10.1 + 0,10.1 + 0,12.0 + 0,10.0 + 0,11.1 + 0,11.1 + 1 = 1,53$

$C_{b3} = 0,12.1 + 0,18.0 + 0,19.0 + 0,10.1 + 0,12.1 + 0,13.0 + 0,11.0 + 0,11.1 + 0,19.1 + 1 = 1,64$

$C_{c3} = 0,18.1 + 0,19.0 + 0,19.0 + 0,12.1 + 0,13.1 + 0,26.0 + 0,11.0 + 0,19.1 + 0,26.1 + 1 = 1,88$

$C_{d3} = 0,19.1 + 0,19.0 + 0,23.0 + 0,13.1 + 0,26.1 + 0,36.0 + 0,19.0 + 0,26.1 + 0,34.1 + 1 = 2,18$

$C_{e3} = 0,19.1 + 0,23.0 + 0,26.0 + 0,26.1 + 0,36.1 + 0,37.0 + 0,26.0 + 0,34.1 + 0,39.1 + 1 = 2,54$

$C_{f3} = 0,23.1 + 0,26.0 + 0,27.0 + 0,36.1 + 0,37.1 + 0,4.0 + 0,34.0 + 0,39.1 + 0,43.1 + 1 = 2,68$

$C_{g3} = 0,26.1 + 0,27.0 + 0,30.0 + 0,37.1 + 0,4.1 + 0,4.0 + 0,39.0 + 0,43.1 + 0,45.1 + 1 = 2,91$

$C_{h3} = 0,27.1 + 0,30.0 + 0,33.0 + 0,4.1 + 0,4.1 + 0,44.0 + 0,43.0 + 0,47.1 + 0,45.1 + 1 = 2,99$

$C_{a4} = 0,10.1 + 0,10.0 + 0,12.0 + 0,10.0 + 0,11.1 + 0,11.0 + 0,06.0 + 0,10.1 + 0,09.1 + 1 = 1,5$

$C_{b4} = 0,10.1 + 0,12.0 + 0,13.0 + 0,11.1 + 0,11.1 + 0,19.0 + 0,10.0 + 0,09.1 + 0,13.1 + 1 = 1,54$

$C_{c4} = 0,12.1 + 0,13.0 + 0,26.0 + 0,11.1 + 0,19.1 + 0,26.0 + 0,09.0 + 0,13.1 + 0,08.1 + 1 = 1,63$

Cd4: 0,36.1+0,37.0+0,14.0+0,34.0+0,39.1+0,43.0+0,15.0+0,20.1+0,24.1+1 = 2,55

Cg4: 0,37.1+0,40.0+0,14.0+0,39.1+0,43.1+0,45.0+0,20.0+0,24.1+0,12.1+1 = 2,48

Ch4: 0,4.1+0,14.0+0,49.0+0,43.1+0,45.1+0,47.0+0,24.0+0,12.1+0,08.1+1 = 2,48

Ca5: 0,10.1+0,11.0+0,11.0+0,06.1+0,10.1+0,09.0+0,10.0+0,09.1+0,07.1+1 = 1,42

Cb5: 0,11.1+0,11.0+0,19.0+0,10.1+0,09.1+0,13.0+0,09.0+0,07.1+0,12.1+1 = 1,49

Cc5: 0,11.1+0,19.0+0,26.0+0,09.1+0,13.1+0,08.0+0,07.0+0,12.1+0,13.1+1 = 1,58

Cd5: 0,19.1+0,26.0+0,34.0+0,13.1+0,08.0+0,15.0+0,12.0+0,13.1+0,10.1+1 = 1,63

Ce5: 0,26.1+0,34.0+0,39.0+0,08.1+0,15.1+0,20.0+0,13.0+0,10.1+0,10.1+1 = 1,69

Cf5: 0,34.1+0,39.0+0,43.0+0,15.1+0,20.1+0,24.0+0,10.0+0,10.1+0,10.1+1 = 1,89

Cg5: 0,39.1+0,43.0+0,45.0+0,20.1+0,24.1+0,12.0+0,10.0+0,10.1+0,07.1+1 = 2

Ch5: 0,43.1+0,45.0+0,47.0+0,24.1+0,12.0+0,08.0+0,10.0+0,07.1+0,07.1+1 = 1,93

Ca6: 0,06.1+0,10.0+0,09.0+0,10.1+0,09.1+0,07.0+0,09.0+0,08.1+0,09.1+1 = 1,42

Cb6: 0,10.1+0,09.0+0,13.0+0,09.1+0,07.1+0,12.0+0,08.0+0,09.1+0,10.1+1 = 1,45

Cc6: 0,09.1+0,13.0+0,08.0+0,07.1+0,12.1+0,13.0+0,09.0+0,10.1+0,10.1+1 = 1,48

Cd6: 0,13.1+0,08.0+0,15.0+0,12.1+0,13.1+0,10.0+0,10.0+0,10.1+0,10.1+1 = 1,58

Ce6: 0,08.1+0,15.0+0,20.0+0,13.1+0,10.1+0,10.1+0,10.0+0,10.0+0,10.1+0,09.1+1 = 1,54

Cf6: 0,15.1+0,20.0+0,24.0+0,10.1+0,10.1+0,10.0+0,10.0+0,10.1+0,09.1+0,07.1+1 = 1,56

Cg6: 0,20.1+0,24.0+0,12.0+0,10.1+0,10.0+0,07.0+0,10.0+0,09.1+0,07.1+1 = 1,55

Ch6: 0,24.1+0,12.0+0,08.0+0,10.1+0,07.1+0,07.0+0,09.0+0,07.1+0,07.1+1 = 1,4

Ca7: 0,10.1+0,09.0+0,07.0+0,09.1+0,08.1+0,09.0+0,06.0+0,06.1+0,07.1+1 = 1,41

Cb7: 0,09.1+0,07.0+0,12.0+0,08.1+0,09.1+0,10.0+0,06.0+0,07.1+0,08.1+1 = 1,44

Cc7: 0,07.1+0,12.0+0,13.0+0,09.1+0,10.1+0,10.0+0,07.0+0,08.1+0,10.1+1 = 1,52

Cd7: 0,12.1+0,13.0+0,10.0+0,10.1+0,10.1+0,10.0+0,08.0+0,10.1+0,10.1+1 = 1,53

Ce7: 0,13.1+0,10.0+0,10.0+0,10.1+0,10.1+0,10.0+0,10.0+0,10.1+0,10.1+1 = 1,5

Cf7: 0,10.1+0,10.0+0,10.0+0,10.1+0,10.1+0,09.0+0,10.0+0,10.1+0,10.1+1 = 1,47

Cg7: 0,10.1+0,10.0+0,07.0+0,10.1+0,09.1+0,07.0+0,10.0+0,10.1+0,08.1+1 = 1,41

Ch7: 0,10.1+0,07.0+0,07.0+0,09.1+0,07.1+0,07.0+0,10.0+0,08.1+0,07.1+1 = 1,41

Ca8: 0,09.1+0,08.0+0,09.0+0,06.1+0,06.1+0,07.0+0,51.0+0,52.1+0,50.1+1 = 2,23

Cb8: 0,08.1+0,09.0+0,10.0+0,06.1+0,07.1+0,08.0+0,52.0+0,50.1+0,47.1+1 = 2,18

Cc8: 0,09.1+0,10.0+0,10.0+0,07.1+0,08.1+0,10.0+0,50.0+0,47.1+0,39.1+1 = 2,1

Cd8: 0,10.1+0,10.0+0,10.0+0,08.1+0,10.1+0,10.0+0,47.0+0,39.1+0,39.1+1 = 2,06

Ce8 : 0,10.1 + 0,10.0 + 0,10.0 + 0,10.1 + 0,10.1 + 0,10.0 + 0,39.0 + 0,39.1 + 0,37.1 + 1 = 2,06

Cf8 : 0,10.1 + 0,10.0 + 0,09.0 + 0,10.1 + 0,10.1 + 0,10.0 + 0,39.0 + 0,37.1 0,35. 1 + 1 = 2,02

Cg8 : 0,10.1 + 0,09.0 + 0,07.0 + 0,10.1 + 0,10.1 + 0,08.0 + 0,37.0 + 0,35.1 + 0,35.1 + 1 = 2

Ch8 : 0,09.1 + 0,07.0 + 0,07.0 + 0,10.1 + 0,08.1 + 0,07.0 + 0,35.0 + 0,35.1 + 0,33.1 + 1 : 1,95

2. Activation layer

1,84	1,92	1,95	1,99	2,05	2,09	2,13	2,18
1,62	1,73	1,94	2,19	2,33	2,44	2,51	2,59
1,53	1,64	1,88	2,18	2,54	2,68	2,91	2,99
1,5	1,54	1,63	1,81	2,21	2,53	2,55	2,48
1,42	1,49	1,58	1,63	1,69	1,89	2	1,93
1,42	1,45	1,48	1,58	1,51	1,54	1,56	1,55
1,4	1,41	1,44	1,52	1,53	1,475	1,47	1,41
2,28	2,28	2,06	2,06	2,06	2,02	2	1,95

3. Max Pooling

1,92	1,95	2,19	2,33	2,44	2,51	2,59
1,64	1,94	2,19	2,54	2,68	2,91	2,99
1,64	1,88	2,18	2,54	2,68	2,91	2,99
1,54	1,63	1,81	2,21	2,53	2,55	2,55
1,49	1,58	1,63	1,69	1,89	2	2
1,45	1,48	1,58	1,58	1,54	1,56	1,56
2,23	2,18	2,11	2,06	2,06	2	2

. Convolational layer 2

Menggunakan filter kernel untuk $\sum_{j=2} w_j = 0$

1	0	-1
-1	-1	0
1	1	0

b: 1

Maka proses konvolusinya sebagai berikut:

C_{a1}: 1,82.1 + 1,95.0 + 2,19.-1 + 1,64.-1 + 1,94.-1 + 2,19.0 + 1,64.1 + 1,88.1 + 2,18.0 + 1 = 0,67

C_{b1}: 1,95.1 + 2,19.0 + 2,33.-1 + 1,94.-1 + 2,19.-1 + 2,54.0 + 1,88.1 + 2,18.1 + 2,54.0 + 1 = 0,55

C_{c1}: 2,19.1 + 2,33.0 + 2,44.-1 + 2,19.-1 + 2,54.-1 + 2,68.0 + 2,18.1 + 2,54.1 + 2,68.0 + 1 = 0,74

C_{d1}: 2,33.1 + 2,44.0 + 2,51.-1 + 2,54.-1 + 2,68.-1 + 2,91.0 + 2,54.1 + 2,68.1 + 2,91.0 + 1 = 0,82

C_{e1}: 2,44.1 + 2,51.0 + 2,59.-1 + 2,68.-1 + 2,91.-1 + 2,99.0 + 2,68.1 + 2,91.1 + 2,99.0 + 1 = 0,85

C_{a2}: 1,64.1 + 1,94.0 + 2,19.-1 + 1,64.-1 + 1,88.-1 + 2,18.0 + 1,54.1 + 1,63.1 + 1,81.0 + 1 = 0,1

C_{b2}: 1,94.1 + 2,19.0 + 2,54.-1 + 1,88.-1 + 2,18.-1 + 2,54.0 + 1,63.1 + 1,81.1 + 2,21.0 + 1 = -0,22

C_{c2}: 2,19.0 + 2,54.0 + 2,68.-1 + 2,18.-1 + 2,54.-1 + 2,68.0 + 1,81.1 + 2,21.1 + 2,53.0 + 1 = -0,19

C_{d2}: 2,54.1 + 2,68.0 + 2,91.-1 + 2,54.-1 + 2,68.-1 + 2,91.0 + 2,21.1 + 2,53.1 + 2,55.0 + 1 = 0,15

C_{e2}: 2,68.1 + 2,91.0 + 2,99.-1 + 2,68.-1 + 2,91.-1 + 2,99.0 + 2,53.1 + 2,55.1 + 2,55.0 + 1 = 0,18

C_{a3}: 1,64.1 + 1,88.0 + 2,18.-1 + 1,54.-1 + 1,63.-1 + 1,81.0 + 1,49.1 + 1,58.1 + 1,63.0 + 1 = 0,36

C_{b3}: 1,88.1 + 2,18.0 + 2,54.-1 + 1,63.-1 + 1,81.-1 + 2,21.0 + 1,58.1 + 1,63.1 + 1,69.0 + 1 = 0,11

C_{c3}: 2,18.1 + 2,54.0 + 2,68.-1 + 1,81.-1 + 2,21.-1 + 2,53.0 + 1,63.1 + 1,69.1 + 1,89.0 + 1 = -0,2

C_{d3}: 2,54.1 + 2,68.0 + 2,91.-1 + 2,21.-1 + 2,53.-1 + 2,55.0 + 1,69.1 + 1,89.1 + 2.0 + 1 = -0,53

C_{e3}: 2,68.1 + 2,91.0 + 2,99.-1 + 2,53.-1 + 2,55.-1 + 2,55.0 + 1,89.1 + 2.1 + 2.0 + 1 = -0,5

C_{a4}: 1,54.1 + 1,63.0 + 1,81.-1 + 1,49.-1 + 1,58.-1 + 1,63.0 + 1,65.1 + 1,48.1 + 1,58.0 + 1 = 0,59

C_{b4}: 1,63.1 + 1,81.0 + 2,21.-1 + 1,58.-1 + 1,63.-1 + 1,69.0 + 1,48.1 + 1,58.1 + 1,58.0 + 1 = 0,27

C_{c4}: 1,81.1 + 2,21.0 + 2,53.-1 + 1,63.-1 + 1,69.-1 + 1,89.0 + 1,58.1 + 1,58.1 + 1,54.0 + 1 = 0,08

C_{d4}: 2,21.1 + 2,53.0 + 2,55.-1 + 1,69.-1 + 1,89.-1 + 2.0 + 1,58.1 + 1,54.1 + 1,56.0 + 1 = 0,2

C_{e4}: 2,53.1 + 2,55.0 + 2,55.-1 + 1,89.-1 + 2.0 + 2.0 + 1,54.1 + 1,56.1 + 1,56.0 + 1 = 0,19

C_{a5}: 1,49.1 + 1,58.0 + 1,63.-1 + 1,45.-1 + 1,48.-1 + 1,58.0 + 2,23.1 + 2,18.1 + 2,1.0 + 1 = 2,34

C_{b5}: 1,58.1 + 1,63.0 + 1,69.-1 + 1,48.-1 + 1,58.-1 + 1,58.0 + 2,18.1 + 2,1.-1 + 2,06.0 + 1 = 2,11

C_{c5}: 1,63.1 + 1,69.0 + 1,89.-1 + 1,58.-1 + 1,58.-1 + 1,54.0 + 2,1.1 + 2,06.1 + 2,06.0 + 1 = 1,74

C_{d5}: 1,69.1 + 1,89.0 + 2.-1 + 1,58.-1 + 1,54.-1 + 1,56.0 + 2,06.1 + 2,06.1 + 2.0 + 1 = 1,69

C_{e5}: 1,89.1 + 2.0 + 2.-1 + 1,54.-1 + 1,56.-1 + 1,56.0 + 2,06.1 + 2.1 + 2.0 + 1 = 1,93

· Activation layer

0,167	0,155	0,174	0,182	0,185
0,1	-0,22	-0,19	0,15	0,18
0,136	0,11	-0,2	-0,53	-0,5
0,159	0,27	0,108	0,2	0,19
2,134	2,11	1,174	1,169	1,193

0,167	0,155	0,174	0,182	0,185
0,1	0	0	0,15	0,18
0,136	0,11	0	0	0
0,159	0,27	0,108	0,2	0,19
2,134	2,11	1,174	1,169	1,193

· Max Pooling

0,167	0,174	0,182	0,185
0,136	0,11	0,18	0,18
0,159	0,27	0,2	0,2
2,134	2,11	1,174	1,193

· Fully Connected layer

· Flattening

0,167	0,174	0,182	0,185
0,136	0,14	0,15	0,18
0,159	0,27	0,2	0,2
2,139	2,14	1,174	1,193

→

0,167
0,174
0,182
0,185
0,136
0,14
0,15
0,18
0,159
0,27
0,2
0,2
2,139
2,11
1,174
1,193

· Activation layer

$S(x_1) = \frac{1}{1+e^{-0.67}} = 0.166$

$S(x_2) = \frac{1}{1+e^{-0.74}} = 0.67$

$S(x_3) = \frac{1}{1+e^{-0.82}} = 0.69$

$S(x_4) = \frac{1}{1+e^{-0.85}} = 0.170$

$S(x_5) = \frac{1}{1+e^{-0.36}} = 0.158$

$S(x_6) = \frac{1}{1+e^{-0.11}} = 0.152$

$S(x_7) = \frac{1}{1+e^{-0.15}} = 0.153$

$S(x_8) = \frac{1}{1+e^{-0.18}} = 0.154$

$S(x_9) = \frac{1}{1+e^{-0.59}} = 0.164$

$S(x_{10}) = \frac{1}{1+e^{-0.27}} = 0.56$

$S(x_{11}) = \frac{1}{1+e^{-0.12}} = 0.154$

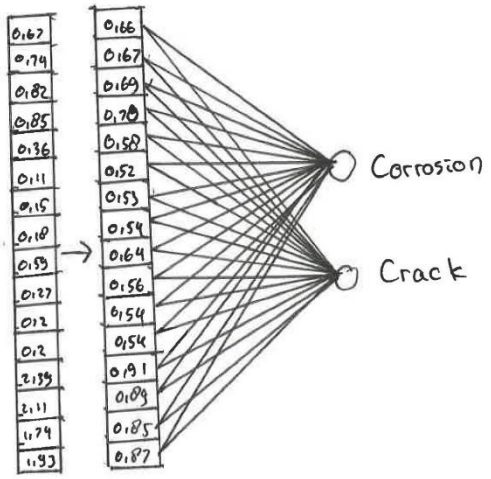
$S(x_{12}) = \frac{1}{1+e^{-0.12}} = 0.154$

