

s-dl-belindamutiara-2540119596-no1

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2 Link Video Jawaban

<https://drive.google.com/drive/folders/1iLxpxIgVLqB1G-cWYxDCVfliwRd05f-k?usp=sharing>

3 About Dataset

age: Age of policyholder

sex: Gender of policy holder (female=0, male=1)

bmi: Body mass index, providing an understanding of body, weights that are relatively high or low relative to height, objective index of body weight (kg / m^2) using the ratio of height to weight, ideally 18.5 to 25

steps: average walking steps per day of policyholder

children: number of children / dependents of policyholder

smoker: Smoker / Non - smoker

region: The residential area of policyholder in the US (northeast=0, northwest=1, southeast=2, southwest=3)

charges: Individual medical costs billed by health insurance

insurace claim: yes=1, no=0

4 Importing Libraries

```
[ ]: import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import warnings

import torch
import torch.nn as nn
```

```
import torch.nn.functional as F
from torch.autograd import Variable
from sklearn.preprocessing import StandardScaler

from torch.utils.data import Dataset
from sklearn.model_selection import train_test_split
from torch.utils.data import DataLoader
```

Kode diatas digunakan untuk mengimport library yang aka digunakan untuk melakukan analisis, visualisasi, dan modelling data insurance.

5 Nomor 1a

[LO 3, LO 4, 5 poin] Dataset yang diberikan memiliki beberapa problem, lakukan praproses data untuk menyelesaikan problem dari data tersebut. Sebutkan problem apa saja yang kalian temukan dari data yang diberikan, berikan penjelasan mengenai pendekatan apa yang kalian gunakan dan kenapa memilih pendekatan yang dipilih?

Untuk mengetahui pre-processing apa saja yang dibutuhkan, harus terlebih dahulu melakukan eksplorasi data sehingga mengetahui permasalahan-permasalahan pada data ini.

5.1 Data Overview

```
[ ]: #Mendefinisikan variabel "data" yang membaca data csv berjudul "insurance.csv".

df = pd.read_csv('https://raw.githubusercontent.com/belindamutiara/dataset/
↳6401c56165a7a929108f4ac88f44336a039ddc8e/insurance.csv')
```

```
[ ]: print(type(df))
      row,column=df.shape

      print("Jumlah baris data insurance adalah ", row)
      print("Jumlah kolom data insurance adalah ", column)
```

```
<class 'pandas.core.frame.DataFrame'>
Jumlah baris data insurance adalah 1338
Jumlah kolom data insurance adalah 9
```

Data Insurance mempunyai 1338 baris, dan 9 kolom.

```
[ ]: print(df.columns.values)
```

```
['age' 'sex' 'bmi' 'steps' 'children' 'smoker' 'region' 'charges'
 'insuranceclaim']
```

Terdapat 9 kolom yaitu 'age' 'sex' 'bmi' 'steps' 'children' 'smoker' 'region' 'charges' 'insuranceclaim'

```
[ ]: df.info()
```

```

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1338 entries, 0 to 1337
Data columns (total 9 columns):
#   Column                Non-Null Count  Dtype
---  -
0   age                   1338 non-null   int64
1   sex                   1338 non-null   int64
2   bmi                   1338 non-null   float64
3   steps                 1338 non-null   int64
4   children              1338 non-null   int64
5   smoker               1338 non-null   int64
6   region               1338 non-null   int64
7   charges               1338 non-null   float64
8   insuranceclaim        1338 non-null   int64
dtypes: float64(2), int64(7)
memory usage: 94.2 KB

```

Setiap atribut memiliki 1338 observasi dengan dua tipe data yang berbeda: float dan integer

```

[ ]: df.head(5)
#Melihat 5 data teratas

```

```

[ ]:
   age  sex    bmi  steps  children  smoker  region  charges  \
0   19   0  27.900   3009         0       1       3  16884.92400
1   18   1  33.770   3008         1       0       2   1725.55230
2   28   1  33.000   3009         3       0       2   4449.46200
3   33   1  22.705  10009         0       0       1  21984.47061
4   32   1  28.880   8010         0       0       1   3866.85520

   insuranceclaim
0                1
1                1
2                0
3                0
4                1

```

```

[ ]: df.tail(5)
#Melihat 5 data terbawah

```

```

[ ]:
   age  sex    bmi  steps  children  smoker  region  charges  \
1333  50   1  30.97   4008         3       0       1  10600.5483
1334  18   0  31.92   3003         0       0       0   2205.9808
1335  18   0  36.85   3008         0       0       2   1629.8335
1336  21   0  25.80   8009         0       0       3   2007.9450
1337  61   0  29.07   8008         0       1       1  29141.3603

   insuranceclaim
1333              0

```

```

1334          1
1335          1
1336          0
1337          1

```

5.2 Checking Duplicate Data

```
[ ]: print(df.shape)
      print(df[df.duplicated()].shape)
```

```

(1338, 9)
(0, 9)

```

```
[ ]: df[df.duplicated(keep=False)]
```

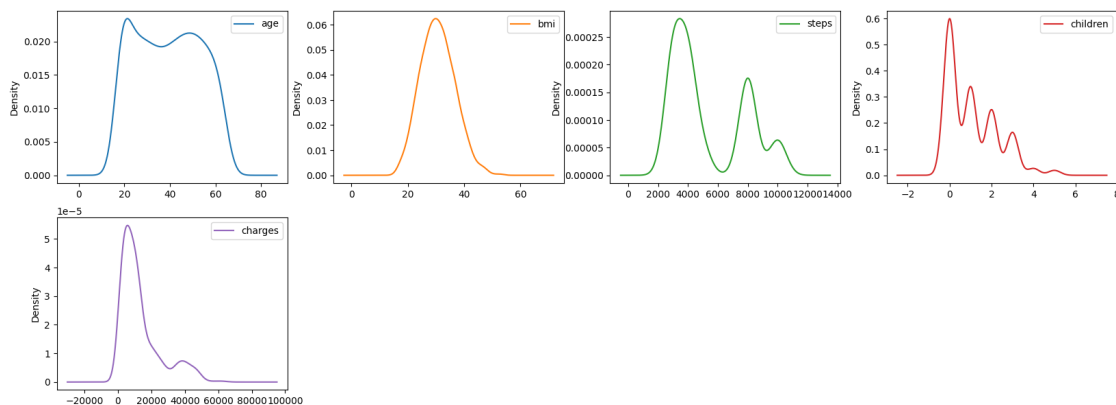
```
[ ]: Empty DataFrame
      Columns: [age, sex, bmi, steps, children, smoker, region, charges,
      insuranceclaim]
      Index: []
```

Dataset terdiri dari 1338 observasi baris, dan 14 columns of data dan tidak memiliki duplikasi data

5.3 Data Description

```
[ ]: categorical = df[["sex", "smoker", "region", "insuranceclaim"]]
      numeric = df[["age", "bmi", "steps", "children", "charges"]]
```

```
[ ]: # Density plots for all attributes to visualize the distribution of each
      ↪ attribute
      numeric.plot(kind='density', subplots=True, layout=(4,4), figsize=(20, 15),
      ↪ sharex=False)
      plt.show()
```



- Output di atas merupakan density plot. Plot tersebut digunakan untuk melihat distribusi data insurance.
- Dapat dilihat bahwa hanya atribut bmi saja yang terdistribusi normal, sedangkan atribut lainnya tidak terdistribusi normal.

5.4 Checking Missing Value

```
[ ]: print(df.isnull().sum())
      print(df.shape)
```

```
age          0
sex          0
bmi          0
steps        0
children     0
smoker       0
region       0
charges      0
insuranceclaim 0
dtype: int64
(1338, 9)
```

Dari pengecekan missing value dalam insurance dataset, tidak ditemukan adanya missing value di seluruh atribut.

5.5 Checking imbalance for categorical data

```
[ ]: df['sex'].value_counts()
```

```
[ ]: 1    676
      0    662
      Name: sex, dtype: int64
```

Dataset dilakukan hampir secara merata ke masing-masing gender, yakni kepada 676 laki-laki dan kepada 662 perempuan

```
[ ]: df['smoker'].value_counts()
```

```
[ ]: 0    1064
      1     274
      Name: smoker, dtype: int64
```

Hanya sekitar 20% dari observasi yang merupakan perokok, sisanya bukan perokok.

```
[ ]: df['region'].value_counts()
```

```
[ ]: 2    364
      3    325
      1    325
```

```
0    324
Name: region, dtype: int64
```

Semua region tercakup dalam dataset dengan perbandingan yang mendekatiimbang.

```
[ ]: df['children'].value_counts()
```

```
[ ]: 0    574
      1    324
      2    240
      3    157
      4     25
      5     18
      Name: children, dtype: int64
```

Sebanyak 85% dari total obsrvasi memiliki jumlah anak dibawah 3.

```
[ ]: df['insuranceclaim'].value_counts()
```

```
[ ]: 1    783
      0    555
      Name: insuranceclaim, dtype: int64
```

Target variabel, yaitu insurance claim memiliki proporsi kelas yang sedikit tidakimbang. Sebesar 41% observasi dikategorikan kedalam kelas yang tidak menerima claim insurance, sebaliknya 59% observasi dikategorikan kedalam kelas yang menerima claim insurance. Dalam klasifikasi binary, data dikatakan baik apabila jumlah kelasnyaimbang, yakni antara 0 dan 1. Akan tetapi, untuk beberapa kasus tertentu, kelas label 1 dengan jumlah lebih banyak merupakan keuntungan dalam pengamatan, sebab dengan demikian peneliti dapat mempelajari ciri-ciri atau karakteristik observasi yang masuk kedalam kelas 1.