$S(x_{13}) = \frac{1}{1+e^{-2.39}} = 0.191$

$S(x_{14}) = \frac{1}{1+e^{-2.11}} = 0.189$

$S(x_{15}) = \frac{1}{1+e^{-1.74}} = 0.185$

$S(x_{16}) = \frac{1}{1+e^{-1.93}} = 0.187$



• Loss Function

Menggunakan Binary Cross Entropy

$$L = -\frac{1}{N}\sum_{i=1}^{N} y_i \cdot \log(\bar{y_i}) + (1-y_i) \cdot \log(1-\bar{y_i})$$

Maka didapatkan nilai :

$L_1 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}166) + (1-0) \cdot \log(1-0{,}166) = 0{,}1234 \cdot -2 = -0{,}1468$

$L_2 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}167) + (1-0) \cdot \log(1-0{,}169) = 0{,}1240 \cdot -2 = -0{,}148$

$L_3 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}169) + (1-0) \cdot \log(1-0{,}169) = 0{,}254 \cdot -2 = -0{,}1508$

$L_4 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}170) + (1-0) \cdot \log(1-0{,}170) = 0{,}261 \cdot -2 = -0{,}1522$

$L_5 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}158) + (1-0) \cdot \log(1-0{,}158) = 0{,}1188 \cdot -2 = -0{,}1376$

$L_6 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}152) + (1-0) \cdot \log(1-0{,}152) = 0{,}1159 \cdot -2 = -0{,}1318$

$L_7 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}153) + (1-0) \cdot \log(1-0{,}153) = 0{,}1163 \cdot -2 = -0{,}1326$

$L_8 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}154) + (1-0) \cdot \log(1-0{,}154) = 0{,}1168 \cdot -2 = -0{,}1336$

$L_9 = -\frac{1}{2} \cdot 0 \cdot \log(0{,}164) + (1-0) \cdot \log(1-0{,}164) = 0{,}2221 \cdot -2 = -0{,}1442$

$L_{10} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}156) + (1-0) \cdot \log(1-0{,}156) = 0{,}1178 \cdot -2 = -0{,}1356$

$L_{11} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}154) + (1-0) \cdot \log(1-0{,}154) = 0{,}1168 \cdot -2 = -0{,}1336$

$L_{12} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}154) + (1-0) \cdot \log(1-0{,}154) = 0{,}1168 \cdot -2 = -0{,}1336$

$L_{13} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}91) + (1-0) \cdot \log(1-0{,}91) = 0{,}52 \cdot -2 = -1{,}04$

$L_{14} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}189) + (1-0) \cdot \log(1-0{,}189) = 0{,}479 \cdot -2 = -0{,}958$

$L_{15} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}185) + (1-0) \cdot \log(1-0{,}185) = 0{,}411 \cdot -2 = -0{,}1822$

$L_{16} = -\frac{1}{2} \cdot 0 \cdot \log(0{,}187) + (1-0) \cdot \log(1-0{,}187) = 0{,}443 \cdot -2 = -0{,}1886$

$L_y = -\frac{1}{2} \cdot (-0{,}1468 - 0{,}148 - 0{,}1508 - 0{,}1522 - 0{,}1376 - 0{,}1318 - 0{,}1326 - 0{,}1336 - 0{,}1442 - 0{,}1356 - 0{,}1336 - 0{,}1336 - 1{,}04 - 0{,}958 - 0{,}1822 - 0{,}1886)$

$= 0{,}153$

2. Perhitungan matematik kasus kerusakan *Crack*

Gambar 1. Tampilan Image input untuk perhitungan matematik kasus *Crack* dengan ukuran 10 x 10 px

1. Tahap Pre-processing.

a	b	c	d	e	f	g	h	i	j	
138	140	158	160	161	165	180	185	175	170	1
94	95	106	100	105	109	125	121	117	120	2
52	55	65	62	64	75	95	97	90	92	3
18	24	32	38	45	56	81	65	50	52	4
13	19	25	31	42	48	56	45	32	35	5
11	16	24	28	30	35	42	40	34	38	6
12	17	25	29	38	40	58	56	45	55	7
20	28	35	40	65	80	95	98	88	94	8
51	59	85	91	98	110	125	131	120	119	9
85	92	129	132	151	182	195	210	189	188	10

a	b	c	d	e	f	g	h	i	j
0,54	0,55	0,62	0,63	0,63	0,65	0,70	0,72	0,68	0,66
0,36	0,37	0,41	0,39	0,41	0,42	0,49	0,47	0,45	0,47
0,20	0,21	0,25	0,24	0,25	0,29	0,37	0,38	0,35	0,36
0,07	0,09	0,12	0,15	0,17	0,21	0,31	0,25	0,19	0,20
0,05	0,07	0,09	0,12	0,16	0,18	0,21	0,17	0,12	0,13
0,04	0,06	0,09	0,11	0,12	0,13	0,16	0,15	0,13	0,14
0,09	0,06	0,09	0,11	0,14	0,15	0,22	0,21	0,17	0,21
0,07	0,10	0,13	0,15	0,25	0,31	0,37	0,38	0,34	0,36
0,2	0,23	0,33	0,35	0,38	0,43	0,49	0,51	0,47	0,46
0,33	0,36	0,48	0,51	0,59	0,71	0,76	0,82	0,74	0,73

2. Tahap Convolutional

- Convolutional layer 1

1. Menggunakan filter kernel untuk $\sum_{i=32} w_i$:

1	0	-1	b = 0
1	0	-1	
1	0	-1	

Maka proses convolutional sebagai berikut:

$C_{a1} = 0{,}54 \cdot 1 + 0{,}55 \cdot 0 + 0{,}62 \cdot -1 + 0{,}36 \cdot 1 + 0{,}37 \cdot 0 + 0{,}41 \cdot -1 + 0{,}20 \cdot 1 + 0{,}21 \cdot 0 + 0{,}25 \cdot -1 = -0{,}18$

$C_{b1} = 0{,}55 \cdot 1 + 0{,}62 \cdot 0 + 0{,}63 \cdot -1 + 0{,}37 \cdot 1 + 0{,}41 \cdot 0 + 0{,}39 \cdot -1 + 0{,}21 \cdot 1 + 0{,}25 \cdot 0 + 0{,}24 \cdot -1 = -0{,}13$

$C_{c1} = 0{,}62 \cdot 1 + 0{,}63 \cdot 0 + 0{,}63 \cdot -1 + 0{,}41 \cdot 1 + 0{,}39 \cdot 0 + 0{,}41 \cdot -1 + 0{,}25 \cdot 1 + 0{,}24 \cdot 0 + 0{,}25 \cdot -1 = -0{,}01$

$C_{d1} = 0{,}63 \cdot 1 + 0{,}63 \cdot 0 + 0{,}65 \cdot -1 + 0{,}39 \cdot 1 + 0{,}41 \cdot 0 + 0{,}42 \cdot -1 + 0{,}24 \cdot 1 + 0{,}25 \cdot 0 + 0{,}29 \cdot -1 = -0{,}1$

$C_{e1} = 0{,}63 \cdot 1 + 0{,}65 \cdot 0 + 0{,}70 \cdot -1 + 0{,}41 \cdot 1 + 0{,}42 \cdot 0 + 0{,}49 \cdot -1 + 0{,}25 \cdot 1 + 0{,}29 \cdot 0 + 0{,}37 \cdot -1 = -0{,}27$

$C_{f1} = 0{,}65 \cdot 1 + 0{,}70 \cdot 0 + 0{,}72 \cdot -1 + 0{,}42 \cdot 1 + 0{,}49 \cdot 0 + 0{,}47 \cdot -1 + 0{,}29 \cdot 1 + 0{,}37 \cdot 0 + 0{,}38 \cdot -1 = -0{,}21$

$C_{g1} = 0{,}70 \cdot 1 + 0{,}72 \cdot 0 + 0{,}68 \cdot -1 + 0{,}49 \cdot 1 + 0{,}47 \cdot 0 + 0{,}45 \cdot -1 + 0{,}37 \cdot 1 + 0{,}38 \cdot 0 + 0{,}35 \cdot -1 = 0{,}08$

$C_{h1} = 0{,}72 \cdot 1 + 0{,}68 \cdot 0 + 0{,}66 \cdot -1 + 0{,}47 \cdot 1 + 0{,}45 \cdot 0 + 0{,}47 \cdot -1 + 0{,}38 \cdot 1 + 0{,}35 \cdot 0 + 0{,}36 \cdot -1 = 0{,}08$

$C_{a2} = 0{,}36 \cdot 1 + 0{,}37 \cdot 0 + 0{,}41 \cdot -1 + 0{,}20 \cdot 1 + 0{,}21 \cdot 0 + 0{,}25 \cdot -1 + 0{,}07 \cdot 1 + 0{,}09 + 0{,}12 \cdot -1 = -0{,}15$

$C_{b2} = 0{,}37 \cdot 1 + 0{,}41 \cdot 0 + 0{,}39 \cdot -1 + 0{,}21 \cdot 1 + 0{,}25 \cdot 0 + 0{,}24 \cdot -1 + 0{,}09 \cdot 1 + 0{,}12 \cdot 0 + 0{,}15 \cdot -1 = -0{,}11$

$C_{c2} = 0{,}41 \cdot 1 + 0{,}39 \cdot 0 + 0{,}41 \cdot -1 + 0{,}25 \cdot 1 + 0{,}24 \cdot 0 + 0{,}25 \cdot -1 + 0{,}12 \cdot 1 + 0{,}15 \cdot 0 + 0{,}17 \cdot -1 = -0{,}05$

$Cd2 = 0{,}39.1 + 0{,}41.0 + 0{,}42.-1 + 0{,}24.1 + 0{,}25.0 + 0{,}29.-1 + 0{,}15.1 + 0{,}17.0 + 0{,}21.-1 = -0{,}14$

$Ce2 = 0{,}41.1 + 0{,}42.0 + 0{,}49.-1 + 0{,}25.1 + 0{,}29.0 + 0{,}37.-1 + 0{,}17.1 + 0{,}21.0 + 0{,}31.-1 = -0{,}34$

$Cf2 = 0{,}42.1 + 0{,}49.0 + 0{,}47.-1 + 0{,}29.1 + 0{,}37.0 + 0{,}38.-1 + 0{,}21.1 + 0{,}31.0 + 0{,}25.-1 = -0{,}18$

$Cg2 = 0{,}49.1 + 0{,}47.0 + 0{,}45.-1 + 0{,}37.1 + 0{,}38.0 + 0{,}35.-1 + 0{,}31.1 + 0{,}25.0 + 0{,}19.-1 = 0{,}18$

$Ch2 = 0{,}47.1 + 0{,}45.0 + 0{,}47.-1 + 0{,}38.1 + 0{,}35.0 + 0{,}36.-1 + 0{,}25.1 + 0{,}19.0 + 0{,}20.-1 = 0{,}07$

$Ca3 = 0{,}20.1 + 0{,}21.0 + 0{,}25.-1 + 0{,}07.1 + 0{,}09.0 + 0{,}12.-1 + 0{,}05.1 + 0{,}07.0 + 0{,}09.-1 = -0{,}14$

$Cb3 = 0{,}21.1 + 0{,}25.0 + 0{,}24.-1 + 0{,}09.1 + 0{,}12.0 + 0{,}15.-1 + 0{,}07.1 + 0{,}09.0 + 0{,}12.-1 = -0{,}14$

$Cc3 = 0{,}25.1 + 0{,}24.0 + 0{,}25.-1 + 0{,}12.1 + 0{,}15.0 + 0{,}17.-1 + 0{,}09.1 + 0{,}12.0 + 0{,}16.-1 = -0{,}12$

$Cd3 = 0{,}24.1 + 0{,}25.0 + 0{,}29.-1 + 0{,}15.1 + 0{,}17.0 + 0{,}21.-1 + 0{,}12.1 + 0{,}16.0 + 0{,}18.-1 = -0{,}17$

$Ce3 = 0{,}25.1 + 0{,}29.0 + 0{,}37.-1 + 0{,}17.1 + 0{,}21.0 + 0{,}31.-1 + 0{,}16.1 + 0{,}18.0 + 0{,}21.-1 = -0{,}31$

$Cf3 = 0{,}29.1 + 0{,}37.0 + 0{,}38.-1 + 0{,}21.1 + 0{,}31.0 + 0{,}25.-1 + 0{,}18.1 + 0{,}21.0 + 0{,}17.-1 = -0{,}12$

$Cg3 = 0{,}37.1 + 0{,}38.0 + 0{,}35.-1 + 0{,}31.1 + 0{,}25.0 + 0{,}19.-1 + 0{,}21.1 + 0{,}17.0 + 0{,}12.-1 = 0{,}23$

$Ch3 = 0{,}38.1 + 0{,}35.0 + 0{,}36.-1 + 0{,}25.1 + 0{,}19.0 + 0{,}20.-1 + 0{,}17.1 + 0{,}12.0 + 0{,}13.-1 = 0{,}11$

$Ca4 = 0{,}07.1 + 0{,}09.0 + 0{,}12.-1 + 0{,}05.1 + 0{,}07.0 + 0{,}09.-1 + 0{,}04.1 + 0{,}06.0 + 0{,}09.-1 = -0{,}14$

$Cb4 = 0{,}09.1 + 0{,}12.0 + 0{,}15.-1 + 0{,}07.1 + 0{,}09.0 + 0{,}12.-1 + 0{,}06.1 + 0{,}09.0 + 0{,}11.-1 = -0{,}16$

$Cc4 = 0{,}12.1 + 0{,}15.0 + 0{,}17.-1 + 0{,}09.1 + 0{,}12.0 + 0{,}16.-1 + 0{,}09.1 + 0{,}11.0 + 0{,}12.-1 = -0{,}15$

$Cd4 = 0{,}15.1 + 0{,}17.0 + 0{,}21.-1 + 0{,}12.1 + 0{,}16.0 + 0{,}18.-1 + 0{,}11.1 + 0{,}12.0 + 0{,}13.-1 = -0{,}14$

$Ce4 = 0{,}17.1 + 0{,}21.0 + 0{,}31.-1 + 0{,}16.1 + 0{,}18.0 + 0{,}21.-1 + 0{,}12.1 + 0{,}13.0 + 0{,}16.-1 = -0{,}23$

$Cf4 = 0{,}21.1 + 0{,}31.0 + 0{,}25.-1 + 0{,}18.1 + 0{,}21.0 + 0{,}17.-1 + 0{,}13.1 + 0{,}16.0 + 0{,}15.-1 = -0{,}05$

$Cg4 = 0{,}31.1 + 0{,}25.0 + 0{,}19.-1 + 0{,}21.1 + 0{,}17.0 + 0{,}12.-1 + 0{,}16.1 + 0{,}15.0 + 0{,}13.-1 = 0{,}24$

$Ch4 = 0{,}25.1 + 0{,}19.0 + 0{,}20.-1 + 0{,}17.1 + 0{,}12.0 + 0{,}13.-1 + 0{,}15.1 + 0{,}13.0 + 0{,}14.-1 = 0{,}1$

$Ca5 = 0{,}05.1 + 0{,}07.0 + 0{,}09.-1 + 0{,}04.1 + 0{,}06.0 + 0{,}09.-1 + 0{,}04.1 + 0{,}06.0 + 0{,}09.-1 = -0{,}14$

$Cb5 = 0{,}07.1 + 0{,}09.0 + 0{,}12.-1 + 0{,}06.1 + 0{,}09.0 + 0{,}11.-1 + 0{,}06.1 + 0{,}09.0 + 0{,}11.-1 = -0{,}15$

$Cc5 = 0{,}09.1 + 0{,}12.0 + 0{,}16.-1 + 0{,}09.1 + 0{,}11.0 + 0{,}12.-1 + 0{,}09.1 + 0{,}11.0 + 0{,}14.-1 = -0{,}15$

$Cd5 = 0{,}12.1 + 0{,}16.0 + 0{,}18.-1 + 0{,}11.1 + 0{,}12.0 + 0{,}13.-1 + 0{,}11.1 + 0{,}14.0 + 0{,}15.-1 = -0{,}12$

$Ce5 = 0{,}16.1 + 0{,}18.0 + 0{,}21.-1 + 0{,}12.1 + 0{,}13.0 + 0{,}16.-1 + 0{,}14.1 + 0{,}15.0 + 0{,}22.-1 = -0{,}17$

$Cf5 = 0{,}18.1 + 0{,}21.0 + 0{,}17.-1 + 0{,}13.1 + 0{,}16.0 + 0{,}15.-1 + 0{,}15.1 + 0{,}22.0 + 0{,}21.-1 = -0{,}07$

$Cg5 = 0{,}21.1 + 0{,}17.0 + 0{,}12.-1 + 0{,}16.1 + 0{,}15.0 + 0{,}13.-1 + 0{,}22.1 + 0{,}21.0 + 0{,}17.-1 = 0{,}17$

$Ch5 = 0{,}17.1 + 0{,}12.0 + 0{,}13.-1 + 0{,}15.1 + 0{,}13.0 + 0{,}14.-1 + 0{,}21.1 + 0{,}17.0 + 0{,}21.-1 = 0{,}05$

$Ca6 = 0{,}04.1 + 0{,}06.0 + 0{,}09.-1 + 0{,}04.1 + 0{,}06.0 + 0{,}09.-1 + 0{,}07.1 + 0{,}10.0 + 0{,}13.-1 = -0{,}16$

$Cb6 = 0{,}06.1 + 0{,}09.0 + 0{,}11.-1 + 0{,}06.1 + 0{,}09.0 + 0{,}11.-1 + 0{,}10.1 + 0{,}13.0 + 0{,}15.-1 = -0{,}15$

$Cc6 = 0{,}09.1 + 0{,}11.0 + 0{,}12.-1 + 0{,}09.1 + 0{,}11.0 + 0{,}14.-1 + 0{,}13.1 + 0{,}15.0 + 0{,}25.-1 = -0{,}2$

$C_{d6} = 0,11 \cdot 1 + 0,12 \cdot 0 + 0,13 \cdot -1 + 0,11 \cdot 1 + 0,14 \cdot 0 + 0,15 \cdot -1 + 0,15 \cdot 1 + 0,25 + 0,31 \cdot -1 = -0,22$

$C_{e6} = 0,12 \cdot 1 + 0,13 \cdot 0 + 0,16 \cdot -1 + 0,14 \cdot 1 + 0,15 \cdot 0 + 0,22 \cdot -1 + 0,25 \cdot 1 + 0,31 \cdot 0 + 0,37 \cdot -1 = -0,24$

$C_{f6} = 0,13 \cdot 1 + 0,16 \cdot 0 + 0,15 \cdot -1 + 0,15 \cdot 1 + 0,22 \cdot 0 + 0,21 \cdot -1 + 0,31 \cdot 1 + 0,37 \cdot 0 + 0,38 \cdot -1 = -0,15$

$C_{g6} = 0,16 \cdot 1 + 0,15 \cdot 0 + 0,13 \cdot -1 + 0,22 \cdot 1 + 0,21 \cdot 0 + 0,17 \cdot -1 + 0,37 \cdot 1 + 0,38 \cdot 0 + 0,34 \cdot -1 = 0,11$

$C_{h6} = 0,15 \cdot 1 + 0,13 \cdot 0 + 0,19 \cdot -1 + 0,21 \cdot 1 + 0,17 \cdot 0 + 0,21 \cdot -1 + 0,38 \cdot 1 + 0,34 \cdot 0 + 0,36 \cdot -1 = 0,03$

$C_{a7} = 0,04 \cdot 1 + 0,06 \cdot 0 + 0,09 \cdot -1 + 0,07 \cdot 1 + 0,10 \cdot 0 + 0,13 \cdot -1 + 0,12 \cdot 1 + 0,23 \cdot 0 + 0,33 \cdot -1 = -0,24$

$C_{b7} = 0,06 \cdot 1 + 0,09 \cdot 0 + 0,11 \cdot -1 + 0,10 \cdot 1 + 0,13 \cdot 0 + 0,15 \cdot -1 + 0,23 \cdot 1 + 0,33 \cdot 0 + 0,35 \cdot -1 = -0,22$

$C_{c7} = 0,09 \cdot 1 + 0,11 \cdot 0 + 0,14 \cdot -1 + 0,13 \cdot 1 + 0,15 \cdot 0 + 0,25 \cdot -1 + 0,33 \cdot 1 + 0,35 \cdot 0 + 0,38 \cdot -1 = -0,22$

$C_{d7} = 0,11 \cdot 1 + 0,14 \cdot 0 + 0,15 \cdot -1 + 0,15 \cdot 1 + 0,25 \cdot 0 + 0,31 \cdot -1 + 0,35 \cdot 1 + 0,38 \cdot 0 + 0,43 \cdot -1 = -0,28$

$C_{e7} = 0,14 \cdot 1 + 0,15 \cdot 0 + 0,22 \cdot -1 + 0,25 \cdot 1 + 0,31 \cdot 0 + 0,37 \cdot -1 + 0,38 \cdot 1 + 0,43 \cdot 0 + 0,49 \cdot -1 = -0,31$

$C_{f7} = 0,15 \cdot 1 + 0,22 \cdot 0 + 0,21 \cdot -1 + 0,31 \cdot 1 + 0,37 \cdot 0 + 0,38 \cdot -1 + 0,43 \cdot 1 + 0,49 \cdot 0 + 0,51 \cdot -1 = -0,21$

$C_{g7} = 0,22 \cdot 1 + 0,21 \cdot 0 + 0,17 \cdot -1 + 0,37 \cdot 1 + 0,38 \cdot 0 + 0,34 \cdot -1 + 0,49 \cdot 1 + 0,51 \cdot 0 + 0,47 \cdot -1 = 0,1$

$C_{h7} = 0,21 \cdot 1 + 0,17 \cdot 0 + 0,21 \cdot -1 + 0,38 \cdot 1 + 0,34 \cdot 0 + 0,36 \cdot -1 + 0,51 \cdot 1 + 0,47 \cdot 0 + 0,46 \cdot -1 = 0,07$

$C_{a8} = 0,07 \cdot 1 + 0,10 \cdot 0 + 0,13 \cdot -1 + 0,12 \cdot 1 + 0,23 \cdot 0 + 0,33 \cdot -1 + 0,33 \cdot 1 + 0,36 \cdot 0 + 0,48 \cdot -1 = -0,34$

$C_{b8} = 0,10 \cdot 1 + 0,13 \cdot 0 + 0,15 \cdot -1 + 0,23 \cdot 1 + 0,33 \cdot 0 + 0,35 \cdot -1 + 0,36 \cdot 1 + 0,48 \cdot 0 + 0,51 \cdot -1 = -0,32$

$C_{c8} = 0,13 \cdot 1 + 0,15 \cdot 0 + 0,25 \cdot -1 + 0,33 \cdot 1 + 0,35 \cdot 0 + 0,38 \cdot -1 + 0,48 \cdot 1 + 0,51 \cdot 0 + 0,59 \cdot -1 = -0,28$

$C_{d8} = 0,15 \cdot 1 + 0,25 \cdot 0 + 0,31 \cdot -1 + 0,33 \cdot 1 + 0,38 \cdot 0 + 0,43 \cdot -1 + 0,51 \cdot 1 + 0,59 \cdot 0 + 0,71 \cdot -1 = -0,44$

$C_{e8} = 0,25 \cdot 1 + 0,31 \cdot 0 + 0,37 \cdot -1 + 0,38 \cdot 1 + 0,43 \cdot 0 + 0,49 \cdot -1 + 0,59 \cdot 1 + 0,71 \cdot 0 + 0,76 \cdot -1 = -0,14$

$C_{f8} = 0,31 \cdot 1 + 0,37 \cdot 0 + 0,38 \cdot -1 + 0,43 \cdot 1 + 0,49 \cdot 0 + 0,51 \cdot -1 + 0,71 \cdot 1 + 0,76 \cdot 0 + 0,82 \cdot -1 = -0,26$

$C_{g8} = 0,37 \cdot 1 + 0,38 \cdot 0 + 0,34 \cdot -1 + 0,49 \cdot 1 + 0,51 \cdot 0 + 0,47 \cdot -1 + 0,76 \cdot 1 + 0,82 \cdot 0 + 0,74 \cdot -1 = 0,07$

$C_{h8} = 0,38 \cdot 1 + 0,34 \cdot 0 + 0,36 \cdot -1 + 0,51 \cdot 1 + 0,47 \cdot 0 + 0,46 \cdot -1 + 0,82 \cdot 1 + 0,74 \cdot 0 + 0,73 \cdot -1 = 0,16$

2. Activation Layer

-0,18	-0,13	-0,01	-0,1	-0,27	-0,21	0,08	0,08
-0,15	-0,11	-0,05	-0,14	-0,34	-0,18	0,18	0,07
-0,14	-0,14	-0,12	-0,17	-0,31	-0,12	0,23	0,11
-0,14	-0,16	-0,15	-0,14	-0,23	-0,05	0,24	0,1
-0,19	-0,15	-0,15	-0,12	-0,17	-0,07	0,17	0,05
-0,16	-0,15	-0,2	-0,22	-0,24	-0,15	0,11	0,03
-0,29	-0,22	-0,22	-0,28	-0,31	-0,21	0,1	0,07
-0,34	-0,32	-0,28	-0,44	-0,4	-0,26	0,07	0,16

0	0	0	0	0	0	0,08	0,08
0	0	0	0	0	0	0,18	0,07
0	0	0	0	0	0	0,23	0,11
0	0	0	0	0	0	0,24	0,1
0	0	0	0	0	0	0,17	0,05
0	0	0	0	0	0	0,11	0,03
0	0	0	0	0	0	0,1	0,07
0	0	0	0	0	0	0,07	0,16

3. Max Pooling

0	0	0	0	0	0	0,08	0,08
0	0	0	0	0	0	0,18	0,07
0	0	0	0	0	0	0,23	0,11
0	0	0	0	0	0	0,24	0,1
0	0	0	0	0	0	0,17	0,05
0	0	0	0	0	0	0,11	0,03
0	0	0	0	0	0	0,1	0,07
0	0	0	0	0	0	0,07	0,16

	a	b	c	d	e	f	g
1	0	0	0	0	0	0,18	0,18
2	0	0	0	0	0	0,23	0,23
3	0	0	0	0	0	0,24	0,24
4	0	0	0	0	0	0,24	0,24
5	0	0	0	0	0	0,17	0,17
6	0	0	0	0	0	0,11	0,11
7	0	0	0	0	0	0,1	0,16

- Convolutional layer 2.

1. Pada tahap ini menggunakan filter kernel untuk $\sum_{j=32} w_j$

0 0 -1 b=0

1 0 0

1 1 0

Maka proses konvolusinya sebagai berikut:

$C_{a1} = 0.0 + 0.0 + -1.0 + 1.0 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$C_{b1} = 0.0 + 0.0 + -1.0 + 1.0 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$C_{c1} = 0.0 + 0.0 + 0.-1 + 1.0 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$C_{d1} = 0.0 + 0.0 + 0.18.-1 + 1.0 + 0.0 + 0.0,23 + 1.0 + 1.0 + 0.0,24 = -0,18$

$C_{e1} = 0.0 + 0.18.0 + 0.18.-1 + 1.0 + 0.0,23 + 0.0,23 + 1.0 + 1.0,24 + 0.0,24 = 0,06$

$C_{a2} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$C_{b2} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$C_{c2} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$C_{d2} = 0.0 + 0.0 + 0,23.-1 + 0.1 + 0.0 + 0.0,24 + 0.1 + 0.1 + 0,24.0 = -0,23$

$C_{e2} = 0.0 + 0,23.0 + 0,23.-1 + 0.1 + 0.0,24 + 0,24.0 + 1.0 + 1.0,24 + 0.0,24 = 0,01$

$C_{a3} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$C_{b3} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$C_{c3} = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 0.1 + 0.1 + 0.0 = 0$

$Cd3 = 0.0 + 0.0 + 0,124 \cdot -1 + 1.0 + 0.0 + 0.0,124 + 1.0 + 1.0 + 0,17 \cdot 0 = -0,124$

$Ce3 = 0.0 + 0,124 \cdot 0 + 0,124 \cdot -1 + 1.0 + 0 \cdot 0,124 + 1.0 + 1.0, 17 + 0,17 \cdot 0 = -0,07$

$Ca4 = 0.0 + 0.0 + -1.0 + 0.1 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$Cb4 = 0.0 + 0.0 + -1.0 + 0.1 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$Cc4 = 0.0 + 0.0 + 0.-1 + 0.1 + 0.0 + 0.0 + 1.0 + 1.0 + 0.0 = 0$

$Cd4 = 0.0 + 0.0 + 0.24 \cdot -1 + 1.0 + 0.0 + 0.0,17 + 1.0 + 1.0 + 0,11 \cdot 0 = -0,124$

$Ce4 = 0.0 + 0,24 \cdot 0 + 0,24 \cdot -1 + 1.0 + 0.0,17 + 0.0,17 + 1.0 + 1.0,11 + 0,11 \cdot 0 = -0,13$

$Ca5 = 0.0 + 0.0 + 0.-1 + 1.0 + 0.0 + 0.0 + 0.1 + 1.0 + 0.0 = 0$

$Cb5 = 0.0 + 0.0 + 0.-1 + 1.0 + 0.0 + 0.0 + 0.1 + 1.0 + 0.0 = 0$

$Cc5 = 0.0 + 0.0 + 0.-1 + 1.0 + 0.0 + 0.0 + 0.1 + 1.0 + 0.0 = 0$

$Cd5 = 0.0 + 0.0 + 0,17 \cdot -1 + 1.0 + 0.0 + 0.0,11 + 1.0 + 1.0 + 0.0,11 = -0,17$

$Ce5 = 0.0 + 0,17 \cdot 0 + 0,17 \cdot -1 + 1.0 + 0 \cdot 0,11 + 0 \cdot 0,11 + 1.0 + 1.0,1 + 0.0,16 = -0,07$

2. Activation Layer

0	0	0	-0,118	0,106
0	0	0	-0,123	0,101
0	0	0	-0,124	-0,107
0	0	0	-0,124	-0,113
0	0	0	-0,17	-0,107

0	0	0	0	0,106
0	0	0	0	0,101
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

3. Max Pooling

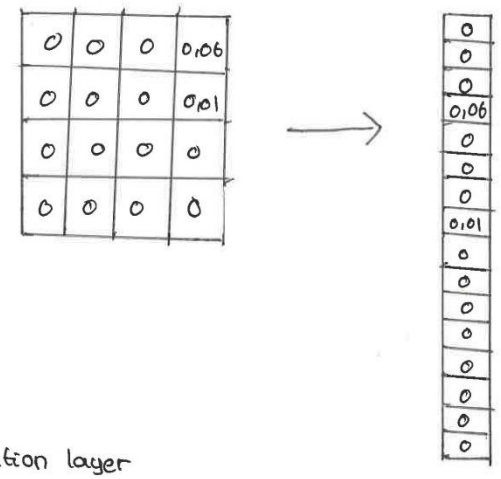
0	0	0	0	0,106
0	0	0	0	0,101
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

→

0	0	0	0,106
0	0	0	0,101
0	0	0	0
0	0	0	0

- Folly Connected layer

1. Flattening



2. Activation layer

$S(x_1) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_2) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_3) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_4) = \frac{1}{1+e^{-0,06}} = 0,51$

$S(x_5) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_6) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_7) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_8) = \frac{1}{1+e^{-0,01}} = 0,501$

$S(x_9) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{10}) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{11}) = \frac{1}{1+e^{-0}} = 0,5$

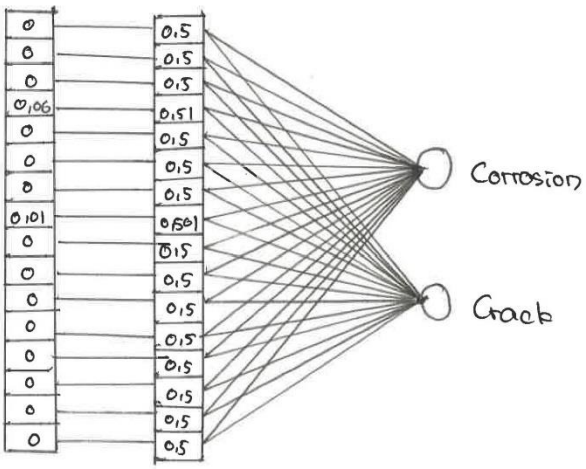
$S(x_{12}) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{13}) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{14}) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{15}) = \frac{1}{1+e^{-0}} = 0,5$

$S(x_{16}) = \frac{1}{1+e^{-0}} = 0,5$



• Loss Function

Menggunakan Binary Cross-Entropy

$$L = -\frac{1}{N}\sum_{i=1}^{N} y_i \cdot (\log(y_i)) + (1-y_i) \cdot \log(1-y_i))$$

Maka didapatkan nilai

$L_1 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_2 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_3 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_4 = 1 \cdot \log(0{,}51) + (1-1) \cdot \log(1-0{,}51) = -0{,}29$

$L_5 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_6 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_7 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_8 = 1 \cdot \log(0{,}501) + (1-1) \cdot \log(1-0{,}501) = -0{,}3$

$L_9 = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{10} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{11} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{12} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{13} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{14} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{15} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$L_{16} = 1 \cdot \log(0{,}5) + (1-1) \cdot \log(1-0{,}5) = -0{,}3$

$$L_{tot} = -\frac{1}{16}\,-0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}29 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3 - 0{,}3$$

$$= 0{,}29$$

2. Tahap Convolational 1.

· Convolational layer 1

1- Menggunakan filter kernel untuk $\sum_{i=32} w_i$:

$$\begin{matrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{matrix} \qquad b = 1$$

Maka proses convolutional sebagai berikut:

$C_{a1} = 0,54.1 + 0,55.0 + 0,62.0 + 0,36.1 + 0,37.1 + 0,41.0 + 0,20.0 + 0,21.1 + 0,25.1 + 1 = 2,73$

$C_{b1} = 0,55.1 + 0,62.0 + 0,63.0 + 0,37.1 + 0,41.1 + 0,39.0 + 0,21.0 + 0,25.1 + 0,24.1 + 1 = 2,82$

$C_{c1} = 0,62.1 + 0,63.0 + 0,63.0 + 0,41.1 + 0,39.1 + 0,41.0 + 0,25.0 + 0,24.1 + 0,25.1 + 1 = 2,91$

$C_{d1} = 0,63.1 + 0,63.0 + 0,65.0 + 0,39.1 + 0,41.1 + 0,42.0 + 0,24.0 + 0,25.1 + 0,29.1 + 1 = 2,97$

$C_{e1} = 0,63.1 + 0,65.0 + 0,70.0 + 0,41.1 + 0,42.1 + 0,49.0 + 0,25.0 + 0,29.1 + 0,37.1 + 1 = 3,12$

$C_{f1} = 0,65.1 + 0,70.0 + 0,72.0 + 0,42.1 + 0,49.1 + 0,47.0 + 0,29.0 + 0,37.1 + 0,38.1 + 1 = 3,31$

$C_{a2} = 0,36.1 + 0,37.0 + 0,41.0 + 0,20.1 + 0,21.1 + 0,25.0 + 0,07.0 + 0,09.1 + 0,12.1 + 1 = 1,78$

$C_{b2} = 0,37.1 + 0,41.0 + 0,39.0 + 0,21.1 + 0,25.1 + 0,24.0 + 0,09.0 + 0,12.1 + 0,15.1 + 1 = 1,89$

$C_{c2} = 0,41.1 + 0,39.0 + 0,41.0 + 0,25.1 + 0,24.1 + 0,25.0 + 0,12.0 + 0,15.1 + 0,17.1 + 1 = 1,97$

$C_{d2} = 0,39.1 + 0,41.0 + 0,42.0 + 0,24.1 + 0,25.1 + 0,29.0 + 0,15.0 + 0,17.1 + 0,21.1 + 1 = 2,02$

$C_{e2} = 0,41.1 + 0,42.0 + 0,49.0 + 0,25.1 + 0,29.1 + 0,37.0 + 0,17.0 + 0,21.1 + 0,31.1 + 1 = 2,22$