Perbedaan kelas pada target insurance claim akan ditangani pada tahap sebelum permodelan menggunakan teknik oversampling.

5.6 Checking Corelation

```
[ ]: df.corr(method='pearson')
```

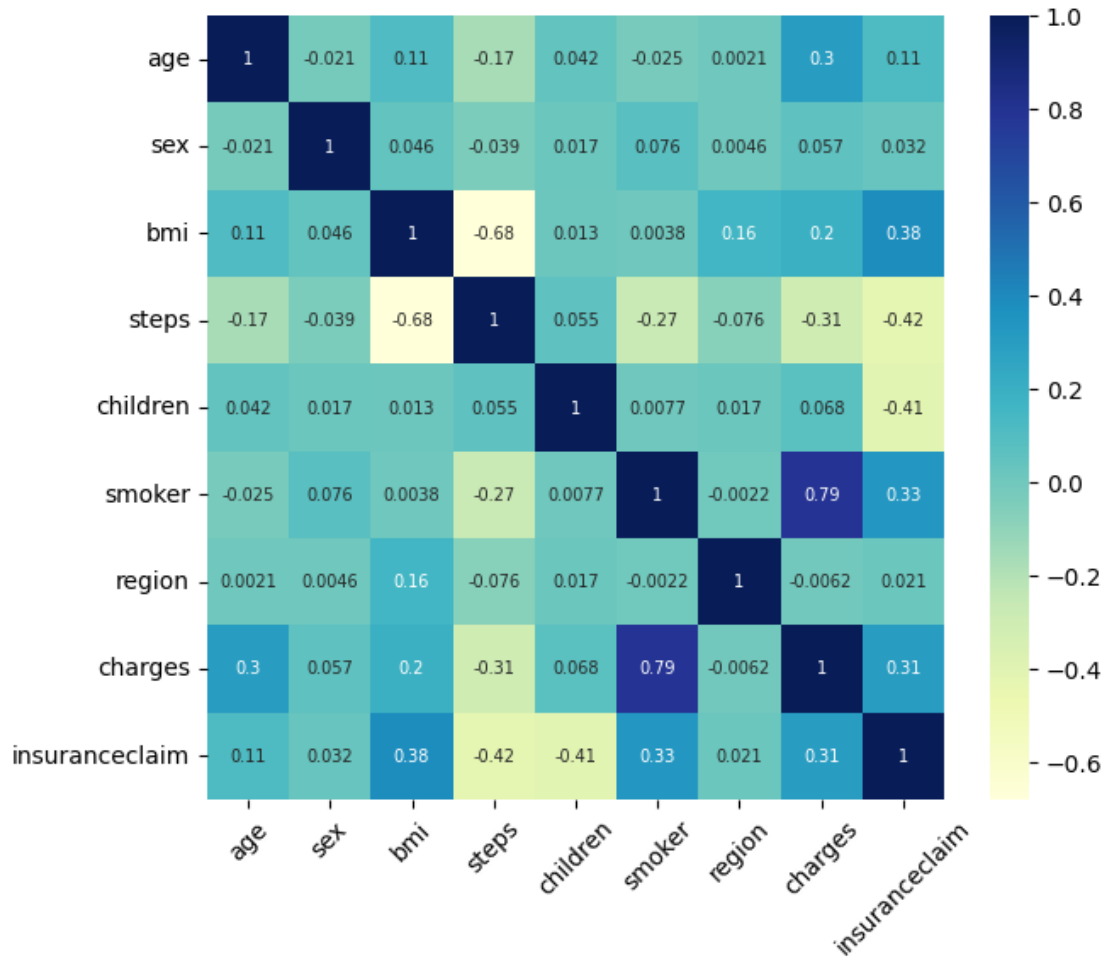
```
[ ]:      age      sex      bmi      steps  children  smoker \
age      1.000000 -0.020856  0.109272 -0.167957  0.042469 -0.025019
sex     -0.020856  1.000000  0.046371 -0.039470  0.017163  0.076185
bmi      0.109272  0.046371  1.000000 -0.681149  0.012759  0.003750
steps   -0.167957 -0.039470 -0.681149  1.000000  0.055346 -0.267845
children  0.042469  0.017163  0.012759  0.055346  1.000000  0.007673
smoker   -0.025019  0.076185  0.003750 -0.267845  0.007673  1.000000
region    0.002127  0.004588  0.157566 -0.076483  0.016569 -0.002181
charges   0.299008  0.057292  0.198341 -0.305570  0.067998  0.787251
insuranceclaim 0.113723  0.031565  0.384198 -0.419514 -0.409526  0.333261
```

	region	charges	insuranceclaim
age	0.002127	0.299008	0.113723
sex	0.004588	0.057292	0.031565
bmi	0.157566	0.198341	0.384198
steps	-0.076483	-0.305570	-0.419514
children	0.016569	0.067998	-0.409526
smoker	-0.002181	0.787251	0.333261
region	1.000000	-0.006208	0.020891
charges	-0.006208	1.000000	0.309418
insuranceclaim	0.020891	0.309418	1.000000

```
[ ]: fig, ax = plt.subplots(figsize=(7, 6))

sns.heatmap(df.corr(),
             annot=True,
             annot_kws={'fontsize': 7},
             cmap='YlGnBu',
             ax=ax)

ax.tick_params(axis='x', rotation=45)
ax.tick_params(axis='y', rotation=360);
```



Nampaknya target variable dataset ini tidak terlaui memiliki korelasi yang benar-benar kuat dengan dependent variable lainnya. Insurance claim memiliki korelasi yang cukup kuat dengan fitur charges, smoker, dan bmi, yakni 0.31, 0.33, dan 0.38. Hal ini berarti ketika ketiga fitur tersebut memiliki nilai mendekati 1, maka akan semakin tinggi pula kecenderungan mereka tergolong kedalam kelas 1. Sebaliknya, fitur insurance claim memiliki korelasi negatif yang cukup kuat dengan fitur steps (-0.42) fitur children (-0.41). Ini berarti bahwa ketika nilai kedua fitur tersebut semakin tinggi, maka kecenderungan seseorang untuk mendapatkan insurance claim semakin rendah.

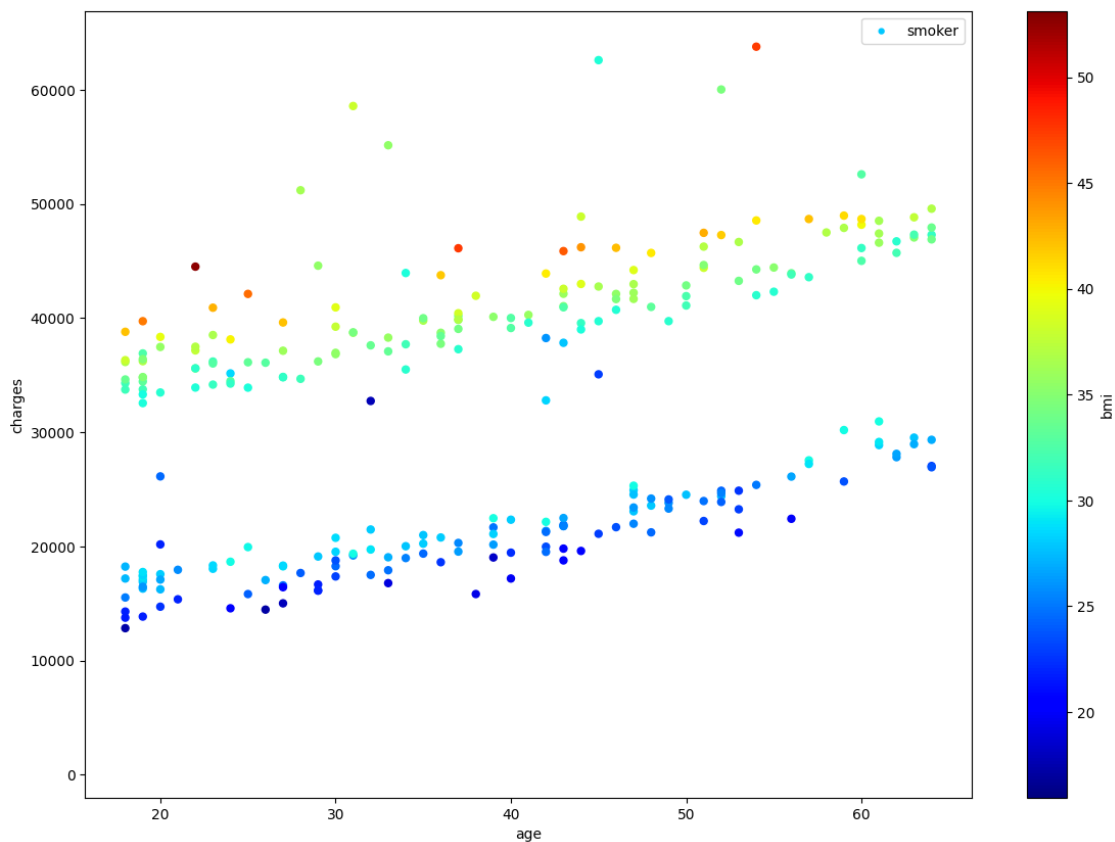
Perlu diingat bahwa nilai-nilai diatas (korelasi dengan insurance clain) tidak dapat sepenuhnya dikatakan berkorelasi kuat, biasanya korelasi kuat ditunjukan dengan angka 0.5 keatas. Misalnya korelasi kuat tersebut terlihat antara fitur bmi dengan fitur steps yakni -0.68. Ini berarti bahwa semakin besar nilai bmi seseorang maka akan semakin rendah jumlah langkah perhari yang dimiliki. Contoh lain ialah korelasi antara fitur smoker dengan fitur charges, semakin seseorang tersebut adalah perkok, maka biaya medical cost yang dimiliki akan semakin tinggi.