$C_{f2} = 0,42.1 + 0,49.0 + 0,47.0 + 0,29.1 + 0,37.1 + 0,38.0 + 0,21.0 + 0,31.1 + 0,38.1 + 1 = 2,48$

$C_{g2} = 0,49.1 + 0,47.0 + 0,45.0 + 0,37.1 + 0,38.0 + 0,35.0 + 0,31.0 + 0,25.1 + 0,19.1 + 1 = 2,31$

$C_{b2} = 0,47.1 + 0,45.0 + 0,47.0 + 0,38.1 + 0,35.1 + 0,36.0 + 0,25.0 + 0,19.1 + 0,20.1 + 1 = 2,21$

$C_{g1} = 0,70.1 + 0,72.0 + 0,68.0 + 0,49.1 + 0,47.1 + 0,45.0 + 0,37.0 + 0,38.1 + 0,35.1 + 1 = 2,9$

$C_{h1} = 0,72.1 + 0,68.0 + 0,66.0 + 0,47.1 + 0,45.1 + 0,47.0 + 0,38.0 + 0,35.1 + 0,36.1 + 1 = 2,889$

$C_{a3} = 0,20.1 + 0,21.0 + 0,25.0 + 0,07.1 + 0,09.1 + 0,12.0 + 0,05.0 + 0,07.1 + 0,09.1 + 1 = 1,45$

$C_{b3} = 0,21.1 + 0,25.0 + 0,24.0 + 0,09.1 + 0,12.1 + 0,15.0 + 0,07.0 + 0,09.1 + 0,12.1 + 1 = 1,54$

$C_{c3} = 0,25.1 + 0,24.0 + 0,25.0 + 0,12.1 + 0,15.1 + 0,17.0 + 0,09.0 + 0,12.1 + 0,16.1 + 1 = 1,68$

$C_{d3} = 0,24.1 + 0,25.0 + 0,29.0 + 0,15.1 + 0,17.1 + 0,21.0 + 0,12.0 + 0,16.1 + 0,18.1 + 1 = 1,75$

$C_{e3} = 0,25.1 + 0,29.0 + 0,37.0 + 0,17.1 + 0,21.1 + 0,31.0 + 0,16.0 + 0,18.1 + 0,21.1 + 1 = 1,85$

$C_{f3} = 0,29.1 + 0,37.0 + 0,38.0 + 0,21.1 + 0,31.1 + 0,25.0 + 0,18.0 + 0,21.1 + 0,17.1 + 1 = 1,98$

$C_{g3} = 0,37.1 + 0,38.0 + 0,35.0 + 0,31.1 + 0,25.1 + 0,19.0 + 0,21.0 + 0,17.1 + 0,12.1 + 1 = 1,91$

$C_{h3} = 0,38.1 + 0,35.0 + 0,36.0 + 0,25.1 + 0,19.1 + 0,20.0 + 0,17.0 + 0,12.1 + 0,13.1 + 1 = 1,82$

$C_{a4} = 0,07.1 + 0,09.0 + 0,12.0 + 0,05.1 + 0,07.1 + 0,09.0 + 0,04.0 + 0,06.1 + 0,09.1 + 1 = 1,29$

$C_{b4} = 0,09.1 + 0,12.0 + 0,15.0 + 0,07.1 + 0,09.1 + 0,12.0 + 0,06.0 + 0,09.1 + 0,11.1 + 1 = 1,38$

Cc4 = 0,12.1 + 0,15.0 + 0,17.0 + 0,09.1 + 0,12.1 + 0,16.0 + 0,09.0 + 0,11.1 + 0,12.1 + 1 = 1,47

Cd4 = 0,15.1 + 0,17.0 + 0,21.0 + 0,12.1 + 0,16.1 + 0,18.0 + 0,11.0 + 0,12.1 + 0,13.1 + 1 = 1,56

Ce4 = 0,17.1 + 0,21.0 + 0,31.0 + 0,18.1 + 0,18.1 + 0,21.0 + 0,12.0 + 0,13.1 + 0,16.1 + 1 = 1,64

Cf4 = 0,21.1 + 0,31.0 + 0,25.0 + 0,18.0 + 0,21.1 + 0,17.0 + 0,13.0 + 0,16.1 + 0,15.1 + 1 = 1,73

Cg4 = 0,31.1 + 0,25.0 + 0,19.0 + 0,21.1 + 0,17.1 + 0,12.0 + 0,16.0 + 0,15.1 + 0,13.1 + 1 = 1,76

Ch4 = 0,25.1 + 0,19.0 + 0,20.0 + 0,17.1 + 0,12.1 + 0,13.0 + 0,15.0 + 0,13.1 + 0,14.1 + 1 = 1,64

Ca5 = 0,05.1 + 0,07.0 + 0,09.0 + 0,04.1 + 0,06.1 + 0,09.0 + 0,04.0 + 0,06.1 + 0,09.1 + 1 = 1,26.

Cb5 = 0,07.1 + 0,09.0 + 0,12.0 + 0,06.1 + 0,09.1 + 0,11.0 + 0,06.0 + 0,09.1 + 0,11.1 + 1 = 1,36

Cc5 = 0,09.1 + 0,12.0 + 0,16.0 + 0,09.1 + 0,11.1 + 0,12.0 + 0,09.0 + 0,11.1 + 0,14.1 + 1 = 1,45

Cd5 = 0,12.1 + 0,16.0 + 0,18.0 + 0,11.1 + 0,12.1 + 0,13.0 + 0,11.0 + 0,14.1 + 0,15.1 + 1 = 1,53

Ce5 = 0,16.1 + 0,18.0 + 0,21.0 + 0,12.1 + 0,13.1 + 0,16.0 + 0,14.0 + 0,15.1 + 0,22.1 + 1 = 1,66

Cf5 = 0,18.1 + 0,21.0 + 0,17.0 + 0,13.1 + 0,16.1 + 0,15.0 + 0,15.0 + 0,22.1 + 0,21.1 + 1 = 1,77

Cg5 = 0,21.1 + 0,17.0 + 0,12.0 + 0,16.1 + 0,15.1 + 0,13.0 + 0,15.0 + 0,21.1 + 0,17.1 + 1 = 1,74

Ca6 = 0,04.1 + 0,06.0 + 0,09.0 + 0,04.1 + 0,06.0 + 0,09.0 + 0,07.0 + 0,10.1 + 0,13.1 + 1 = 1,33

Cb6 = 0,06.1 + 0,09.0 + 0,11.0 + 0,06.1 + 0,09.1 + 0,11.0 + 0,10.0 + 0,13.1 + 0,15.1 + 1 = 1,43

Cc6 = 0,09.1 + 0,11.0 + 0,12.0 + 0,09.1 + 0,11.1 + 0,14.0 + 0,13.0 + 0,15.1 + 0,25.1 + 1 = 1,6

Cd6 = 0,11.1 + 0,12.0 + 0,13.0 + 0,11.1 + 0,14.1 + 0,15.0 + 0,15.0 + 0,25.1 + 0,31.1 + 1 = 1,81

Ce6 = 0,12.1 + 0,13.0 + 0,16.0 + 0,14.1 + 0,15.1 + 0,22.0 + 0,25.0 + 0,31.1 + 0,37.1 + 1 = 1,95

Cf6 = 0,13.1 + 0,16.0 + 0,15.0 + 0,15.1 + 0,22.1 + 0,21.0 + 0,31.0 + 0,37.1 + 0,38.1 + 1 = 2,1

Cg6 = 0,16.1 + 0,15.0 + 0,13.0 + 0,22.1 + 0,21.1 + 0,17.0 + 0,37.0 + 0,38.1 + 0,34.1 + 1 = 2,09

Ch6 = 0,15.1 + 0,13.0 + 0,14.0 + 0,21.1 + 0,17.1 + 0,21.0 + 0,38.0 + 0,34.1 + 0,36.1 + 1 = 2,02

Ca7 = 0,04.1 + 0,06.0 + 0,09.0 + 0,07.1 + 0,10.1 + 0,13.0 + 0,20.0 + 0,23.1 + 0,33.1 + 1 = 1,7

Cb7 = 0,06.1 + 0,09.0 + 0,11.0 + 0,10.1 + 0,13.1 + 0,15.0 + 0,23.0 + 0,33.1 + 0,35.1 + 1 = 1,87

Cc7 = 0,09.1 + 0,11.0 + 0,14.0 + 0,13.1 + 0,15.1 + 0,25.0 + 0,33.0 + 0,35.1 + 0,38.1 + 1 = 1,97

Cd7 = 0,11.1 + 0,14.0 + 0,15.0 + 0,15.1 + 0,25.1 + 0,31.0 + 0,35.0 + 0,38.1 + 0,43.1 + 1 = 2.17

Ce7 = 0,14.1 + 0,15.0 + 0,22.0 + 0,25.1 + 0,31.1 + 0,37.0 + 0,38.0 + 0,43.1 + 0,49.1 + 1 = 2,37

Cf7 = 0,15.1 + 0,22.0 + 0,21.0 + 0,31.1 + 0,37.1 + 0,38.0 + 0,43.0 + 0,49.1 + 0,51.1 + 1 = 2,52

Cg7 = 0,22.1 + 0,21.0 + 0,17.0 + 0,37.1 + 0,38.1 + 0,34.0 + 0,49.0 + 0,51.1 + 0,47.1 + 1 = 2,58

Ch7 = 0,21.1 + 0,17.0 + 0,21.0 + 0,38.1 + 0,34.1 + 0,36.0 + 0,51.0 + 0,47.1 + 0,46.1 + 1 = 2,48

Ch5 = 0,17.1 + 0,12.0 + 0,13.0 + 0,15.1 + 0,13.1 + 0,19.0 + 0,21.0 + 0,17.1 + 0,21.1 + 1 = 1,68

Ca8 = 0,07.1 + 0,10.0 + 0,13.0 + 0,2.1 + 0,23.1 + 0,33.0 + 0,33.0 + 0,36.1 + 0,48.1 + 1 = 2,14

Cb8 = 0,10.1 + 0,13.0 + 0,15.0 + 0,23.1 + 0,33.1 + 0,35.0 + 0,36.0 + 0,48.1 + 0,51.1 + 1 = 2,42

Cc8 = 0,13.1 + 0,15.0 + 0,25.0 + 0,33.1 + 0,35.1 + 0,38.0 + 0,48.0 + 0,51.1 + 0,59.1 + 1 = 2,58

Cd8 = 0,15.1 + 0,25.0 + 0,31.0 + 0,35.1 + 0,38.1 + 0,43.0 + 0,51.0 + 0,59.1 + 0,71.1 + 1 = 2,83

Ce8 = 0,25.1 + 0,31.0 + 0,37.0 + 0,38.1 + 0,43.1 + 0,49.0 + 0,59.0 + 0,71.1 + 0,76.1 + 1 = 3,15

Cf8 = 0,31.1 + 0,37.0 + 0,38.0 + 0,43.1 + 0,49.1 + 0,51.0 + 0,71.0 + 0,76.1 + 0,82.1 + 1 = 3,38

Cg8 = 0,37.1 + 0,38.0 + 0,34.0 + 0,49.1 + 0,51.1 + 0,47.0 + 0,76.0 + 0,82.1 + 0,74.1 + 1 = 3,44

Ch8 = 0,38.1 + 0,34.0 + 0,36.0 + 0,51.1 + 0,47.0 + 0,46.0 + 0,82.0 + 0,74.1 + 0,73.1 + 1 = 3,36

2. Activation layer

2,73	2,82	2,91	2,97	3,12	3,31	2,9	2,8
1,78	1,89	1,97	2,02	2,22	2,48	2,31	2,21
1,45	1,54	1,68	1,75	1,85	1,98	1,91	1,82
1,29	1,38	1,47	1,56	1,66	1,73	1,76	1,64
1,26	1,36	1,45	1,53	1,66	1,77	1,74	1,68
1,33	1,43	1,6	1,81	1,95	2,1	2,09	2,02
1,7	1,87	1,97	2,17	2,37	2,52	2,58	2,48
2,14	2,42	2,58	2,83	3,15	3,38	3,44	3,36

3. Max Pooling

2,82	2,91	2,97	3,12	3,48	3,31	2,9
1,89	1,97	2,02	2,22	2,48	2,48	2,31
1,54	1,68	1,75	1,85	1,98	1,98	1,91
1,38	1,47	1,56	1,66	1,77	1,77	1,74
1,43	1,45	1,81	1,95	2,1	2,1	2,09
1,87	1,97	2,17	2,37	2,52	2,58	2,58
2,42	2,58	2,83	3,15	3,38	3,44	3,44

8. Tahap Convolutional 2

Menggunakan filter kernel untuk $\omega \sum_{j,32} \omega_j$:

1	0	-1	b : 1
-1	-1	0	
1	1	0	

Maka proses konvulasinya sebagai berikut :

C_{a1} : 2,82.1+2,91.0+2,97.-1+1,89.-7+1,97.-1+2,02.0+1,54.1+1,68.1+1,75.0+1,79 +1 = 0,21

C_{b1} = 2,91.1+2,97.0+3,12.-1+1,97.-1+2,02.-7+2,22.0+1,68.1+1,75.1+1,85.0+1 : 0,23

C_{c1} = 2,97.1+3,12.0+3,31.-1+2,02.-7+2,22.-1+2,48.0+1,75.1+1,85.1+1,98.0+1 : 0,02

C_{d1} : 3,12.1+3,31.0+3,31.0+2,22.-1+2,98.-1+2,48.0+1,85.1+1,98.1+1,98.0+1 : -0,06

C_{e1} : 3,31.1+3,31.0+2,9.-1+2,48.-1+2,48.-1+2,31.0+1,98.1+1,98.1+1,91.0+1 = 0,41

C_{a2} : 1,89.1+1,97.0+2,02.-1+1,54.-1+1,68.-1+1,75.0+1,38.1+1,47.1+1,56.0+1 = 0,5

C_{b2} : 1,97.1+2,02.0+2,22.-1+1,68.-1+1,75.-1+1,85.0+1,47.1+1,56.1+1,66.0+1 = 0,35

C_{c2} = 2,02.1+2,22.0+2,48.-1+1,75.-1+1,85.-1+1,98.0+1,56.1+1,66.1+1,77.0+1 : 0,16

C_{d2} : 2,22.1+2,48.0+2,48.-1+1,85.-1+1,98.-1+1,98.0+1,66.1+1,77.1+1,77.0+1 : 0,34

C_{e2} : 2,48.1+2,48.0+2,31.-1+1,98.-1+1,98.-1+1,91.0+1,77.1+1,77.1+1,74.0+1 : 0,175

C_{a3} : 1,54.1+1,68.0+1,75.-1+1,38.-1+1,47.-1+1,56.0+1,43.1+1,45.1+1,81.0+1 : 0,082

C_{b3} : 1,68.1+1,75.0+1,85.-1+1,47.-1+1,56.-1+1,66.0+1,47.1+1,81.1+1,95.0+1 = 1,108

C_{c3} : 1,75.1+1,85.0+1,98.-1+1,56.-1+1,66.-1+1,77.0+1,81.1+1,95.1+2,1.0+1 : 1,31

C_{d3} : 1,85.1+1,98.0+1,98.-1+1,66.-1+1,77.-1+1,77.0+1,95.1+2,1.-1+2,1.0+1 : 1,49

C_{e3} : 1,98.1+1,98.0+1,91.-1+1,77.-1+1,77.-1+1,74.0+2,1.1+2,1.-1+2,09.0+1 : 1,73

C_{a4} : 1,38.1+1,47.0+1,56.-1+1,43.-1+1,45.-1+1,81.0+1,87.1+1,97.1+2,17.0+1 : 1,78

C_{b4} : 1,47.1+1,56.0+1,66.-1+1,45.-1+1,81.-1+1,95.0+1,97.1+2,17.1+2,37.0+1 = 1,69

C_{c4} : 1,56.1+1,66.0+1,77.-1+1,81.-1+1,95.-1+2,1.0+2,17.1+2,37.1+2,52.0+1 : 1,57

C_{d4} : 1,66.1+1,77.0+1,77.-1+1,95.-1+2,1.-1+2,1.0+2,37.1+2,52.1+2,58.0+1 : 1,73

C_{e4} : 1,77.-1+1,77.0+1,74.-1+2,1.-1+2,1.-1+2,09.0+2,52.1+2,58.1+2,58.0+1 : 1,93

C_{a5} : 1,43.1+1,45.0+1,81.-1+1,87.-1+1,97.-1+2,17.0+2,42.1+2,58.1+2,83.0+1 : 1,78

C_{b5} : 1,45.1+1,81.0+1,95.-1+1,97.-1+2,17.-1+2,37.0+2,58.1+2,83.1+3,15.0+1 : 1,77

C_{c5} : 1,81.1+1,95.0+2,1.-1+2,17.-1+2,37.-1+2,52.0+2,83.1+3,15.1+3,38.0+1 : 2,15

C_{d5} : 2,1.1+2,1.0+2,09.-1+2,52.-1+2,58.-1+2,58.0+3,38.1+3,44.1+3,44.0+1 : 2,73

C_{d5} : 1,95.1+2,1.0+2,1-1+2,37.-1+2,52.-1+2,58.0+3,15.1+3,38.1+3,44.0+1 = 2,49

2. Activation layer

0,21	0,23	0,02	-0,06	0,41
0,5	0,35	0,16	0,34	0,75
0,82	1,08	1,31	1,49	1,73
1,78	1,69	1,57	1,73	1,93
1,78	1,77	2,15	2,49	2,73

0,21	0,23	0,02	0	0,41
0,5	0,35	0,16	0,34	0,75
0,82	1,08	1,31	1,49	1,73
1,78	1,67	1,57	1,73	1,93
1,78	1,77	2,15	2,49	2,73

3. Max Pooling

0,35	0,35	0,34	0,75
1,08	1,31	1,49	1,73
1,78	1,67	1,73	1,93
1,78	2,15	2,49	2,73

- Fully Connected Layer

1. Flattening

0,35	0,35	0,34	0,75
1,08	1,31	1,49	1,73
1,78	1,67	1,73	1,93
1,78	2,15	2,49	2,73

→

0,35
0,35
0,34
0,75
1,08
1,31
1,49
1,73
1,78
1,67
1,73
1,93
1,78
2,15
2,49
2,73

2. Activation layer

$S(x_1) = \frac{1}{1+e^{-0,135}} = 0,158$

$S(x_2) = \frac{1}{1+e^{-0,135}} = 0,158$

$S(x_3) = \frac{1}{1+e^{-0,134}} = 0,158$

$S(x_4) = \frac{1}{1+e^{-0,73}} = 0,167$

$S(x_5) = \frac{1}{1+e^{-1,08}} = 0,174$

$S(x_6) = \frac{1}{1+e^{-1,31}} = 0,178$

$S(x_7) = \frac{1}{1+e^{-1,49}} = 0,181$

$S(x_8) = \frac{1}{1+e^{-1,77}} = 0,185$

$S(x_9) = \frac{1}{1+e^{-1,78}} = 0,185$

$S(x_{10}) = \frac{1}{1+e^{-1,67}} = 0,184$

$S(x_{11}) = \frac{1}{1+e^{-1,73}} = 0,184$

$S(x_{12}) = \frac{1}{1+e^{-1,93}} = 0,187$

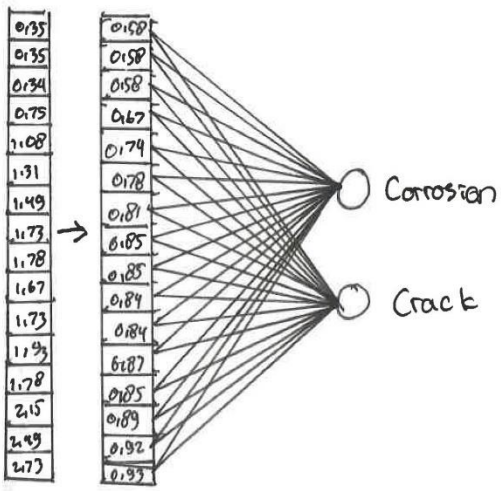
$S(x_{13}) = \frac{1}{1+e^{-1,78}} = 0,185$

$S(x_{14}) = \frac{1}{1+e^{-2,15}} = 0,189$

$S(x_{15}) = \frac{1}{1+e^{-2,49}} = 0,192$

$S(x_{16}) = \frac{1}{1+e^{-2,73}} = 0,193$

~~$S(x_9)$~~:



. Loss Function

Menggunakan Binary Cross-Entropy

$$L = \frac{1}{N}\sum_{i=1}^{N} (y_i \cdot \log(\bar{y}_i) + (1-y_i) \cdot \log(1-\bar{y}_i))$$

Maka didapatkan nilai:

$L_1 = -\frac{1}{2} \cdot 1 \cdot \log(0,58) + (1-y_i) \cdot \log(1-0,58) = 0,118 \cdot -2 = -0,236$

$L_2 = -\frac{1}{2} \cdot 1 \cdot \log(0,58) + (1-1) \cdot \log(1-0,58) = 0,118 \cdot -2 = -0,236$

$L_3 = -\frac{1}{2} \cdot 1 \cdot \log(0,58) + (1-1) \cdot \log(1-0,58) = 0,118 \cdot -2 = -0,236$

$L_4 = -\frac{1}{2} \cdot 1 \log(0,67) + (1-1) \cdot \log(1-0,67) = 0,086 \cdot -2 = -0,172$

$L_5 = -\frac{1}{2} \cdot 1 \cdot \log(0,74) + (1-1) \cdot \log(1-0,74) = 0,065 \cdot -2 = -0,13$

$L_6 = -\frac{1}{2} \cdot 1 \cdot \log(0,78) + (1-1) \cdot \log(1-0,78) = 0,053 \cdot -2 = -0,106$

$L_7 = -\frac{1}{2} \cdot 1 \cdot \log(0,81) + (1-1) \cdot \log(1-0,81) = 0,045 \cdot -2 = -0,09$

$L_8 = -\frac{1}{2} \cdot 1 \cdot \log(0,85) + (1-1) \cdot \log(1-0,85) = 0,035 \cdot -2 = -0,07$

$L_9 = -\frac{1}{2} \cdot 1 \cdot \log(0,84) + (1-1) \cdot \log(1-0,84) = 0,037 \cdot -2 = -0,074$

$L_{10} = -\frac{1}{2} \cdot 1 \cdot \log(0,84) + (1-1) \cdot \log(1-0,84) = 0,037 \cdot -2 = -0,074$

$L_{11} = -\frac{1}{2} \cdot 1 \cdot \log(0,87) + (1-1) \cdot \log(1-0,87) = 0,0302 \cdot -2 = -0,0604$

$L_{12} = -\frac{1}{2} \cdot 1 \cdot \log(0,85) + (1-1) \cdot \log(1-0,85) = 0,035 \cdot -2 = -0,07$

$L_{13} = -\frac{1}{2} \cdot 1 \cdot \log(0,89) + (1-1) \cdot \log(1-0,89) = 0,025 \cdot -2 = -0,05$

$L_{14} = -\frac{1}{2} \cdot 1 \cdot \log(0,85) + (1-1) \cdot \log(1-0,85) = 0,035 \cdot -2 = -0,07$

$L_{15} = -\frac{1}{2} \cdot 1 \cdot \log(0,92) + (1-1) \cdot \log(1-0,92) = 0,018 \cdot -2 = -0,036$

$L_{16} = -\frac{1}{2} \cdot 1 \cdot \log(0,93) + (1-1) \cdot \log(1-0,93) = 0,015 \cdot -2 = -0,03$

$L_{tot} = -\frac{1}{2}(-0,236 - 0,236 - 0,236 - 0,172 - 0,13 - 0,106 - 0,09 - 0,07 - 0,074 - 0,074 - 0,0604 - 0,07 - 0,05 - 0,07 - 0,036 - 0,03)$

$= 0,108$

Backpropagation

↳ Backward Pass (Output → Fc)

$$\frac{\partial Loss}{\partial w_{fc0}} = \frac{\partial Loss}{\partial out} \times \frac{\partial out}{\partial o_{in}} \times \frac{\partial o_{in}}{\partial w_{fc0}}$$

→ $Loss = \frac{1}{N} \sum_{i=1}^{N} y_i \cdot \log(\bar{y}_i) + (1-y_i) \cdot \log(1-\bar{y}_i)$

$$\frac{\partial Loss}{\partial out} = \frac{1}{m} \sum_{i}^{m} [\bar{y}_i - y_i] \times \hat{i}$$

$$\frac{\partial Loss}{\partial \bar{y}_i} = \frac{1}{16} [(0,108-1).0,158 + (0,108-1).0,158 + (-0,1892).0,167 + (-0,1892).0,174 + (-0,1892).0,178 + (-0,1892).0,181 + (-0,1892).0,185 + (-0,1892).0,185 + (-0,1892).0,184 + (-0,1892).0,184 + (-0,1892).0,187 + (-0,1892).0,185 + (-0,1892).0,189 + (-0,1892).0,192 + (-0,1892).0,193 + (-0,1892).0,158]$$

$$= -0,656$$

→ Gradient $\bar{y}_i$ terhadap x_i :

$$\bar{y}_i = \frac{1}{1+e^{-wx}}$$

$$\frac{\partial \bar{y}_i}{\partial x} = \frac{1}{1+e^{-x}} \times \left(1 - \frac{1}{1+e^{-x}}\right)$$

$\frac{\partial \bar{y}_1}{\partial x} = 0,158 \times (1-0,158) = 0,12436$

$\frac{\partial \bar{y}_2}{\partial x} = 0,158 \times (1-0,158) = 0,12436$

$\frac{\partial \bar{y}_3}{\partial x} = 0,158 \times (1-0,158) = 0,12436$

$\frac{\partial \bar{y}_4}{\partial x} = 0,167 \times (1-0,167) = 0,2211$

$\frac{\partial \bar{y}_5}{\partial x} = 0,174 \times (1-0,174) = 0,1192$

$\frac{\partial \bar{y}_6}{\partial x} = 0,178 \times (1-0,178) = 0,1716$

$\frac{\partial \bar{y}_7}{\partial x} = 0,181 \times (1-0,181) = 0,1539$

$\frac{\partial \bar{y}_8}{\partial x} = 0,185 \times (1-0,185) = 0,1275$

$\frac{\partial \bar{y}_9}{\partial x} = 0,185 \times (1-0,185) = 0,1275$

$\frac{\partial \bar{y}_{10}}{\partial x} = 0,184 \times (1-0,184) = 0,1344$

$\frac{\partial \bar{y}_{11}}{\partial x} = 0,184 \times (1-0,184) = 0,1344$

$\frac{\partial \bar{y}_{12}}{\partial x} = 0,187 \times (1-0,187) = 0,1131$

$\frac{\partial \bar{y}_{13}}{\partial x} = 0,185 \times (1-0,185) = 0,1275$

$\frac{\partial \bar{y}_{14}}{\partial x} = 0,189 \times (1-0,189) = 0,0979$

$\frac{\partial \bar{y}_{15}}{\partial x} = 0,192 \times (1-0,192) = 0,0736$

$\frac{\partial \bar{y}_{16}}{\partial x} = 0,193 \times (1-0,193) = 0,0651$

→ Gradient x terhadap w_{x0}

$x = w_1 \bar{y}_1 + w_2 \bar{y}_2 + \dots + w_{16} \bar{y}_{16} + b$

$$\frac{\partial x}{\partial w_x} = \frac{\partial(\bar{y}_1 w_1 + \bar{y}_2 . w_2 + \dots + \bar{y}_{16} * w_{16} + b_0)}{\partial w_{x0}}$$

$\frac{\partial x_1}{\partial w_x} = \bar{y}_1 = 0,158$

$\frac{\partial x_2}{\partial w_2} = \bar{y}_2 = 0,158$

$\frac{\partial x_3}{\partial w_3} = \bar{y}_3 = 0,158$

$\frac{\partial x_4}{\partial w_4} = \bar{y}_4 = 0,167$

$\frac{\partial x_5}{\partial w_5} = \bar{y}_5 = 0,174$

$\frac{\partial x_6}{\partial w_6} = \bar{y}_6 = 0,178$

$\frac{\partial x_7}{\partial w_7} = \bar{y}_7 = 0,181$

$\frac{\partial x_8}{\partial w_8} = \bar{y}_8 = 0,185$

$\frac{\partial x_9}{\partial w_9} = \bar{y}_9 = 0,185$

$\frac{\partial x_{10}}{\partial_{10}} = \bar{y}_{10} = 0,184$

$\frac{\partial x_{11}}{\partial w_{11}} = \bar{y}_{11} = 0,184$

$\frac{\partial x_{12}}{w_{12}} = \bar{y}_{12} = 0,187$

$\frac{\partial x_{13}}{w_{13}} = \bar{y}_{13} = 0,185$

$\frac{\partial x_{14}}{w_{14}} = \bar{y}_{14} = 0,189$

$\frac{\partial x_{15}}{w_{15}} = \bar{y}_{15} = 0,192$

$\frac{\partial x_{16}}{w_{16}} = \bar{y}_{16} = 0,193$

→ Gradient loss terhadap weight

$$\frac{\partial Loss}{\partial w_i} = \left[\frac{\partial Loss}{\partial \bar{y}_i} \times \frac{\partial \bar{y}_i}{\partial x} \times \frac{\partial x}{\partial w_i} \right]$$

$\frac{\partial Loss}{\partial w_1} = -0,1656 \times 0,12436 \times 0,158 = -0,09$

$\frac{\partial Loss}{\partial w_2} = -0,1656 \times 0,12436 \times 0,158) = -0,09$

$\frac{\partial Loss}{\partial w_3} = -0,1656 \times 0,12436 \times 0,158 = -0,09$

$\frac{\partial Loss}{\partial w_4} = -0,1656 \times 0,12211 \times 0,167 = -0,09$

$\frac{\partial Loss}{\partial w_5} = -0,1636 \times 0,192 \times 0,174 = -0,09$

$\frac{\partial Loss}{\partial w_6} = -0,1656 \times 0,1716 \times 0,178 = -0,08$

$\frac{\partial Loss}{\partial w_7} = -0,1656 \times 0,1539 \times 0,81 = -0,08$

$\frac{\partial Loss}{\partial w_8} = -0,1656 \times 0,1275 \times 0,85 = -0,07$

$\frac{\partial Loss}{\partial w_9} = -0,1656 \times 0,1275 \times 0,85 = -0,07$

$\frac{\partial Loss}{\partial w_{10}} = -0,1656 \times 0,1344 \times 0,84 = -0,07$

$\frac{\partial Loss}{\partial w_{11}} = -0,1656 \times 0,1344 \times 0,84 = -0,07$

$\frac{\partial Loss}{\partial w_{12}} = -0,1656 \times 0,1131 \times 0,89 = -0,06$

$\frac{\partial Loss}{\partial w_{13}} = -0,1656 \times 0,1275 \times 0,85 = -0,07$

$\frac{\partial Loss}{\partial w_{14}} = -0,1656 \times 0,10979 \times 0,89 = -0,05$

$\frac{\partial Loss}{\partial w_{15}} = -0,1656 \times 0,0736 \times 0,92 = -0,04$

$\frac{\partial Loss}{\partial w_{16}} = -0,1656 \times 0,0651 \times 0,93 = -0,039$

→ Stochastic Gradient Descent (SGD) update

$w'_x = w_x - \alpha\left(\frac{\partial Loss}{\partial w_x}\right)$

$w'_1 = w_1 - 0,001(-0,09) = 1,000009$

$w'_2 = 1 - 0,001(-0,09) = 1,000009$

$w'_3 = 1 - 0,001(-0,09) = 1,000009$

$w'_4 = 1 - 0,001(-0,09) = 1,000009$

$w'_5 = 1 - 0,001(-0,09) = 1,000009$

$w'_6 = 1 - 0,001(-0,08) = 1,000008$

$w'_7 = 1 - 0,001(-0,08) = 1,000008$

$w'_8 = 1 - 0,001(-0,07) = 1,000007$

$w'_9 = 1 - 0,001(-0,07) = 1,000007$

$w'_{10} = 1 - 0,001(-0,07) = 1,000007$

$w'_{11} = 1 - 0,001(-0,07) = 1,000007$

$w'_{12} = 1 - 0,001(-0,06) = 1,000006$

$w'_{13} = 1 - 0,001(-0,06) = 1,000006$

$w'_{14} = 1 - 0,001(-0,05) = 1,000005$

$w'_{15} = 1 - 0,001(-0,04) = 1,000004$

$w'_{16} = 1 - 0,001(-0,039) = 1,000039$

2. Backward Pass (FC - Conv 2)

$$\frac{\partial loss}{\partial w_{jxi}} = \frac{\partial loss}{\partial \bar{y}_c} \times \frac{\partial \bar{w}_{ji}}{\partial x_j} \times \frac{\partial \bar{x}_j}{\partial w_{jxj}}$$

→ Gradient Loss terhadap w_{jixi}

$$\frac{\partial loss}{\partial \bar{y}_{iout}} = \left(\frac{\partial Loss}{\partial Out} \times \frac{\partial \bar{y}_i}{\partial x} \times \frac{\partial x}{\partial w_{xi}} \times \frac{\partial w_{xi}}{\partial \bar{y}_{iout}} \right)$$

$$\frac{\partial loss}{\partial \bar{y}_{iout}} = -0{,}1656 \cdot \frac{\partial loss}{\partial w_{xi}} \cdot \frac{\partial w_{xi}}{\partial y_{iout}}$$

$\frac{\partial loss}{\partial \bar{y}_{1out}} = -0{,}09 \cdot 1 = -0{,}09$

$\frac{\partial loss}{\partial \bar{y}_{2out}} = -0{,}09 \cdot 1 = -0{,}09$

$\frac{\partial loss}{\partial \bar{y}_{3out}} = -0{,}09 \cdot 1 = -0{,}09$

$\frac{\partial loss}{\partial \bar{y}_{4out}} = -0{,}09 \cdot 1 = -0{,}09$

$\frac{\partial loss}{\partial \bar{y}_{5out}} = -0{,}09 \cdot 1 = -0{,}09$

$\frac{\partial loss}{\partial \bar{y}_{6out}} = -0{,}08 \cdot 1 = -0{,}08$

$\frac{\partial loss}{\partial \bar{y}_{7out}} = -0{,}08 \cdot 1 = -0{,}08$

$\frac{\partial loss}{\partial \bar{y}_{8out}} = -0{,}07 \cdot 1 = -0{,}07$

$\frac{\partial loss}{\partial \bar{y}_{9out}} = -0{,}07 \cdot 1 = -0{,}07$

$\frac{\partial loss}{\partial \bar{y}_{10out}} = -0{,}07 \cdot 1 = -0{,}07$

$\frac{\partial loss}{\partial \bar{y}_{11out}} = -0{,}07 \cdot 1 = -0{,}07$

$\frac{\partial loss}{\partial \bar{y}_{12out}} = -0{,}06 \cdot 1 = -0{,}06$

$\frac{\partial loss}{\partial \bar{y}_{13out}} = -0{,}07 \cdot 1 = -0{,}07$

$\frac{\partial loss}{\partial \bar{y}_{14out}} = -0{,}05 \cdot 1 = -0{,}05$

$\frac{\partial loss}{\partial \bar{y}_{15out}} = -0{,}08 \cdot 1 = -0{,}04$

$\frac{\partial loss}{\partial \bar{y}_{16out}} = -0{,}039 \cdot 1 = -0{,}039$

$\frac{\partial loss}{\partial \bar{y}_{17out}} = 0 \cdot 1 = 0$

$\frac{\partial loss}{\partial b_0} = -0{,}1656 \cdot 1 \cdot 1 = -0{,}1656$

→ Gradient $\bar{y}_{1out}$ terhadap x_i:

$y_{1out} = max(0, x_{1in})$

$y_{1out} = max(0, x_{1in})$

$$\frac{\partial \bar{y}_{1out}}{\partial y_{in}} = \frac{\partial (ReLU)}{\partial j_{1in}} = \begin{cases} 1 & \bar{y}_{1in} > 0 \\ 0 & \bar{y}_{1in} = 0 \end{cases}$$