Kemudian saya menemukan permasalahan berkaitan dengan korelasi. Dapat dilihat bahwa fitur sex dan region memiliki korelasi yang sangat kecil dengan target variabel kita, besarnya hanya 0.032 dan 0.021. Hal ini disebabkan secara data, persebaran antara gender dan region yang masuk

kedalam kelas 0 maupun 1 cukupimbang. Oleh karena itu pada data pre-processing nanti saya akan menghapus kedua variabel tersebut. Adapun beberapa alasan lain ialah, karena korelasi dan nilai p-value nya yang rendah, fitur tersebut tidak memiliki pengaruh yang signifikan pada prediksi model. Hal ini akan membantu model untuk bisa fokus pada fitur yang lebih penting. Selain itu dengan adanya fitur korelasi rendah akan meningkatkan kemungkinan overfitting dan menurunkan generalisasi. Sedangkan untuk variabel bmi, step, charges, dan smoker, meskipun mereka memiliki korelasi yang tinggi, saya tidak akan membuang variabel tersebut sebab ke-empat variabel tersebut memiliki korelasi yang cukup besar terhadap target variable kita, keempat variabel tersebut masih dapat memberikan informasi yang berbeda dalam memprediksi target variable sehingga saya memutuskan untuk tidak menghapusnya.

```
[ ]: df.plot(kind="scatter", x="age", y="charges",  
        s=df["smoker"]*25, label="smoker", figsize=(14,10),  
        c='bmi', cmap=plt.get_cmap("jet"), colorbar=True,  
        sharex=False)  
plt.legend()
```

```
[ ]: <matplotlib.legend.Legend at 0x7fc09254feb0>
```



Relasi yang menarik nampak pada ketiga fitur: BMI, Charges, dan Smoking Status.

5.7 Pre-Processing

Sebelum melanjutkan pada tahap modelling, ada beberapa tahapan yang perlu dilakukan untuk mempersiapkan data. Pada dataset ini tidak terlalu banyak masalah yang ditemukan. Adapun yang akan saya lakukan ialah: 1. Memastikan bahwa tipe data adalah numerik. 2. Menghapus variable yang berkorelasi sangat rendah terhadap target variable. 3. Melakukan Scaling terhadap fitur dependent. 4. Melakukan SMOTE Oversampling (Ini akan dilakukan setelah membagi data menjadi train, validation, dan test set.

5.7.1 Memastikan bahwa tipe data adalah numerik

```
[ ]: df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1338 entries, 0 to 1337
Data columns (total 9 columns):
#   Column          Non-Null Count  Dtype
---  -
0   age             1338 non-null   int64
1   sex             1338 non-null   int64
2   bmi             1338 non-null   float64
3   steps           1338 non-null   int64
4   children        1338 non-null   int64
5   smoker          1338 non-null   int64
6   region          1338 non-null   int64
7   charges         1338 non-null   float64
8   insuranceclaim  1338 non-null   int64
dtypes: float64(2), int64(7)
memory usage: 94.2 KB
```

5.7.2 Menghapus variabel yang memiliki korelasi sangat rendah dengan target variable

```
[ ]: dfdrop = df.drop(["sex","region"], axis=1)
```

Pertama, saya memastikan bahwa seluruh isi data berupa numerik. Hal ini disebabkan model neural network hanya dapat memproses dan belajar dari data numerik. Pada data insurance ini, seluruh fitur telah memiliki tipe data numerik. Data insurance tidak membutuhkan data pre-processing berupa encoding.

5.7.3 Normalisasi data

Langkah selanjutnya yang saya lakukan adalah melakukan normalisasi data menggunakan scaling. Ada banyak metode dalam melakukan scaling seperti menggunakan min-max scaler, robust scaler, log scaler, power transformer, standard scaler, dan masih banyak lagi. Akan tetapi pada kesempatan ini saya akan menggunakan standard sebab metode ini merupakan metode yang paling umum digunakan, tahan terhadap outlier, serta dapat memberikan hasil yang stabil sebab metode ini mengubah skala data sehingga distribusi data akan memiliki mean=0 dan standar deviasi = 1.

```
[ ]: # get the features and labels from the dataset
X = dfdrop[dfdrop.columns[0:6]].values
y = dfdrop.insuranceclaim.values.astype(np.int64)

# preprocessing with z-score normalization
scaler = StandardScaler()
X = scaler.fit_transform(X)
```

```
[ ]: dfdrop
```

```
[ ]:      age    bmi  steps  children  smoker    charges  insuranceclaim
0      19  27.900   3009          0        1  16884.92400            1
1      18  33.770   3008          1        0   1725.55230            1
2      28  33.000   3009          3        0   4449.46200            0
3      33  22.705  10009          0        0  21984.47061            0
4      32  28.880   8010          0        0   3866.85520            1
...  ...  ...  ...  ...  ...  ...
1333   50  30.970   4008          3        0  10600.54830            0
1334   18  31.920   3003          0        0   2205.98080            1
1335   18  36.850   3008          0        0   1629.83350            1
1336   21  25.800   8009          0        0   2007.94500            0
1337   61  29.070   8008          0        1  29141.36030            1
```

[1338 rows x 7 columns]

6 Nomor 1b

Lakukan eksplorasi data terlebih dahulu untuk memahami permasalahan yang dihadapi terlebih dahulu. Selanjutnya pisahkan dataset menjadi train, test dan validation set dengan ketentuan (80 train, 10 val, 10 test)

6.1 Data Visualization & description

```
[ ]: df.describe().T
```

Dari output diatas, dapat dilihat jumlah dari data yang ada, nilai rata-rata, standar deviasi, nilai minimal, nilai q1 (kuartil bawah), median (q2), nilai q3 (kuartil atas), nilai maksimum dari tiap variable dalam dataset.

- Observasi dilakukan pada usia dengan rentang 18 - 64 tahun. Hal ini berarti bahawa pengambilan data dilakukan pada kalangan dewasa yang secara fisik masih aktif melakukan kegiatan sehari-hari.
- Dalam observasi, bmi terendah ialah 15.9 dan bmi tertinggi adalah 53.1 dengan rata-rata bmi adalah 30.6. Ini berarti bahwa dalam observasi mungkin ada yang mengalami gejala “underweight” atau “Obesity”.
- Rata-rata jumlah langkah yang pada seluruh observasi adalah sekitar 5000 langkah, rata-rata observasi pada data insurance melebihi rata-rata langkah pada negara US, yakni 3000

langkah.

- Tidak semua observasi memiliki tanggungan anak.
- Terdapat observasi yang merupakan perokok, namun nampaknya observasi perokok jumlahnya lebih sedikit dari observasi yang bukan perokok, hal ini ditandai dengan rata-rata dibawah 0.5 yakni 0.2.
- Jumlah premi terendah dalam dataset ini adlah 1121 dolar, premi tertinggi sebesar 63770, dan rata-rata premi yang dibayarkan adalah 13270

```
[ ]: df.groupby('insuranceclaim').mean()
```

```
[ ]:
insuranceclaim      age      sex      bmi      steps  children \
0      37.309910  0.486486  27.881586  6550.787387  1.681081
1      40.551724  0.518519  32.635179  4462.338442  0.679438

insuranceclaim      smoker      region      charges
0      0.045045  1.488288  8821.421892
1      0.318008  1.535121  16423.928277
```

- Kelas 1 (asuransi di claim) memiliki rata-rata observasi berusia 40 tahun, bmi sebesar 32.6, jumlah langkah perhari 4462 langkah, dan memiliki medical cost sekitar 16423 US dollar.
- Sementara itu, Kelas 0 (asuransi tidak dikalim) memiliki rata-rata observasi berusia 37 tahun, bmi sebesar 27.8, jumlah langkah perhari 6550, cenderung bukan merupakan perokok, dan memiliki rata-rata medical cost sekitar 8821 US dollar.

6.1.1 Insurance Claim

```
[ ]: Not_Claimed = df["insuranceclaim"].value_counts()[0]
      Claimed = df["insuranceclaim"].value_counts()[1]

print("Not Claimed:", Not_Claimed)
print("Claimed:", Claimed)
```

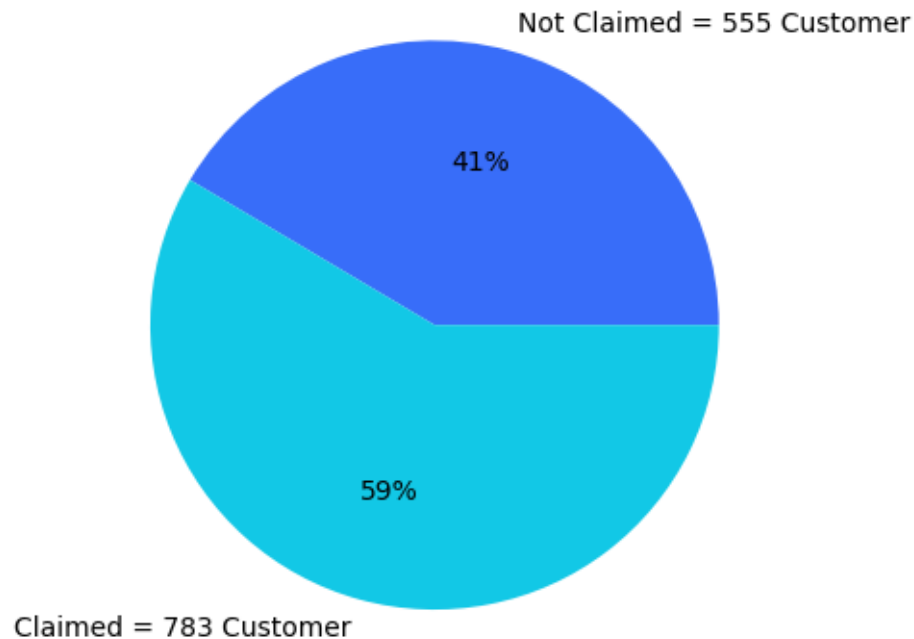
Not Claimed: 555

Claimed: 783

```
[ ]: data = [555,783]
      labels = ['Not Claimed = 555 Customer', 'Claimed = 783 Customer']

      colors = sns.color_palette('rainbow')[0:5]
      plt.title("Comparison between claimed with Not Claimed Observation")
      plt.pie(data, labels = labels, colors = colors, autopct='%0.0f%%')
      plt.show()
```

Comparison between claimed with Not Claimed Observation



Jumlah perbandingan observasi di kelas 1 dan kelas 0 tidakimbang, meski hanya berbeda tipis. Namun data dikatakan baik apabila memiliki perbandingan kelas yangimbang anatar kelas positif (kelas 1) dengan kelas negatif (kelas 0). Oleh karena itu, hal ini akan ditangani pada tahap pre-processing menggunakan SMOTE Oversampling.

6.1.2 Numeric Variable: Age, BMI, Steps,Charges

```
[ ]: df_claimed = df[df['insuranceclaim'] == 1]
df_not_claimed = df[df['insuranceclaim'] == 0]

def plot_continuous(feature):
    '''Plot a histogram and boxplot for the Claimed and Not Claimed_
    ↳distributions for the specified feature.'''
    df_func = df.copy()
    df_func['insuranceclaim'] = df_func['insuranceclaim'].astype('category')

    fig, (ax1, ax2) = plt.subplots(2,
                                   figsize=(9, 7),
                                   sharex=True,
                                   gridspec_kw={'height_ratios': (.7, .3)})
```

```

    for data, color, label in zip([df_not_claimed, df_claimed], colors, ['Not_
↳ Claimed', 'Claimed']):
        sns.histplot(data=data,
                      x=feature,
                      bins=15,
                      color=color,
                      alpha=0.66,
                      edgecolor='firebrick',
                      label=label,
                      kde=False,
                      ax=ax1)

    ax1.legend()

    sns.boxplot(x=feature, y='insuranceclaim', data=df_func, palette=colors,
↳ ax=ax2)
    ax2.set_ylabel('')
    ax2.set_yticklabels(['Not Claimed', 'Claimed'])

    plt.tight_layout();

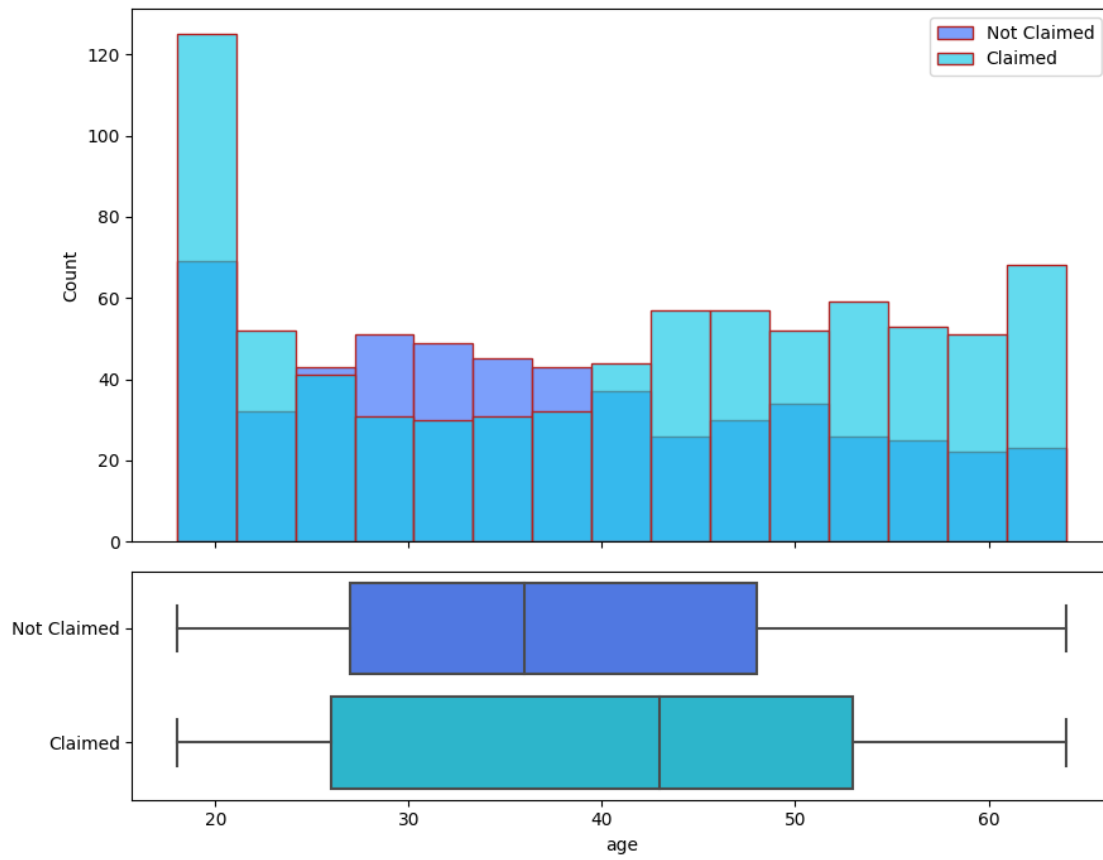
print(' Function Defined!')

```

Function Defined!

Age

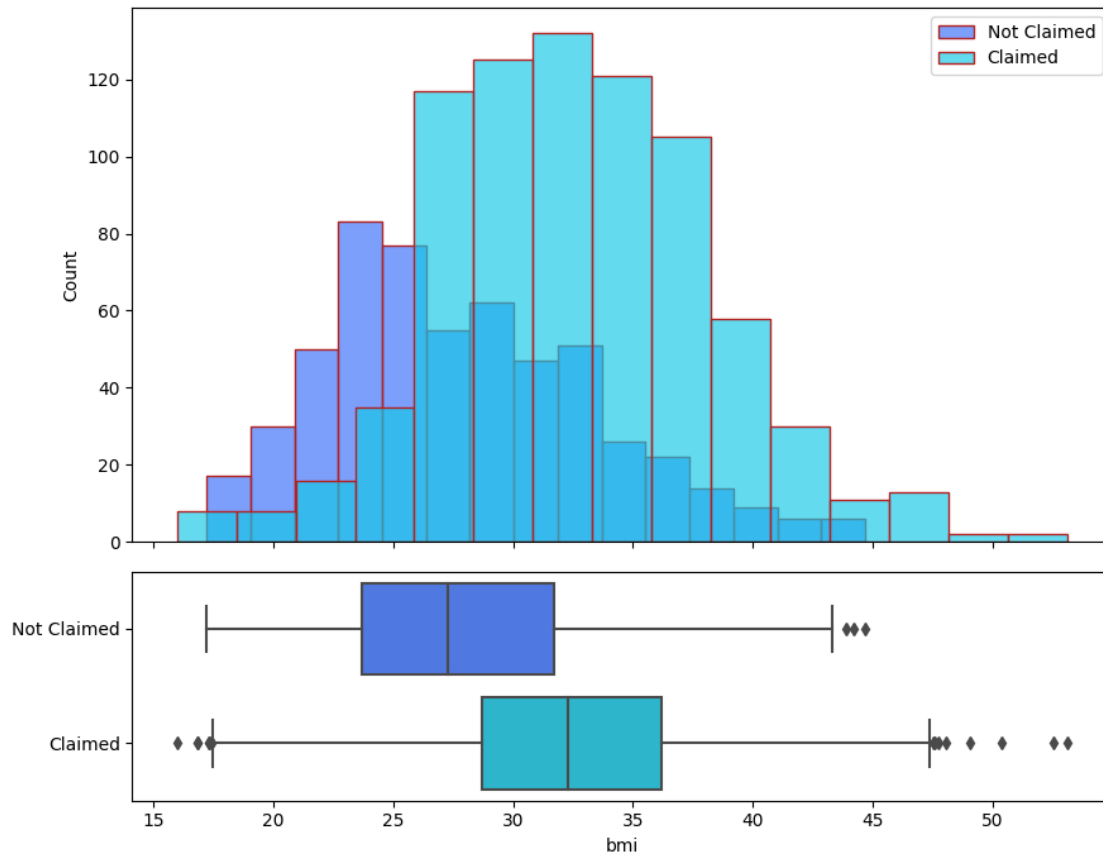
```
[ ]: plot_continuous('age')
```



Pada fitur usia, tidak ditemukan adanya outlier. Rata-rata usia observasi yang tidak mendapat claim asuransi sekitar 37 tahun, sedangkan rata-rata observasi yang mendapatkan claim asuransi ialah sekitar 41 tahun. Pada kelas 1 nampaknya memiliki banyak observasi yang berusia sekitar 20 tahun. Sedangkan untuk kelas 0, nampaknya persebaran sedikit condong di rentang usia 25 sampai 40 tahun.