$\frac{\partial \bar{y}_{1out}}{\partial y_{in}} = 0 + max(0, 0, 1, 2) = 1$

$\frac{\partial \bar{y}_{2out}}{\partial y_{in}} = max(0, 0, 1, 3) = 1$

→ Pooling Back-propagation

0,35	0,35	0,34	0,75
1,08	1,31	1,49	1,73
1,78	1,67	1,73	1,93
1,78	2,15	2,49	2,73

→

0	0	0	0	0
0	0,35	0	0,34	0,75
0	1,08	1,31	1,49	1,73
0	1,78	1,67	1,73	1,93
0	1,78	2,15	2,49	2,73

→ Gradient $\bar{y}_{out}$ terhadap x_i :

$\bar{y}_{iout} = max(0, x_{in})$

$\frac{\partial \bar{y}_{iout}}{\partial y_{in}} = \frac{\partial (ReLu)}{\partial \bar{y}_{in}} = \begin{cases} 1, \bar{y}_{in} > 0 \\ 0, \bar{y}_{in} = 0 \end{cases}$

$\frac{\partial \bar{y}_{0out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{1out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{2out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{3out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial y_{12out}}{\partial y_{in}} = max(0,1,08) : 1$

$\frac{\partial \bar{y}_{13out}}{\partial y_{in}} = max(0,1,78) : 1$

$\frac{\partial \bar{y}_{4out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{14out}}{\partial y_{in}} = max(0,1,31) : 1$

$\frac{\partial \bar{y}_{23out}}{\partial y_{in}} = max(0,2,15) : 1$

$\frac{\partial \bar{y}_{5out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{15out}}{\partial y_{in}} = max(0,1,49) : 1$

$\frac{\partial \bar{y}_{24out}}{\partial y_{in}} = max(0,2,49) : 1$

$\frac{\partial \bar{y}_{6out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{15out}}{\partial y_{in}} = max(0,1,73) : 1$

$\frac{\partial \bar{y}_{25out}}{\partial y_{in}} = max(0,2,73) : 1$

$\frac{\partial \bar{y}_{7out}}{\partial y_{in}} = max(0,0,35) : 1$

$\frac{\partial \bar{y}_{16out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{8out}}{\partial y_{in}} = max(0,0) : 0$

$\frac{\partial \bar{y}_{17out}}{\partial y_{in}} = max(0,1,78) : 1$

$\frac{\partial \bar{y}_{9out}}{\partial y_{in}} = max(0,0,34) : 1$

$\frac{\partial \bar{y}_{18out}}{\partial y_{in}} = max(0,1,67) : 1$

$\frac{\partial y_{10out}}{\partial y_{in}} = max(0,0,75) : 1$

$\frac{\partial \bar{y}_{19out}}{\partial y_{in}} = max(0,1,73) : 1$

$\frac{\partial y_{20out}}{\partial y_{in}} = max(0,1,93) : 1$

→ Gradient loss terhadap weight.

$$\frac{\partial L}{\partial w} = \sum_{i=1}^{N} \frac{\partial L}{\partial y_i} \cdot x_i$$

Input:

2,82	2,91	2,97	3,12	3,31	3,31	2,9
1,89	1,97	2,02	2,22	2,48	2,48	2,31
1,54	1,68	1,75	1,85	1,98	1,98	1,91
1,38	1,47	1,56	1,66	1,77	1,77	1,74
1,43	1,45	1,81	1,95	2,1	2,1	2,09
1,87	1,97	2,17	2,37	2,52	2,58	2,58
2,42	2,58	2,83	3,15	3,38	3,44	3,44

$\frac{\partial L}{\partial o}$:

0	0	0	0	0
0	-0,09	0	-0,09	-0,09
0	-0,09	-0,08	-0,08	-0,07
0	-0,07	-0,07	-0,07	-0,06
0	-0,07	-0,05	-0,04	-0,039

kernel = 3 x 3

$$\frac{\partial L}{\partial w_1} = 2,82.0 + 2,91.0 + 2,97.0 + 3,12.0 + 3,31.0 + 1,89.0 + 1,97.-0,09 + 2,02.-0,09 + 2,22.-0,09 + 2,48.-0,09$$
$$0.1,54 + 1,68.-0,09 + 1,75.-0,08 + 1,85.-0,08 + 1,98.-0,07 + 1,38.0 + 1,47.-0,07 + 1,56.-0,07 + 1,66.-0,07$$
$$+ 1,77.-0,06 + 1,43.0 + -0,07.1,45 + 1,81.-0,05 + 1,95.-0,04 + 2,1.-0,039 = -3,02569 \approx -2,48259$$

$$\frac{\partial L}{\partial w_2} = 2,91.0 + 2,97.0 + 3,12.0 + 3,31.0 + 3,31.0 + 1,97.0 + 2,02.-0,09 + 2,22.0 + 2,48.-0,09 + 2,48.-0,09$$
$$1,68.0 + 1,75.-0,09 + 1,85.-0,08 + 1,98.-0,08 + 1,98.-0,07 + 1,47.0 + 1,56.-0,07 + 1,66.-0,07 +$$
$$1,77.-0,07 + 1,77.-0,06 + 1,45.-0,07 + 1,81.-0,07 + 1,95.-0,05 + -0,04.2,1 + 2,1.-0,039 = -2,10799$$

$$\frac{\partial L}{\partial w_3} = 2,97.0 + 3,12.0 + 3,31.0 + 3,31.0 + 2,9.0 + 2,02.0 + 2,22.-0,09 + 2,48.0 + 2,48.-0,09 + 2,31.-0,09$$
$$1,75.0 + 1,85.-0,09 + 1,98.-0,08 + 1,98.-0,08 + 1,91.-0,07 + 1,56.0 + 1,66.-0,07 +$$
$$+ 1,77.-0,07 + 1,77.-0,07 + 1,74.0 + 1,85.0 + -0,07.1,95 + 2,1.-0,05 + 2,1.-0,04 + 2,09.-0,039$$
$$= -2,11233$$

$$\frac{\partial L}{\partial w_4} = 1,89.0 + 1,97.0 + 2,02.0 + 2,22.0 + 2,48.0 + 1,54.0 + 1,68.-0,09 + 1,75.0 + 1,85.-0,09 + 1,98.-0,09$$
$$1,38.0 + 1,47.-0,09 + 1,56.-0,08 + 1,66.-0,08 + 1,77.-0,07 + 1,43.0 + 1,45.-0,07 + 1,81.-0,07$$
$$+ 1,95.-0,07 + 2,1.-0,06 + 1,87.0 + 1,97.-0,07 + 2,17.-0,05 + 2,37.-0,04 + 2,52.-0,039 = -1,939$$

$$\frac{\partial L}{\partial w_5} = 1,97.0 + 2,02.0 + 2,22.0 + 2,48.0 + 2,48.0 + 1,68.0 + 1,75.-0,09 + 1,85.0 + 1,98.-0,09 + 1,98.-0,09$$
$$1,47.0 + 1,56.-0,09 + 1,66.-0,08 + 1,77.-0,08 + 1,77.-0,07 + 1,45.0 + 1,81.-0,07 + 1,95.-0,07$$
$$2,1.-0,07 + 2,1.-0,06 + 1,97.0 + 2,17.-0,07 + 2,37.-0,05 + 2,52.-0,04 + 2,58.-0,39 = -2,09609$$

$$\frac{\partial L}{\partial w_6} = 2,02.0 + 2,22.0 + 2,48.0 + 2,48.0 + 2,31.0 + 1,75.0 + 1,85.-0,09 + 1,98.0 + 1,98.-0,09 + 1,91.-0,09$$
$$1,56.0 + 1,66.-0,09 + 1,77.-0,08 + 1,77.-0,08 + 1,74.-0,07 + 1,85.0 + 1,95.-0,07 + 2,1.-0,07$$
$$2,1.-0,07 + 2,09.-0,06 + 2,17.0 + 2,37.-0,07 + 2,52.-0,05 + 2,58.-0,04 + 2,58.-0,039 = -2,11226$$

$\frac{\partial L}{\partial w_7}$ = 1,54.0 + 1,68.0+1,75.0 + 1,85.0 + 1,98.0 + 1,38.0 + 1,47.-0,09 +1,56.0 + 1,66. -0,09+1,77. -0,09
1,43.0 + 1,45:0,09 + 1,81.-0,08 + 1,95. -0,08 + 2,1. -0,07 + 1,81.0 + 1,97.-0,07 + 2,17.-0,07
2,37. -0,07 + 2,52. -0,06 + 2,42.0 + 2,58. -0,07 + 2,83.-0,05 + 3,15.-0,04 + 3,38.-0,039 = -2,20612

$\frac{\partial L}{\partial w_8}$ = 1,68.0 + 1,75.0 + 1,85.0 + 1,98.0 + 1,98.0 + 1,47.0 + 1,56.-0,09 + 1,66.0 + 1,77.-0,09 + 1,77.-0,09
1,45.0 + 1,81.-0,09 + 1,95.-0,08 + 2,1.-0,08 + 2,1.-0,07 + 1,97.0 + 2,17.-0,07 + 2,37.-0,07
2,52.-0,07 + 2,58.-0,06 + 2,58.0 + 2,83.-0,07 + 3,15.-0,05 + 3,38.-0,04 + 3,44.-0,039 = -2,366

$\frac{\partial L}{\partial w_9}$ = 1,75.0 + 1,85.0 + 1,98.0 + 1,98.0 + 1,91.0 + 1,56.0 + -0,09.1,60 + 1,77.0 + 1,77.-0,09 + 1,74.-0,09
1,81.0 + 1,95.-0,09 + 2,1.-0,08 + 2,1.-0,08 + 2,09.-0,07 + 0.2,17 + 2,37.-0,07 + 2,52.-0,07
2,58.-0,07 + 2,58.-0,06 + 2,83.0 + 3,15.-0,07 + 3,38.-0,05 + 3,44.-0,04 + 3,44.-0,039 = -2,462

→ Stochastic Gradient Descent (SGD) update

$w'_x = w_x - \alpha\left(\frac{\partial Loss}{\partial w_x}\right)$

w'_1 = 1 - 0,001(-2,4259) = ~~1,0024259~~ 1,0024259

w'_2 = 0 - 0,001(-2,0799) = 0,0020799

w'_3 = -1 - 0,001(-2,1233) = -0,9978767

w'_4 = -1 - 0,001($-\frac{1,939}{2,1226}$) = ~~-0,9978224~~ -0,998061

w'_5 = -1 - 0,001(-2,0606) = -0,9979

w'_6 = 0 - 0,001(-2,1226) = 0,0021226

w'_7 = 1 - 0,001(-2,20612) = 1,0022061 2

w'_8 = 1 - 0,001(-2,3668) = 1,0023668

w'_9 = 0 - 0,001(-2,462) = 0,0024622

b'_0 = 1 - 0,001(-0,1656) = 1,0000656

-) Gradient loss terhadap x_i

$$\frac{\partial L}{\partial x_i} = \sum \frac{\partial L}{\partial y_i} \cdot \frac{\partial y_i}{\partial x_i}$$

$\frac{\partial L}{\partial y_i}$:

-0,039	-0,039	-0,039	-0,039
-0,039	-0,038	-0,038	-0,037
-0,037	-0,037	-0,037	-0,036
-0,037	-0,035	-0,034	-0,033

$\frac{\partial y}{\partial x_i}$ (180°) :

1	1	1	1	0
1	1	1	1	0
1	1	1	1	0
1	1	0	1	0
0	0	0	0	0

$\frac{\partial L}{\partial x_m} = 1+0+1.0+1.0+1.0+1.0+0.0+1.0+1.0+1.0+1.0+0.0+1.0+1.0+1.0+0.0+1.0+1.0+0.0+1.0+0.0+0.0+0.0+0.0+0.0+0.0+0.0+0.0+0.0 = 0$

$\frac{\partial L}{\partial x_{11}} = -0,039 . 1 = -0,039$

$\frac{\partial L}{\partial x_{12}} = -0,04 . 1 + -0,039 . 1 = -0,079$

$\frac{\partial L}{\partial x_{13}} = -0,05 . 1 + -0,04 . 1 + -0,039 . 1 = -0,129$

$\frac{\partial L}{\partial x_{14}} = -0,07 . 1 + -0,05 . 1 + -0,04 . 1 + 1 . -0,039 = -0,199$

$\frac{\partial L}{\partial x_{15}} = -0,07 . 1 + -0,05 . 1 + 1 . -0,04 + 0 . -0,039 = -0,16$

$\frac{\partial L}{\partial x_{16}} = -0,07 . 1 + -0,05 . 1 + 0 . -0,04 = -0,12$

$\frac{\partial L}{\partial x_{17}} = -0,07 . 1 + -0,05 . 0 = -0,07$

$\frac{\partial L}{\partial x_{18}} = -0,07 . 0 = 0$

$\frac{\partial L}{\partial x_{21}} = -0,06 . 1 + -0,039 . 1 = -0,096$

$\frac{\partial L}{\partial x_{22}} = -0,07 . 1 + -0,06 . 1 + 1 . -0,04 + 1 . -0,039 = -0,209$

$\frac{\partial L}{\partial x_{23}} = -0,07 . 1 + 1 . -0,07 + 1 . -0,06 + 1 . -0,05 + 1 . -0,04 + 1 . -0,039 = -0,329$

$\frac{\partial L}{\partial x_{24}} = -0,07 . 1 + 1 . -0,07 + 1 . -0,07 + 1 . -0,06 + 1 . -0,07 + 1 . -0,05 + 1 . -0,04 + 1 . -0,039 = -0,469$

$\frac{\partial L}{\partial x_{25}} = -0,07 . 1 + 1 . -0,07 + 1 . -0,07 + 0 . -0,06 + 1 . -0,07 + 1 . -0,05 + 1 . -0,04 + 0 . -0,039 = -0,37$

$\frac{\partial L}{\partial x_{26}} = -0,07 . 1 + 1 . -0,07 + 0 . -0,07 + 1 . -0,07 + 1 . -0,05 + 0 . -0,04 = -0,26$

$\frac{\partial L}{\partial x_{27}} = -0,07.1 + 1.-0,07 = -0,14$

$\frac{\partial L}{\partial x_{28}} = -0,07.0 + 0.-0,07 = 0$

$\frac{\partial L}{\partial x_{31}} = -0,07.1 + 0,06.1 + 1.-0,039 = -0,159$

$\frac{\partial L}{\partial x_{32}} = -0,08.1 + -0,07.1 + -0,07.1 + 1.-0,06 + 1.-0,09 + 1.-0,039 = -0,359$

$\frac{\partial L}{\partial x_{33}} = -0,08.1 + 1.-0,08 + 1.-0,07 + 1.-0,07 + 1.-0,06 + 1.-0,05 + 1.-0,04 + 1.-0,039 = -0,559$

$\frac{\partial L}{\partial x_{34}} = -0,09.1 + 1.-0,08 + 1.-0,08 + 1.-0,07 + 1.-0,07 + 1.-0,07 + 1.-0,06 + 1.-0,07 + 1.-0,05 + 1.-0,04 + 1.-0,039 = -0,789$

$\frac{\partial L}{\partial x_{35}} = -0,09.1 + 1.-0,08 + 1.-0,08 + 0.-0,07 + 1.-0,07 + 1.-0,07 + 0.-0,06 + 1.-0,07 + 1.-0,05 + 1.-0,04 + 0.-0,039 = -0,62$

$\frac{\partial L}{\partial x_{36}} = -0,09.1 + -0,08.1 + 0.-0,08 + 1.-0,07 + 1.-0,07 + 0.-0,07 + 1.-0,07 + 1.-0,05 + 1.-0,04 = -0,43$

$\frac{\partial L}{\partial x_{37}} = -0,09.1.1 + 0.-0,08 + 1.-0,07 + 0.-0,07 + 0,07.1 + 0.-0,05 = -0,23$

$\frac{\partial L}{\partial x_{38}} = -0,09.0 + 0.-0,07 + 0.-0,07 = 0$

$\frac{\partial L}{\partial x_{41}} = -0,09.1 + 1.-0,07 + 1.-0,06 + 1.-0,039 = -0,259$

$\frac{\partial L}{\partial x_{42}} = -0,09.1 + 1.-0,09 + 1.-0,08 + 1.-0,07 + 1.-0,07 + 1.-0,06 + 1.-0,04 + 1.-0,039 = -0,539$

$\frac{\partial L}{\partial x_{43}} = -0,09.1 + 1.-0,09 + 1.-0,09 + 1.-0,08 + 1.-0,07 + 1.-0,05 + 1.-0,04 + 0.-0,039 = -0,79$

$\frac{\partial L}{\partial x_{44}} = -0,09.1 + 1.-0,09 + 1.-0,09 + 1.-0,09 + 1.-0,08 + 1.-0,08 + 1.-0,07 + 1.-0,07 + 1.-0,07 + 1.-0,07 + 1.-0,06 + 1.-0,07 + 1.-0,05 + 0.-0,04 + 1.-0,039 = -1,109$

$\frac{\partial L}{\partial x_{45}} = -0,09.1 + 1.-0,09 + 1.-0,09 + 0.-0,09 + 1.-0,09 + 1.-0,08 + 1.-0,08 + 0.-0,07 + 1.-0,07 + 1.-0,07 + 1.-0,07 + 0.-0,06 + 1.-0,07 + 0.-0,05 + 1.-0,04 + 0.-0,039 = -0,84$

$\frac{\partial L}{\partial x_{46}} = -0,09.1 + 1.-0,09 + 0.-0,09 + 1.-0,09 + 1.-0,08 + 0.-0,08 + 1.-0,07 + 1.-0,07 + 0.-0,07 + 0.-0,07 + 1.-0,05 + 0.-0,04 = -0,46$

$\frac{\partial L}{\partial x_{47}} = -0,09.1 + 0.-0,09 + 1.-0,09 + 0.-0,08 + 1.-0,07 + 0.-0,07 + 1.-0,07 + 0.-0,05 = -0,32$