BMI

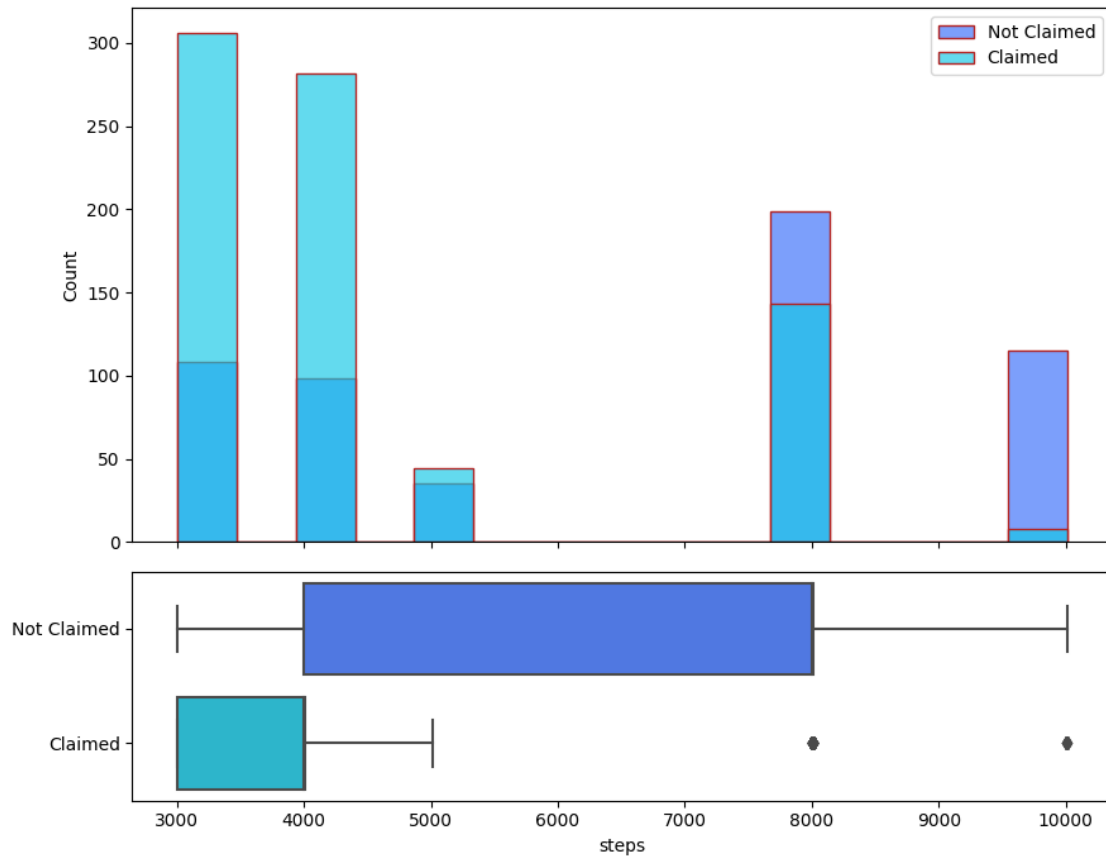
```
[ ]: plot_continuous('bmi')
```



Dari plot diatas dapat dilihat bahwa kelas 0 dan 1 memiliki persebaran yang mendekati normal. Rata-rata bmi pada observasi kelas 0 adalah sekitar 27, sedangkan untuk kelas 1 ialah sekitar 32-33. Observasi yang tergolong kedalam kelas 0 cenderung untuk memiliki bmi di sekitar 20 sampai 30, sedangkan observasi yang tergolong kedalam kelas 1 cenderung untuk memiliki bmi 25 sampai 40. Pada fitur ini ditemukan beberapa outlier, namun ini merupakan hal yang wajar sebab dataset ini termasuk kedalam data medical, dimana berbagai kondisi sangat memungkinkan.

Steps

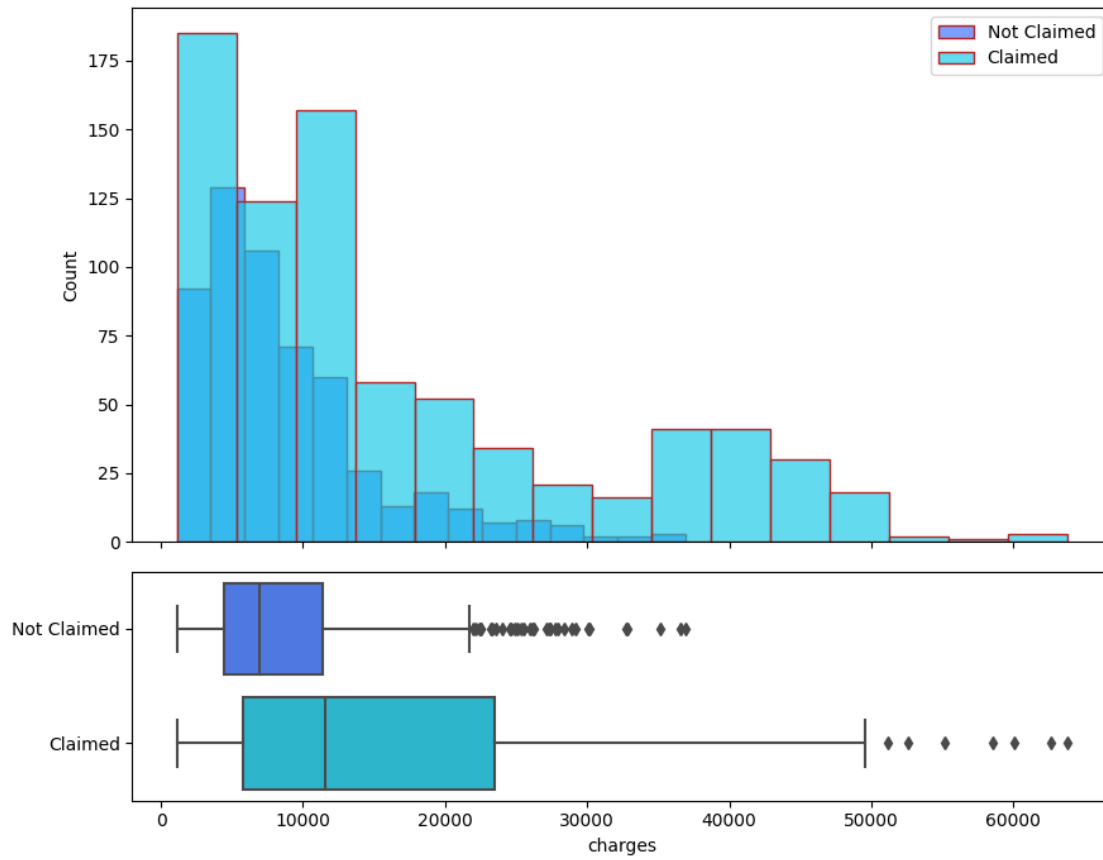
```
[ ]: plot_continuous('steps')
```

Untuk observasi yang tergolong kedalam kelas 1, cenderung untuk memiliki langkah yang lebih sedikit dibandingkan dengan kelas 0. Dalam fitur tidak ditemukan adanya outlier pada kelas 0, namun sebaliknya, ditemukan beberapa outlier pada kelas 1.

Charges

```
[ ]: plot_continuous('charges')
```



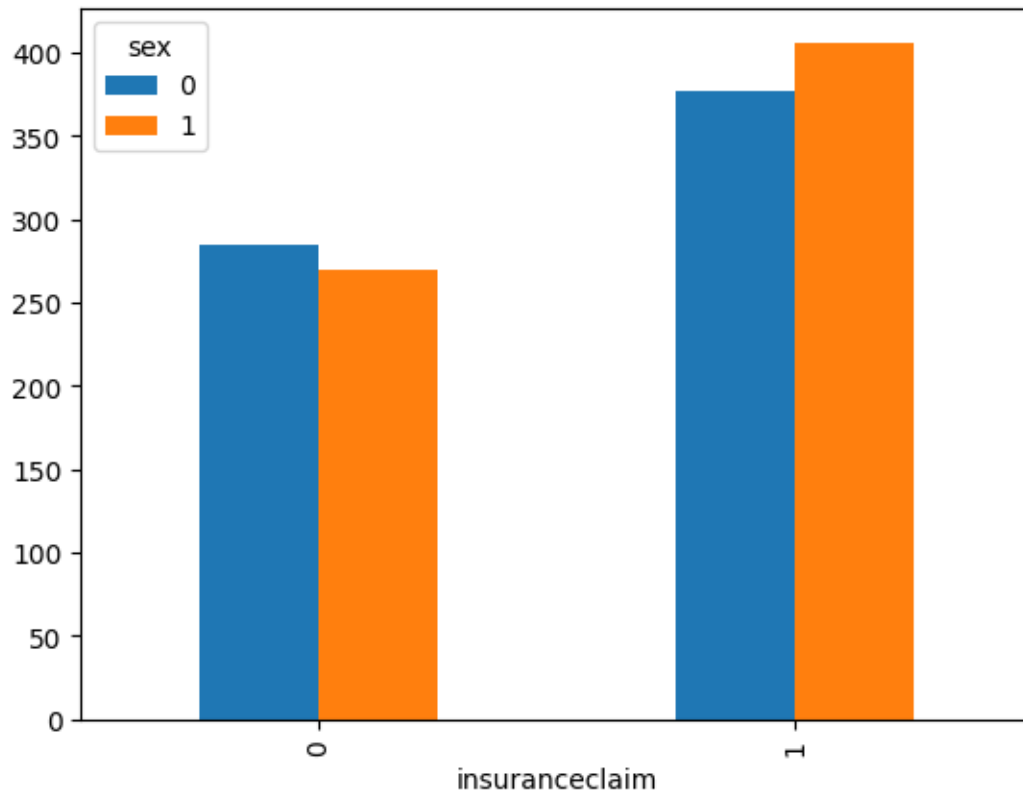
Pada fitur charges, sangat terlihat terjadi distribusi yang condong ke kiri, hal ini berarti nilai median lebih kecil dari nilai rata-rata. Ditrmukan cukup banyak outlier, khususnya pada kelas 0.

6.1.3 Categorical Variable: Sex, Children, Smoker, Region

Sex

```
[ ]: df_plot = df.groupby(['sex', 'insuranceclaim']).size().reset_index().
      pivot(columns='sex', index='insuranceclaim', values=0)
df_plot.plot(kind='bar', stacked=False)
```

```
[ ]: <Axes: xlabel='insuranceclaim'>
```



```
[ ]: df[["sex", "insuranceclaim"]].groupby(['sex']).mean().
      ↪sort_values(by="insuranceclaim", ascending=True)
```

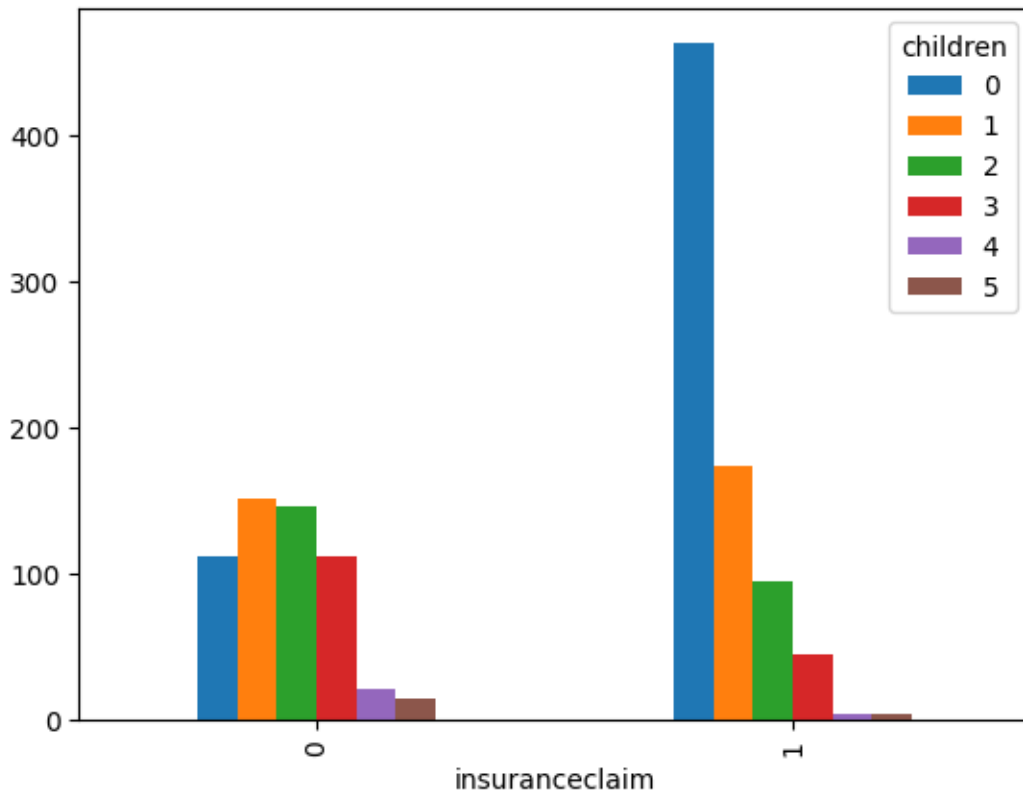
```
[ ]:      insuranceclaim
      sex
0      0.569486
1      0.600592
```

Perbandingan gender di kelas 0 maupun kelas 1 tidak begitu jauh, pada kelas 0 gender perempuan memiliki jumlah yang lebih banyak dari gender laki-laki, sebaliknya pada kelas 1, jumlah gender laki-laki lebih banyak dari gender perempuan. Akan tetapi, perbedaan angka yang tidak begitu signifikan bisa menjadi tanda bahwa antara gender dengan insuranceclaim tidak memiliki relasi yang kuat.

Children

```
[ ]: df_plot = df.groupby(['children', 'insuranceclaim']).size().reset_index().
      ↪pivot(columns='children', index='insuranceclaim', values=0)
      df_plot.plot(kind='bar', stacked=False)
```

```
[ ]: <Axes: xlabel='insuranceclaim'>
```



```
[ ]: df[["children", "insuranceclaim"]].groupby(['children']).mean().
      ↪sort_values(by="insuranceclaim", ascending=True)
```

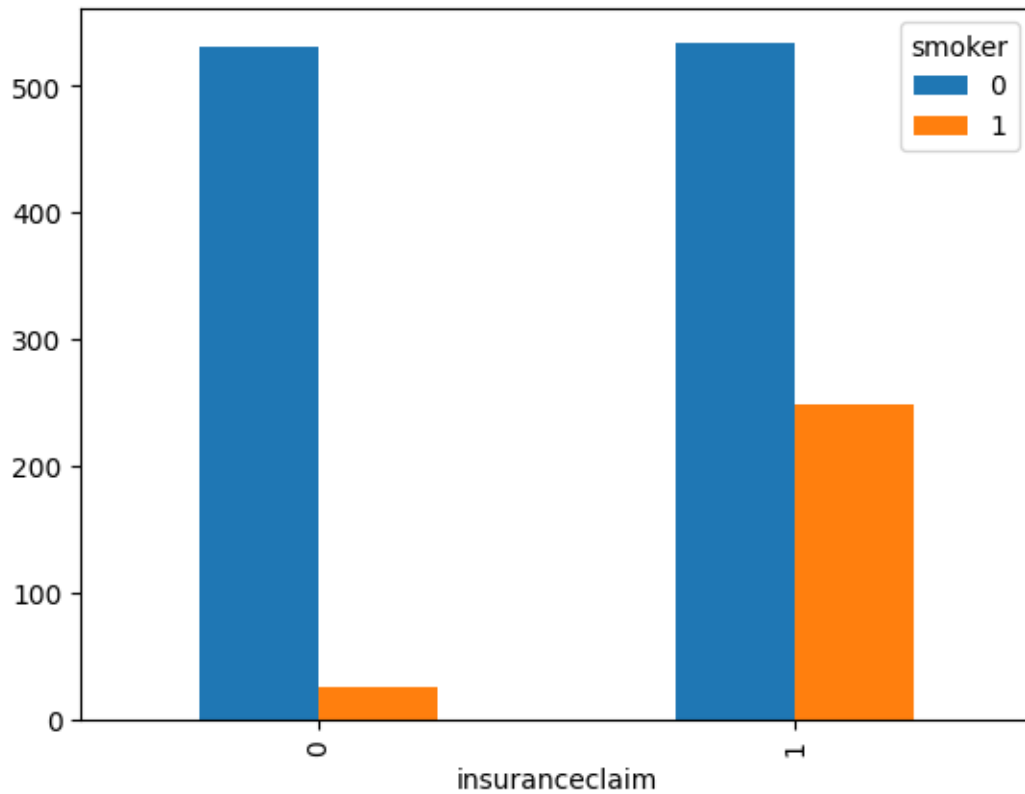
```
[ ]:      insuranceclaim
children
4         0.160000
5         0.222222
3         0.286624
2         0.391667
1         0.533951
0         0.806620
```

Baik pada kelas 0 maupun kelas 1, kecenderungan yang didapatkan ialah sama-sama memiliki tanggungan anak dibawah 4. Observasi dengan tanggungan anak 0 cenderung untuk masuk kedalam kelas 1.