$\frac{\partial L}{\partial x_{48}} = -0,09.0 + 0.-0,09 + 0.-0,07 + 0.-0,07 = 0$

$\frac{\partial L}{\partial x_{51}} = -0,09.1 + 1.-0,07 + 1.-0,06 + -0,039.0 = -0,22$

$\frac{\partial L}{\partial x_{52}} = -0,09.1 + 1.-0,09 + 1.-0,08 + 1.-0,07 + 1.-0,07 + 1.-0,06 + 0.-0,04 + 0.-0,039 = -0,46$

$$\frac{\partial L}{\partial x_{53}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}08 + 1 \cdot -0{,}08 + 1 \cdot -0{,}07 + 1 \cdot -0{,}07 + 1 \cdot -0{,}07 + 0 \cdot -0{,}06 + -0{,}05 \cdot 0 + 0 \cdot -0{,}04 + 0 \cdot -0{,}039 = -0{,}65$$

$$\frac{\partial L}{\partial x_{54}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}09 + 1 \cdot -0{,}08 + 1 \cdot -0{,}08 + 1 \cdot -0{,}07 + 1 \cdot -0{,}07 + 1 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 + 0 \cdot -0{,}05 + 0 \cdot -0{,}04 + 0 \cdot -0{,}039 = -0{,}88$$

$$\frac{\partial L}{\partial x_{55}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}09 + 1 \cdot -0{,}08 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 1 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 + 0 \cdot -0{,}05 + 0 \cdot -0{,}04 + 0 \cdot -0{,}039 = -0{,}86$$

$$\frac{\partial L}{\partial x_{56}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 1 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 + 0 \cdot -0{,}05 + 0 \cdot -0{,}04 = -0{,}42$$

$$\frac{\partial L}{\partial x_{57}} = -0{,}09 \cdot 1 + 0 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}25$$

$$\frac{\partial L}{\partial x_{58}} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 = 0$$

$$\frac{\partial L}{\partial x_{61}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}16$$

$$\frac{\partial L}{\partial x_{62}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}08 + 1 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}33$$

$$\frac{\partial L}{\partial x_{63}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}08 + 1 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}43$$

$$\frac{\partial L}{\partial x_{64}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}60$$

$$\frac{\partial L}{\partial x_{65}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 0 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}06 = -0{,}44$$

$$\frac{\partial L}{\partial x_{66}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 0 \cdot -0{,}09 + 1 \cdot -0{,}08 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 = -0{,}26$$

$$\frac{\partial L}{\partial x_{67}} = -0{,}09 \cdot 1 + 0 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 + 0 \cdot -0{,}07 = -0{,}18$$

$$\frac{\partial L}{\partial x_{68}} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}07 = 0$$

$$\frac{\partial L}{\partial x_{71}} = -0{,}09 \cdot 1 + 0 \cdot -0{,}07 = -0{,}09$$

$$\frac{\partial L}{\partial x_{72}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 = -0{,}18$$

$$\frac{\partial L}{\partial x_{73}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 = -0{,}18$$

$$\frac{\partial L}{\partial x_{74}} = -0{,}09 \cdot 1 + 1 \cdot -0{,}09 + 0 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 = -0{,}27$$

$$\frac{\partial L}{\partial x_{75}} = -0{,}09 \cdot 1 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 1 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}07 = -0{,}18$$

$$\frac{\partial f}{\partial x_{16}} = -0{,}09 \cdot 0 + 1 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = -0{,}09$$

$$\frac{\partial f}{\partial x_{11}} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}08 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 1 \cdot -0{,}09 = -0{,}09$$

$$\frac{\partial f}{\partial x_8} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_1} = -0{,}09 \cdot 0 = 0$$

$$\frac{\partial f}{\partial x_2} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 = -0 \Rightarrow$$

$$\frac{\partial f}{\partial x_3} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_4} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_5} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_9} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_7} = -0{,}09 \cdot 0 + 0 \cdot -0{,}09 = 0$$

$$\frac{\partial f}{\partial x_8} = -0{,}09 \cdot 0 = 0$$

$$\frac{\partial f}{\partial x} =$$

0	0	0	0	0	0	0	0
-0,09	-0,18	-0,18	-0,27	-0,18	-0,09	-0,18	0
-0,18	-0,33	-0,43	-0,61	-0,44	-0,26	-0,18	0
-0,22	-0,46	-0,59	-0,88	-0,68	-0,42	-0,25	0
-0,32	-0,53	-0,67	-0,98	-0,84	-0,46	-0,32	0
-0,51	-0,85	-0,65	-0,89	-0,62	-0,43	-0,23	0
-0,36	-0,90	-0,82	-0,69	-0,37	-0,26	-0,14	0
-0,60	-0,79	-0,61	-0,91	-0,44	-0,21	-0,08	0

$\frac{\partial L}{\partial x_i}$ =

0	0	0	0	0	0	0
0	-0,09	0	-0,18	-0,18	-0,09	-0,18
0	-0,18	-0,17	-0,35	-0,42	-0,34	-0,33
0	-0,25	-0,33	-0,57	-0,79	-0,55	-0,46
0	-0,32	-0,47	-0,75	-1,019	-0,70	-0,539
0	-0,23	-0,43	-0,62	-0,789	-0,559	-0,353
0	-0,14	-0,26	-0,36	-0,469	-0,329	-0,209

3. Backward Pass (Conv2 - Conv1)

$$\frac{\partial Loss}{\partial w_{jxc}} = \frac{\partial Loss}{\partial \bar{y}_i} \times \frac{\partial \bar{y}_i}{\partial \bar{x}_i} \times \frac{d\bar{x}_i}{\partial w_{jxs}}$$

-) Pooling Backpropagation

2,82	2,91	2,97	3,72	3,31	3,31	2,9
1,89	1,97	2,02	2,22	2,48	2,48	2,31
1,54	1,67	1,75	1,85	1,98	1,98	1,91
1,38	1,47	1,56	1,66	1,77	1,77	1,74
1,43	1,45	1,81	1,95	2,1	2,1	2,09
1,87	1,97	2,17	2,37	2,52	2,58	2,58
2,42	2,58	2,83	3,15	3,38	3,44	3,44

0	2,82	2,91	2,97	3,12	3,31	0	2,9
0	1,89	1,97	2,02	2,22	2,48	0	2,31
0	1,54	1,68	1,75	1,85	1,98	0	1,91
0	1,38	1,47	1,56	1,64	1,77	0	1,74
0	1,43	1,45	1,81	1,95	2,1	0	2,09
0	0	0	0	0	0	0	0
0	1,87	1,97	2,17	2,37	2,52	2,58	0
0	2,42	2,58	2,83	3,15	3,38	3,44	0

→ Gradient $\bar{y}_{out}$ terhadap x_i :

$\bar{y}_{i\,out} = \max(0, x_{in})$

$\frac{\partial \bar{y}_{i\,out}}{\partial y_{in}} = \frac{\partial (ReLU)}{\partial \bar{y}_{in}} = \begin{cases} 1, \bar{y}_{in} > 0 \\ 0, \bar{y}_{in} = 0 \end{cases}$

$\frac{\partial \bar{y}_{1\,out}}{\partial y_{in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{2\,out}}{\partial z_{in}} = \max(0,2,82) = 1$

$\frac{\partial \bar{y}_{3\,out}}{\partial z_{in}} = \max(0,2,81) = 1$

$\frac{\partial \bar{y}_{4\,out}}{\partial z_{in}} = \max(0,2,97) = 1$

$\frac{\partial \bar{y}_{5\,out}}{\partial y_{5in}} = \max(0,3,12) = 1$

$\frac{\partial \bar{y}_{6\,out}}{\partial y_{6in}} = \max(0,3,31) = 1$

$\frac{\partial \bar{y}_{7\,out}}{\partial y_{7in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{8\,out}}{\partial y_{8in}} = \max(0,2,9) = 1$

$\frac{\partial \bar{y}_{9\,out}}{\partial y_{9in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{10\,out}}{\partial y_{10in}} = \max(0,1,89) = 1$

$\frac{\partial \bar{y}_{11\,out}}{\partial y_{11in}} = \max(0,1,97) = 1$

$\frac{\partial \bar{y}_{12\,out}}{\partial y_{12in}} = \max(0,2,02) = 1$

$\frac{\partial \bar{y}_{13\,out}}{\partial y_{13in}} = \max(0,2,22) = 1$

$\frac{\partial \bar{y}_{14\,out}}{\partial y_{14in}} = \max(0,2,48) = 1$

$\frac{\partial \bar{y}_{15\,out}}{\partial y_{15in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{16\,out}}{\partial y_{16in}} = \max(0,2,31) = 1$

$\frac{\partial \bar{y}_{17\,out}}{\partial z_{17in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{18\,out}}{\partial y_{18in}} = \max(0,1,54) = 1$

$\frac{\partial \bar{y}_{19\,out}}{\partial y_{19in}} = \max(0,1,68) = 1$

$\frac{\partial \bar{y}_{20\,out}}{\partial y_{20in}} = \max(0,1,75) = 1$

$\frac{\partial \bar{y}_{21\,out}}{\partial y_{21in}} = \max(0,1,85) = 1$

$\frac{\partial \bar{y}_{22\,out}}{\partial y_{22in}} = \max(0,1,98) = 1$

$\frac{\partial \bar{y}_{23\,out}}{\partial y_{23in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{24\,out}}{\partial y_{24in}} = \max(0,1,91) = 1$

$\frac{\partial \bar{y}_{25\,out}}{\partial y_{25in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{26\,out}}{\partial y_{26in}} = \max(0,1,38) = 1$

$\frac{\partial \bar{y}_{27\,out}}{\partial y_{27in}} = \max(0,1,47) = 1$

$\frac{\partial \bar{y}_{28\,out}}{\partial y_{28in}} = \max(0,1,56) = 1$

$\frac{\partial \bar{y}_{29\,out}}{\partial y_{29in}} = \max(0,1,64) = 1$

$\frac{\partial \bar{y}_{30\,out}}{\partial y_{30in}} = \max(0,1,77) = 1$

$\frac{\partial \bar{y}_{31\,out}}{\partial y_{31in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{32\,out}}{\partial y_{32in}} = \max(0,1,74) = 1$

$\frac{\partial \bar{y}_{33\,out}}{\partial y_{33in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{34\,out}}{\partial y_{34in}} = \max(0,1,43) = 1$

$\frac{\partial \bar{y}_{35\,out}}{\partial y_{35in}} = \max(0,1,45) = 1$

$\frac{\partial \bar{y}_{36\,out}}{\partial y_{36in}} = \max(0,1,81) = 1$

$\frac{\partial \bar{y}_{37\,out}}{\partial y_{37in}} = \max(0,1,95) = 1$

$\frac{\partial \bar{y}_{38\,out}}{\partial y_{38in}} = \max(0,2,1) = 1$

$\frac{\partial \bar{y}_{39\,out}}{\partial y_{39in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{40\,out}}{\partial y_{40in}} = \max(0,2,09) = 1$

$\frac{\partial \bar{y}_{41\,out}}{\partial y_{41in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{42\,out}}{\partial y_{42in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{43\,out}}{\partial y_{43in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{44\,out}}{\partial y_{44in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{45\,out}}{\partial y_{45in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{46\,out}}{\partial y_{46in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{47\,out}}{\partial y_{47in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{48\,out}}{\partial y_{48in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{30out}}{\partial y_{30in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{31out}}{\partial y_{31in}} = \max(0,1,87) = 1$

$\frac{\partial \bar{y}_{32out}}{\partial y_{32in}} = \max(0,1,97) = 1$

$\frac{\partial \bar{y}_{33out}}{\partial y_{33in}} = \max(0,2,17) = 1$

$\frac{\partial \bar{y}_{34out}}{\partial y_{34in}} = \max(0,2,37) = 1$

$\frac{\partial \bar{y}_{35out}}{\partial y_{35in}} = \max(0,2,52) = 1$

$\frac{\partial \bar{y}_{36out}}{\partial y_{36in}} = \max(0,2,58) = 1$

$\frac{\partial \bar{y}_{37out}}{\partial y_{37in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{38out}}{\partial y_{38in}} = \max(0,0) = 0$

$\frac{\partial \bar{y}_{39out}}{\partial y_{39in}} = \max(0,2,42) = 1$

$\frac{\partial \bar{y}_{40out}}{\partial y_{40in}} = \max(0,2,58) = 1$

$\frac{\partial \bar{y}_{41out}}{\partial y_{41in}} = \max(0,2,83) = 1$

$\frac{\partial \bar{y}_{42out}}{\partial y_{42in}} = \max(0,3,15) = 1$

$\frac{\partial \bar{y}_{43out}}{\partial y_{43in}} = \max(0,3,38) = 1$

$\frac{\partial \bar{y}_{44out}}{\partial y_{44in}} = \max(0,3,54) = 1$

$\frac{\partial \bar{y}_{xxout}}{\partial y_{xxin}} = \max(0,0) = 0$

→ Gradient loss terhadap weight

$$\frac{\partial L}{\partial w} = \sum_{i=1}^{N} \frac{\partial L}{\partial y_i} \cdot x_i$$

0,54	0,55	0,62	0,63	0,63	0,65	0,70	0,72	0,68	0,66
0,36	0,37	0,41	0,39	0,41	0,42	0,49	0,47	0,45	0,47
0,20	0,21	0,25	0,24	0,25	0,29	0,37	0,38	0,35	0,36
0,07	0,09	0,12	0,15	0,17	0,21	0,31	0,25	0,19	0,20
0,05	0,07	0,09	0,12	0,16	0,18	0,21	0,17	0,12	0,13
0,04	0,06	0,09	0,11	0,12	0,13	0,16	0,15	0,13	0,14
0,04	0,06	0,09	0,11	0,14	0,15	0,22	0,21	0,17	0,21
0,07	0,10	0,13	0,15	0,25	0,31	0,37	0,38	0,34	0,36
0,2	0,23	0,33	0,35	0,38	0,43	0,49	0,51	0,47	0,46
0,33	0,36	0,48	0,51	0,59	0,71	0,76	0,82	0,74	0,73

-0,639	-0,079	-0,129	-0,198	-0,16	-0,12	-0,07	0
-0,106	-0,206	-0,329	-0,469	-0,37	-0,26	-0,14	0
-0,159	-0,359	-0,539	-0,789	-0,62	-0,43	-0,23	0
-0,259	-0,539	-0,79	-1,109	-0,84	-0,46	-0,32	0
-0,22	-0,46	-0,65	-0,88	-0,68	-0,42	-0,25	0
-0,16	-0,33	-0,43	-0,60	-0,44	-0,26	-0,18	0
-0,09	-0,18	-0,18	-0,27	-0,18	-0,09	-0,09	0
0	0	0	0	0	0	0	0

$$\frac{\partial L}{\partial w_1} = 0{,}54 \cdot -0{,}039 + 0{,}55 \cdot -0{,}079 + 0{,}62 \cdot -0{,}129 + 0{,}63 \cdot -0{,}199 + 0{,}63 \cdot -0{,}16 + 0{,}65 \cdot -0{,}112 + 0{,}70 \cdot -0{,}107 + 0 + 0{,}72 +$$
$$0{,}36 \cdot -0{,}096 + 0{,}37 \cdot -0{,}206 + 0{,}41 \cdot -0{,}329 + 0{,}39 \cdot -0{,}469 + 0{,}41 \cdot -0{,}37 + 0{,}42 \cdot -0{,}26 + 0{,}49 \cdot -0{,}141 + 0{,}47 \cdot 0 +$$
$$0{,}20 \cdot -0{,}159 + 0{,}21 \cdot -0{,}359 + 0{,}25 \cdot -0{,}559 + 0{,}24 \cdot -0{,}789 + 0{,}25 \cdot -0{,}62 + 0{,}29 \cdot -0{,}143 + 0{,}37 \cdot -0{,}23 + 0{,}38 \cdot 0 +$$
$$0{,}07 \cdot -0{,}259 + 0{,}09 \cdot -0{,}539 + 0{,}12 \cdot -0{,}79 + 0{,}15 \cdot -1{,}109 + 0{,}17 \cdot -0{,}84 + 0{,}21 \cdot -0{,}46 + 0{,}31 \cdot -0{,}32 + 0{,}25 \cdot 0 +$$
$$0{,}05 \cdot -0{,}22 + 0{,}07 \cdot -0{,}46 + 0{,}09 \cdot -0{,}65 + 0{,}12 \cdot -0{,}88 + 0{,}16 \cdot -0{,}68 + 0{,}18 \cdot -0{,}42 + 0{,}21 \cdot -0{,}25 + 0{,}0 \cdot 0{,}17 +$$
$$0{,}04 \cdot -0{,}16 + 0{,}06 \cdot -0{,}33 + 0{,}09 \cdot -0{,}43 + 0{,}11 \cdot -0{,}60 + 0{,}12 \cdot -0{,}44 + 0{,}13 + -0{,}26 + 0{,}16 \cdot -0{,}18 + 0{,}15 \cdot 0 +$$
$$0{,}04 \cdot -0{,}09 + 0{,}06 \cdot -0{,}88 + 0{,}09 \cdot -0{,}18 + 0{,}11 \cdot -0{,}27 + 0{,}14 + -0{,}18 + 0{,}15 \cdot -0{,}09 + 0{,}22 \cdot -0{,}09 + 0{,}21 \cdot 0 +$$
$$0{,}07 \cdot 0 + 0{,}10 \cdot 0 + 0{,}13 \cdot 0 + 0{,}15 \cdot 0 + 0{,}25 \cdot 0 + 0{,}31 \cdot 0 + 0{,}37 \cdot 0 + 0{,}38 \cdot 0 = -3{,}153302 = -3{,}428845142$$