Smoker

```
[ ]: df_plot = df.groupby(['smoker', 'insuranceclaim']).size().reset_index().
      ↪pivot(columns='smoker', index='insuranceclaim', values=0)
df_plot.plot(kind='bar', stacked=False)
```

```
[ ]: <Axes: xlabel='insuranceclaim'>
```



```
[ ]: df[["smoker", "insuranceclaim"]].groupby(['smoker']).mean().  
      ↪sort_values(by="insuranceclaim", ascending=True)
```

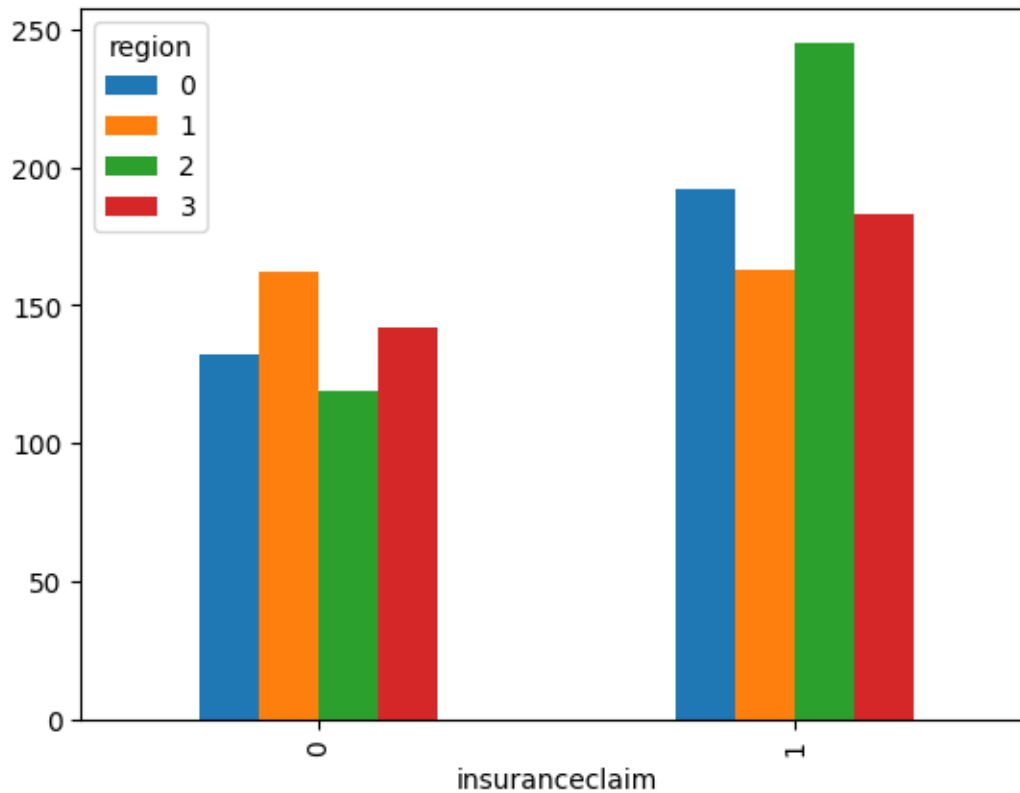
```
[ ]:      insuranceclaim  
      smoker  
0      0.501880  
1      0.908759
```

kelas 1 memiliki lebih banyak observasi yang merupakan perokok ketimbang kelas 0.

Region

```
[ ]: df_plot = df.groupby(['insuranceclaim', 'region']).size().reset_index().  
      ↪pivot(columns='region', index='insuranceclaim', values=0)  
      df_plot.plot(kind='bar', stacked=False)
```

```
[ ]: <Axes: xlabel='insuranceclaim'>
```



```
[ ]: df[["region", "insuranceclaim"]].groupby(['region']).mean().
      ↪sort_values(by="insuranceclaim", ascending=True)
```

```
[ ]:      insuranceclaim
      region
1      0.501538
3      0.563077
0      0.592593
2      0.673077
```

Seluruh region hampir memiliki kemungkinan untuk tergolong kedalam kelas 0 ataupun kelas 1. Hal ini dapat menjadi pertanda bahwa region tidak terlalu berpengaruh terhadap target variabel yaitu insurance claim.

```
[ ]: df
```

```
[ ]:      age  sex    bmi  steps  children  smoker  region    charges  \
0      19   0  27.900   3009         0        1        3  16884.92400
1      18   1  33.770   3008         1        0        2   1725.55230
2      28   1  33.000   3009         3        0        2   4449.46200
3      33   1  22.705  10009         0        0        1  21984.47061
4      32   1  28.880   8010         0        0        1   3866.85520
```

...
1333	50	1	30.970	4008		3	0	1	10600.54830
1334	18	0	31.920	3003		0	0	0	2205.98080
1335	18	0	36.850	3008		0	0	2	1629.83350
1336	21	0	25.800	8009		0	0	3	2007.94500
1337	61	0	29.070	8008		0	1	1	29141.36030

	insuranceclaim
0	1
1	1
2	0
3	0
4	1
...	...
1333	0
1334	1
1335	1
1336	0
1337	1

[1338 rows x 9 columns]

6.2 Memisahkan data menjadi 80% Train, 10% Validation, dan 10% Test

Sebelum saya melakukan data pre-processing yang ketiga, saya akan membagi data terlebih dahulu menjadi 80% train, 10% validation, dan 10% test. Hal ini disebabkan karena SMOTE oversampling hanya dilakukan pada training data, oversampling dilakukan untuk memanipulasi data pada training sehingga data tersebut tidak merepresentasikan data asli. Jika training data yang telah dimanipulasi digunakan pada proses validasi maupun proses testing, maka hasil evaluasi model tidak lagi merepresentasikan performa model dalam memprediksi data asli. Sehingga tahap oversampling ini perlu dilakukan dengan hati-hati agar tidak terjadi kebocoran data pada data validasi dan testing.

```
[ ]: #Membuat kelas untuk dataset insurance
class InsuranceDataset(Dataset):
    def __init__(self, X, y):
        self.X = X
        self.y = y

    def __getitem__(self, index):
        X = torch.Tensor(self.X[index])
        y = torch.LongTensor(self.y[index, None])

        return X, y

    def __len__(self):
        return len(self.X)
```

```
[ ]: train_X, test_X, train_y, test_y = train_test_split(X, y, test_size=0.1,
    ↪random_state=1) #10 persen test , 90 persen training

train_X, valid_X, train_y, valid_y = train_test_split(train_X, train_y, #dari
    ↪90 persen itu, 10 persennya validation, 90 persennya train.
    test_size=0.1,
    ↪random_state=1)
```

6.3 SMOTE Oversampling

```
[ ]: from imblearn.over_sampling import SMOTE
over = SMOTE(sampling_strategy='auto', random_state=1)
train_X, train_y = over.fit_resample(train_X, train_y)
```

Seperti yang telah diketahui sebelumnya bahwa perbandingan kelas target tidakimbang yaitu 41% kelas 0 dan 59% kelas 1. Oleh karena itu saya melakukan teknik oversampling pada dataset ini untuk meningkatkan kinerja algoritma dengan cara meningkatkan keberagaman dataset dan mengurangi kecondongan ke arah kelas mayoritas. SMOTE juga dapat mencegah overfitting dengan menghasilkan contoh baru yang mirip dengan kelas minoritas namun tidak identik, sehingga meningkatkan generalisasi model.

Alasan lain mengapa saya melakukan SMOTE Oversampling ialah, pada percobaan sebelumnya, saya telah melakukan komparasi pada dataset ini, dan didapatkan hasil yang lebih memuaskan ketimbang tanpa adanya oversampling

7 Nomor 1c

[LO 3, LO 4, 5 poin] Buatlah arsitektur baseline dengan n nodes input layer, 2 buah hidden layer dengan banyak $2 \times n$ nodes awal dan layer akhir banyak kelas nya ($n, 2 \times n, 2 \times n, \text{num_class}$). Keterangan: n adalah banyak input dan num_class adalah banyak kelas. Activation function untuk tiap hidden layer menggunakan ReLU

7.1 Membuat kelas objek dataset

```
[ ]: #membuat kelas objek dataset. Salah satu ciri khas pytorch ialah bersifat
    ↪object oriented.

train_ds = InsuranceDataset(train_X, train_y)
train_loader = DataLoader(train_ds, batch_size=16,
    shuffle=True, num_workers=0)

valid_ds = InsuranceDataset(valid_X, valid_y)
valid_loader = DataLoader(valid_ds, batch_size=16,
    shuffle=False, num_workers=0)

test_ds = InsuranceDataset(test_X, test_y)
test_loader = DataLoader(test_ds, batch_size=16,
    shuffle=False, num_workers=0)
```


7.2 Modelling Architechture (Base)

```
[ ]: #Membuat object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 12) #Input data ada 6 fitur, 12 menunjukan
        ↪ jumlah neuron di hidden layer pertama.
        self.bn1 = nn.BatchNorm1d(12) #Normalisasi, agar mempercepat training.

        self.fc2 = nn.Linear(12, 12) #12 merupakan jumlah hidden layer pertama,
        ↪ 12 berikutnya merupakan hidden layer kedua
        self.bn2 = nn.BatchNorm1d(12) #Normalisasi

        self.fc3 = nn.Linear(12, 2) #Jumlah output ada 2 yaitu 1 dan 0.

#total ada 2 hidden layer.

#arsitektur, model yg akan dirancang
    def forward(self, X):
        X = self.fc1(X) #fc1 --> Linier
        X = F.relu(X)
        X = self.bn1(X) #Untuk mempercepat proses training
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X
```

Kode diatas dilakuakn untuk merancang arsitektur neural netrowk menggunakan framework pytorch. Arsitektur terdiri dari 1 input layer (6 neuron), 2 hidden layer (setiap hidden layer memiliki 12 neuron), dan 1 output layer (2 neuron). Fungsi aktivasi yang digunakan adalah ReLU dan menggunakan model linier. Pada arsitektur diatas juga dilakukan normalisasi untuk mempercepat proses training.