$$\frac{\partial L}{\partial w_2} = 0{,}55 \cdot -0{,}039 + 0{,}62 \cdot -0{,}079 + 0{,}63 \cdot -0{,}129 + 0{,}63 \cdot -0{,}199 + 0{,}65 \cdot -0{,}16 + 0{,}70 \cdot -0{,}12 + 0{,}72 \cdot -0{,}07 + 0{,}68 \cdot 0 +$$
$$0{,}37 \cdot -0{,}096 + 0{,}41 \cdot -0{,}206 + 0{,}39 \cdot -0{,}329 + 0{,}41 \cdot -0{,}469 + 0{,}42 \cdot -0{,}37 + 0{,}49 \cdot -0{,}26 + 0{,}47 \cdot -0{,}14 + 0{,}45 \cdot 0 +$$
$$0{,}21 \cdot -0{,}159 + 0{,}25 \cdot -0{,}359 + 0{,}24 \cdot -0{,}559 + 0{,}25 \cdot -0{,}789 + 0{,}29 \cdot -0{,}62 + 0{,}37 \cdot -0{,}43 + 0{,}38 \cdot -0{,}23 + 0{,}35 \cdot 0 +$$
$$0{,}09 \cdot -0{,}259 + 0{,}12 \cdot -0{,}539 + 0{,}15 \cdot -0{,}79 + 0{,}17 \cdot -1{,}109 + 0{,}21 \cdot -0{,}84 + 0{,}31 \cdot -0{,}46 + 0{,}25 \cdot -0{,}32 + 0{,}19 \cdot 0 +$$
$$0{,}07 \cdot -0{,}22 + 0{,}09 \cdot -0{,}46 + 0{,}12 \cdot -0{,}65 + 0{,}16 \cdot -0{,}88 + 0{,}18 \cdot -0{,}68 + 0{,}21 \cdot -0{,}42 + 0{,}17 \cdot -0{,}25 + 0{,}12 \cdot 0 +$$
$$0{,}06 \cdot -0{,}16 + 0{,}09 \cdot -0{,}33 + 0{,}11 \cdot -0{,}43 + 0{,}12 \cdot -0{,}60 + 0{,}13 \cdot -0{,}44 + 0{,}16 \cdot -0{,}26 + 0{,}15 \cdot -0{,}18 + 0{,}13 \cdot 0 +$$
$$0{,}06 \cdot -0{,}09 + 0{,}09 \cdot -0{,}18 + 0{,}11 \cdot -0{,}18 + 0{,}14 \cdot -0{,}27 + 0{,}15 \cdot -0{,}18 + 0{,}22 \cdot -0{,}09 + 0{,}21 \cdot -0{,}09 + 0{,}17 \cdot 0 +$$
$$0{,}10 \cdot 0 + 0{,}13 \cdot 0 + 0{,}15 \cdot 0 + 0{,}25 \cdot 0 + 0{,}31 \cdot 0 + 0{,}37 \cdot 0 + 0{,}38 \cdot 0 + 0{,}34 \cdot 0 = -3{,}089792 - 3{,}93092$$

$$\frac{\partial L}{\partial w_3} = 0{,}62 \cdot -0{,}039 + 0{,}63 \cdot -0{,}079 + 0{,}63 \cdot -0{,}129 + 0{,}65 \cdot -0{,}199 + 0{,}70 \cdot -0{,}16 + 0{,}72 \cdot -0{,}112 + 0{,}68 \cdot -0{,}107 + 0{,}66 \cdot 0 +$$
$$0{,}41 \cdot -0{,}096 + 0{,}39 \cdot -0{,}206 + 0{,}41 \cdot -0{,}329 + 0{,}42 \cdot -0{,}469 + 0{,}49 \cdot -0{,}37 + 0{,}47 \cdot -0{,}26 + 0{,}45 \cdot -0{,}14 + 0{,}47 \cdot 0 +$$
$$0{,}25 \cdot -0{,}159 + 0{,}24 \cdot -0{,}359 + 0{,}25 \cdot -0{,}559 + 0{,}29 \cdot -0{,}789 + 0{,}37 \cdot -0{,}62 + 0{,}38 \cdot -0{,}43 + 0{,}35 \cdot -0{,}23 + 0{,}36 \cdot 0 +$$
$$0{,}12 \cdot -0{,}259 + 0{,}15 \cdot -0{,}539 + 0{,}17 \cdot -0{,}79 + 0{,}21 \cdot -1{,}109 + 0{,}31 \cdot -0{,}84 + 0{,}25 \cdot -0{,}46 + 0{,}19 \cdot -0{,}32 + 0{,}20 \cdot 0 +$$
$$0{,}09 \cdot -0{,}22 + 0{,}12 \cdot -0{,}46 + 0{,}16 \cdot -0{,}65 + 0{,}18 \cdot -0{,}88 + 0{,}21 \cdot -0{,}68 + 0{,}17 \cdot -0{,}42 + 0{,}12 \cdot -0{,}25 + 0{,}13 \cdot 0 +$$
$$0{,}09 \cdot -0{,}16 + 0{,}11 \cdot -0{,}33 + 0{,}12 \cdot -0{,}43 + 0{,}13 \cdot -0{,}60 + 0{,}16 \cdot -0{,}44 + 0{,}15 \cdot -0{,}26 + 0{,}13 \cdot -0{,}18 + 0{,}14 \cdot 0 +$$
$$0{,}09 \cdot -0{,}09 + 0{,}11 \cdot -0{,}18 + 0{,}14 \cdot -0{,}18 + 0{,}15 \cdot -0{,}27 + 0{,}22 \cdot -0{,}18 + 0{,}21 \cdot -0{,}09 + 0{,}17 \cdot -0{,}09 + 0{,}21 \cdot 0 +$$
$$0{,}13 \cdot 0 + 0{,}15 \cdot 0 + 0{,}25 \cdot 0 + 0{,}31 \cdot 0 + 0{,}37 \cdot 0 + 0{,}38 \cdot 0 + 0{,}34 \cdot 0 + 0{,}36 \cdot 0 = -4{,}264343 - 4{,}27583$$

$$\frac{\partial L}{\partial w_4} = 0{,}36 + 0{,}039 + 0{,}37 \cdot -0{,}079 + 0{,}41 \cdot -0{,}129 + 0{,}39 \cdot -0{,}199 + 0{,}41 \cdot -0{,}16 + 0{,}42 \cdot -0{,}112 + 0{,}49 \cdot -0{,}107 + 0{,}47 \cdot 0 +$$
$$0{,}20 \cdot -0{,}096 + 0{,}21 \cdot -0{,}206 + 0{,}25 \cdot -0{,}329 + 0{,}24 \cdot -0{,}469 + 0{,}25 \cdot -0{,}37 + 0{,}29 \cdot -0{,}26 + 0{,}37 \cdot -0{,}14 + 0{,}38 \cdot 0 +$$
$$0{,}07 \cdot -0{,}159 + 0{,}09 \cdot -0{,}359 + 0{,}12 \cdot -0{,}559 + 0{,}15 \cdot -0{,}789 + 0{,}17 \cdot -0{,}62 + 0{,}21 \cdot -0{,}43 + 0{,}31 \cdot -0{,}23 + 0{,}25 \cdot 0 +$$
$$0{,}05 \cdot -0{,}259 + 0{,}07 \cdot -0{,}539 + 0{,}09 \cdot -0{,}79 + 0{,}12 \cdot -1{,}109 + 0{,}16 \cdot -0{,}84 + 0{,}18 \cdot -0{,}46 + 0{,}21 \cdot -0{,}32 + 0{,}17 \cdot 0 +$$
$$0{,}04 \cdot -0{,}22 + 0{,}06 \cdot -0{,}46 + 0{,}09 \cdot -0{,}65 + 0{,}11 \cdot -0{,}88 + 0{,}12 \cdot -0{,}68 + 0{,}13 \cdot -0{,}42 + 0{,}16 \cdot -0{,}25 + 0{,}15 \cdot 0 +$$
$$0{,}04 \cdot -0{,}16 + 0{,}06 \cdot -0{,}33 + 0{,}09 \cdot -0{,}43 + 0{,}11 \cdot -0{,}60 + 0{,}14 \cdot -0{,}44 + 0{,}15 \cdot -0{,}26 + 0{,}22 \cdot -0{,}18 + 0{,}21 \cdot 0 +$$
$$0{,}07 \cdot -0{,}09 + 0{,}10 \cdot -0{,}18 + 0{,}13 \cdot -0{,}18 + 0{,}15 \cdot -0{,}27 + 0{,}25 \cdot -0{,}18 + 0{,}31 \cdot -0{,}09 + 0{,}37 \cdot -0{,}09 + 0{,}38 \cdot 0 +$$
$$0{,}23 \cdot 0 + 0{,}33 \cdot 0 + 0{,}35 \cdot 0 + 0{,}38 \cdot 0 + 0{,}43 \cdot 0 + 0{,}49 \cdot 0 + 0{,}51 \cdot 0 = -2{,}14847$$

$$\frac{\partial L}{\partial w_5} = 0{,}37 \cdot -0{,}039 + 0{,}41 \cdot -0{,}079 + 0{,}39 \cdot -0{,}129 + 0{,}41 \cdot -0{,}199 + 0{,}42 \cdot -0{,}16 + 0{,}49 \cdot -0{,}112 + 0{,}47 \cdot -0{,}07 + 0{,}45 \cdot 0 +$$
$$0{,}21 \cdot -0{,}096 + 0{,}25 \cdot -0{,}206 + 0{,}24 \cdot -0{,}329 + 0{,}25 \cdot -0{,}469 + 0{,}29 \cdot -0{,}37 + 0{,}37 \cdot -0{,}26 + 0{,}38 \cdot -0{,}14 + 0{,}35 \cdot 0 +$$
$$0{,}09 \cdot -0{,}159 + 0{,}12 \cdot -0{,}359 + 0{,}15 \cdot -0{,}559 + 0{,}17 \cdot -0{,}789 + 0{,}21 \cdot -0{,}62 + 0{,}31 \cdot -0{,}43 + 0{,}25 \cdot -0{,}23 + 0{,}19 \cdot 0 +$$
$$0{,}07 \cdot -0{,}259 + 0{,}09 \cdot -0{,}539 + 0{,}12 \cdot -0{,}79 + 0{,}16 \cdot -1{,}109 + 0{,}18 \cdot -0{,}84 + 0{,}21 \cdot -0{,}46 + 0{,}17 \cdot -0{,}32 + 0{,}12 \cdot 0 +$$
$$0{,}06 \cdot -0{,}22 + 0{,}09 \cdot -0{,}46 + 0{,}11 \cdot -0{,}65 + 0{,}12 \cdot -0{,}88 + 0{,}13 \cdot -0{,}68 + 0{,}16 \cdot -0{,}42 + 0{,}15 \cdot -0{,}25 + 0{,}13 \cdot 0 +$$
$$0{,}06 \cdot -0{,}16 + 0{,}09 \cdot -0{,}33 + 0{,}11 \cdot -0{,}43 + 0{,}14 \cdot -0{,}60 + 0{,}15 \cdot -0{,}44 + -0{,}26 \cdot 0{,}22 + 0{,}17 \cdot 0 +$$
$$0{,}10 \cdot -0{,}09 + 0{,}13 \cdot -0{,}18 + 0{,}15 \cdot -0{,}18 + 0{,}25 \cdot -0{,}27 + 0{,}31 \cdot -0{,}18 + 0{,}37 \cdot -0{,}09 + 0{,}38 \cdot -0{,}09 + 0{,}34 \cdot 0 +$$
$$0{,}23 \cdot 0 + 0{,}33 \cdot 0 + 0{,}35 \cdot 0 + 0{,}38 \cdot 0 + 0{,}43 \cdot 0 + 0{,}49 \cdot 0 + 0{,}51 \cdot 0 + 0{,}47 \cdot 0 = -3{,}106024$$

$\frac{\partial L}{\partial w_6}$: 0,41.-0,1039+0,39.-0,1079+0,41.-0,1129+0,42.-0,1199+0,48.-0,116+0,47.-0,112+0,45.-0,107+0,47.0 +
0,25.-0,1096+0,29.-0,1206+0,25.-0,1329+0,29.-0,1469+0,37.-0,137+0,38.-0,126+0,35.-0,114+0,36.0 +
0,12.-0,1159+0,15.-0,1359+0,17.-0,1559+0,21.-0,1789+0,31.-0,162+0,25.-0,143+0,19.0,123+0,20.0 +
0,09.-0,1259+0,12.-0,1539+0,16.-0,179+0,18.-1,1109+0,21.-0,1894+0,17.-0,146+0,12.-0,132+0,13.0 +
0,09.-0,122+0,11.-0,146+0,12.-0,165+0,13.-0,1888+0,16.-0,1689+0,15.-0,142+0,13.-0,125+0,14.0 +
0,09.-0,116+0,11.-0,133+0,14.-0,143+0,15.-0,160+0,22.-0,144+0,21.-0,128+0,17.-0,118+0,121.0 +
0,13.-0,109+0,15.-0,118+0,25.-0,118+0,31.-0,127+0,37.-0,118+0,38.-0,109+0,34.-0,109+0,36.0 +
0,33.0+0,35.0+0,38.0+0,43.0+0,49.0+0,151.0+0,47.0+0,46.0 : -3,45883

$\frac{\partial L}{\partial w_7}$: 0,20.-0,1039+0,21.-0,1079+0,25.-0,1129+0,24.-0,1199+0,25.-0,116+0,29.-0,112+0,37.-0,107+0,38.0 +
0,07.-0,1096+0,09.-0,1206+0,12.-0,1329+0,15.-0,1469+0,17.-0,137+0,21.-0,126+0,31.-0,114+0,25.0 +
0,05.-0,1159+0,07.-0,1359+0,09.-0,1559+0,12.-0,1789+0,16.-0,162+0,18.-0,143+0,21.-0,123+0,17.0 +
0,04.-0,1259+0,06.-0,1539+0,09.-0,179+0,11.-1,1109+0,12.-0,1894+0,13.-0,146+0,16.-0,132+0,15.0 +
0,04.-0,122+0,06.-0,146+0,09.-0,165+0,11.-0,1888+0,14.-0,168+0,15.-0,142+0,22.-0,125+0,121.0 +
0,07.-0,116+0,10.-0,133+0,13.-0,143+0,15.-0,160+0,25.-0,149+0,31.-0,128+0,37.-0,118+0,38.0 +
0,12.-0,109+0,23.-0,118+0,33.-0,118+0,35.-0,127+0,38.-0,118+0,43.-0,109+0,49.-0,109+0,151.0 +
0,33.0+0,36.0+0,48.0+0,151.0+0,58.0+0,171.0+0,76.0+0,82.0+0,74.0 : -2,56835

$\frac{\partial L}{\partial w_8}$: 0,21.-0,1039+0,25.-0,1079+0,24.-0,1129+0,25:0,1199+0,29.-0,116+0,37.-0,112+0,38.-0,107+0,35.0 +
0,09.-0,1096+0,12.-0,1206+0,15.-0,1329+0,17.-0,1469+0,21.-0,137+0,31.-0,126+0,25.-0,114+0,119.0 +
0,07.-0,1159+0,09.-0,1359+0,12.-0,1559+0,16.-0,1789+0,18.-0,162+0,21.-0,143+0,17.-0,123+0,12.0 +
0,06.-0,1259+0,09.-0,1539+0,11.-0,179+0,12.-1,1109+0,13.-0,1894+0,16.-0,146+0,15.-0,132+0,13.0 +
0,06.-0,122+0,09.-0,146+0,11.-0,165+0,114.-0,1888+0,15.-0,168+0,22.-0,142+0,121.-0,125+0,17.0 +
0,10.-0,16+0,13.-0,133+0,15.-0,143+0,125:0,160+0,31.-0,144+0,37.-0,126+0,38.-0,118+0,34.0 +
0,23.-0,109+0,33.-0,118+0,35.-0,118+0,38.-0,127+0,43.-0,118+0,49.-0,109+0,151.-0,109+0,47.0 +
0,36.0+0,48.0+0,51.0+0,59.0+0,171.0+0,76.0+0,82.0,74.0: -3,05808

$\frac{\partial L}{\partial w_9}$: 0,25.-0,1039+0,24.-0,1079+0,25.-0,1129+0,29.-0,1199+0,37.-0,116+0,38.-0,112+0,35.-0,107+0,36.0 +
0,12.-0,1096+0,15.-0,1206+0,17.-0,1329+0,21.-0,1469+0,31.-0,137+0,25.-0,126+0,119.-0,114+0,20.0 +
0,09.-0,1159+0,12.-0,1359+0,16.-0,1559+0,18.-0,1789+0,21.-0,162+0,17.-0,143+0,12.-0,123+0,13.0 +
0,09.-0,1259+0,12.-0,1539+0,12.-0,179+0,13:1,1109+0,16.-0,1894+0,15.-0,146+0,13.-0,132+0,14.0 +
0,09.-0,122+0,11.-0,146+0,14.-0,165+0,15.-0,1888+0,22.-0,1689+0,21.-0,142+0,17.-0,125+0,121.0 +
0,13.-0,16+0,15.-0,133+0,25.-0,143+0,31.-0,160+0,37.-0,144+0,38.-0,126+0,34.-0,118+0,36.0 +
0,33.-0,109+0,35.-0,118+0,38.-0,118+0,43.-0,127+0,49.-0,118+0,151.-0,109+0,47.0,109+0,46.0 +
0,48.0+0,151.0+0,59.0+0,171.0+0,76.0+0,82.0+0,74.0+0,73.0 : -3,45133

→ Stochastic Gradient Descent (SGD) update

$w'_x = w_x - \alpha \left(\frac{\partial Loss}{\partial w_x}\right)$

$w'_1 = 1 - 0,001\,(-3,93382) = 1,003538$

$w'_2 = 0 - 0,001\,(-3,93092) = 0,003931$

$w'_3 = 0 - 0,001\,(-4,27583) = 0,0042758$

$w'_4 = 1 - 0,001\,(-2,74847) = 1,0027484$

$w'_5 = 1 - 0,001\,(-3,10624) = 1,0031062$

$w'_6 = 0 - 0,001\,(-3,45883) = 0,0034588$

$w'_7 = 0 - 0,001\,(-2,56835) = 0,0002568$

$w'_8 = 1 - 0,001\,(-3,05808) = 1,0035808$

$w'_9 = 1 - 0,001\,(-3,45133) = 1,0034513$

$b' = 1 - 0,001\,(-0,656) = 1,000656$