Ketika menggunakan framework seperti PyTorch, TensorFlow, dan sebagainya untuk membuat neural network model, kita tidak perlu membuat proses backpropagationnya secara manual. Framework yang disediakan telah dilengkapi dengan berbagai fungsi dan metode untuk menghitung gradien dari setiap parameter. Dengan begitu tugas kita adalah merancang arsitektur model neural network dan menentukan paramater yang cocok agar mendapatkan hasil yang paling optimal

```
[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
```

```

criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.Adam(net.parameters(), lr=0.2)

```

Pada kesempatan kali ini saya menggunakan `nn.CrossEntropyLoss` sebagai fungsi loss. Kita dapat menggunakan `nn.CrossEntropyLoss` untuk kasus klasifikasi biner dan akan memperlakukannya sebagai kasus klasifikasi multiclass dengan 2 kelas. Dalam hal ini kita mengeluarkan 2 output pada layer terakhir. Sebenarnya untuk kasus binary classification kita juga dapat menggunakan `nn.BCELoss`, akan tetapi kita menggunakan `BCELoss` ketika pada layer terakhir jumlah outputnya adalah 1. Sehingga pada kasus ini saya menggunakan `nn.CrossEntropyLoss` sebagai fungsi loss dan memperlakukannya sebagai multiclass 2 kelas.

```

[ ]: epochs = 100

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward() # perhitungan backpropagation
        optimizer.step()

        train_losses.append(loss) #memperbaharui setiap weight atau bbotot

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====

```

```

# validation
#setiap epoch lakukan validation
valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.51818955
validation loss: 0.45291004
=====
Epoch 1
training loss: 0.38477057
validation loss: 0.38229349
=====
Epoch 2
training loss: 0.35651681
validation loss: 0.26474166
=====
Epoch 3
training loss: 0.36155200
validation loss: 0.41861546
=====
Epoch 4
training loss: 0.33232474
validation loss: 0.26793084
=====
Epoch 5
training loss: 0.36998308
validation loss: 0.34606192
=====

```

```
Epoch 6
training loss: 0.42757609
validation loss: 0.31666753
=====
Epoch 7
training loss: 0.29739246
validation loss: 0.46353972
=====
Epoch 8
training loss: 0.38848051
validation loss: 0.26026851
=====
Epoch 9
training loss: 0.42296559
validation loss: 0.33177680
=====
Epoch 10
training loss: 0.31663328
validation loss: 0.27049240
=====
Epoch 11
training loss: 0.30243647
validation loss: 0.23141582
=====
Epoch 12
training loss: 0.29623455
validation loss: 0.26741692
=====
Epoch 13
training loss: 0.25691050
validation loss: 0.27989852
=====
Epoch 14
training loss: 0.26507556
validation loss: 0.42780858
=====
Epoch 15
training loss: 0.31207785
validation loss: 0.31059420
=====
Epoch 16
training loss: 0.27657747
validation loss: 0.29316565
=====
Epoch 17
training loss: 0.30139178
validation loss: 0.21974641
=====
```

```
Epoch 18
training loss: 0.28273618
validation loss: 0.22324002
=====
Epoch 19
training loss: 0.27771789
validation loss: 0.25290295
=====
Epoch 20
training loss: 0.24037941
validation loss: 0.21509124
=====
Epoch 21
training loss: 0.38019353
validation loss: 0.25822422
=====
Epoch 22
training loss: 0.31927091
validation loss: 0.21102932
=====
Epoch 23
training loss: 0.26157138
validation loss: 0.19195220
=====
Epoch 24
training loss: 0.24621500
validation loss: 0.19647107
=====
Epoch 25
training loss: 0.26338685
validation loss: 0.25105900
=====
Epoch 26
training loss: 0.29601383
validation loss: 0.32438895
=====
Epoch 27
training loss: 0.39585522
validation loss: 0.26116213
=====
Epoch 28
training loss: 0.34256780
validation loss: 0.27218288
=====
Epoch 29
training loss: 0.27141789
validation loss: 0.35022894
=====
```

```
Epoch 30
training loss: 0.29987052
validation loss: 0.28046930
=====
Epoch 31
training loss: 0.34024501
validation loss: 0.21999529
=====
Epoch 32
training loss: 0.26508090
validation loss: 0.32237411
=====
Epoch 33
training loss: 0.46465236
validation loss: 0.38646856
=====
Epoch 34
training loss: 0.25601560
validation loss: 0.25617316
=====
Epoch 35
training loss: 0.27944174
validation loss: 0.24537206
=====
Epoch 36
training loss: 0.23075655
validation loss: 0.24014407
=====
Epoch 37
training loss: 0.23422647
validation loss: 0.26011288
=====
Epoch 38
training loss: 0.30747464
validation loss: 0.27974567
=====
Epoch 39
training loss: 0.31449342
validation loss: 0.43431577
=====
Epoch 40
training loss: 0.26450577
validation loss: 0.41431007
=====
Epoch 41
training loss: 0.36522880
validation loss: 0.22327484
=====
```

```
Epoch 42
training loss: 0.30979621
validation loss: 0.28267145
=====
Epoch 43
training loss: 0.26637065
validation loss: 0.20838885
=====
Epoch 44
training loss: 0.22170830
validation loss: 0.22849205
=====
Epoch 45
training loss: 0.27859947
validation loss: 0.31546274
=====
Epoch 46
training loss: 0.32979396
validation loss: 0.21262297
=====
Epoch 47
training loss: 0.27665281
validation loss: 0.25241226
=====
Epoch 48
training loss: 0.33895132
validation loss: 0.23464401
=====
Epoch 49
training loss: 0.23718169
validation loss: 0.22349335
=====
Epoch 50
training loss: 0.23163857
validation loss: 0.29326051
=====
Epoch 51
training loss: 0.26850560
validation loss: 0.22548367
=====
Epoch 52
training loss: 0.25871158
validation loss: 0.64839077
=====
Epoch 53
training loss: 0.54098004
validation loss: 0.20254594
=====
```

```

Epoch 54
training loss: 0.24296273
validation loss: 0.20814015
=====
Epoch 55
training loss: 0.26052555
validation loss: 0.23918016
=====
Epoch 56
training loss: 0.27148607
validation loss: 0.20135973
=====
Epoch 57
training loss: 0.24758084
validation loss: 0.21340689
=====
Epoch 58
training loss: 0.22752494
validation loss: 0.23945375
=====
Epoch 59
training loss: 0.22709535
validation loss: 0.19755784
=====
Epoch 60
training loss: 0.21733612
validation loss: 0.20099781
=====
Epoch 61
training loss: 0.29008916
validation loss: 0.26955035
=====
Epoch 62
training loss: 0.27105570
validation loss: 0.21776207
=====
Epoch 63
training loss: 0.21161312
validation loss: 0.20666400
=====
Epoch 64
training loss: 0.23632926
validation loss: 0.20732711
=====
Epoch 65
training loss: 0.23625779
validation loss: 0.20617136
=====

```



```
Epoch 66
training loss: 0.22947954
validation loss: 0.18167943
=====
Epoch 67
training loss: 0.27787000
validation loss: 0.18635853
=====
Epoch 68
training loss: 0.23605818
validation loss: 0.21496846
=====
Epoch 69
training loss: 0.20733675
validation loss: 0.22473852
=====
Epoch 70
training loss: 0.27109936
validation loss: 0.34958673
=====
Epoch 71
training loss: 0.35089678
validation loss: 0.49003232
=====
Epoch 72
training loss: 0.38656500
validation loss: 0.23399156
=====
Epoch 73
training loss: 0.42826650
validation loss: 0.29426458
=====
Epoch 74
training loss: 0.31164861
validation loss: 0.23644249
=====
Epoch 75
training loss: 0.61376578
validation loss: 0.33264232
=====
Epoch 76
training loss: 0.45902795
validation loss: 0.22820157
=====
Epoch 77
training loss: 0.25058883
validation loss: 0.31992593
=====
```

```
Epoch 78
training loss: 0.32530618
validation loss: 0.21809095
=====
Epoch 79
training loss: 0.28940347
validation loss: 0.25552255
=====
Epoch 80
training loss: 0.26835951
validation loss: 0.31802234
=====
Epoch 81
training loss: 0.26218969
validation loss: 0.24589247
=====
Epoch 82
training loss: 0.22156626
validation loss: 0.22368199
=====
Epoch 83
training loss: 0.29416811
validation loss: 0.31450674
=====
Epoch 84
training loss: 0.25559789
validation loss: 0.22888096
=====
Epoch 85
training loss: 0.22151692
validation loss: 0.20520324
=====
Epoch 86
training loss: 0.22441435
validation loss: 0.20652778
=====
Epoch 87
training loss: 0.20343862
validation loss: 0.25334111
=====
Epoch 88
training loss: 0.23915535
validation loss: 0.19491947
=====
Epoch 89
training loss: 0.19472598
validation loss: 0.23895936
=====
```

```

Epoch 90
training loss: 0.26784801
validation loss: 0.21300685
=====
Epoch 91
training loss: 0.26871440
validation loss: 0.34035826
=====
Epoch 92
training loss: 0.31858382
validation loss: 0.19383186
=====
Epoch 93
training loss: 0.23345752
validation loss: 0.25860867
=====
Epoch 94
training loss: 0.25001273
validation loss: 0.25494432
=====
Epoch 95
training loss: 0.26125592
validation loss: 0.20437303
=====
Epoch 96
training loss: 0.21454993
validation loss: 0.19251199
=====
Epoch 97
training loss: 0.22774282
validation loss: 0.24858539
=====
Epoch 98
training loss: 0.26253927
validation loss: 0.21689260
=====
Epoch 99
training loss: 0.21997014
validation loss: 0.25638014

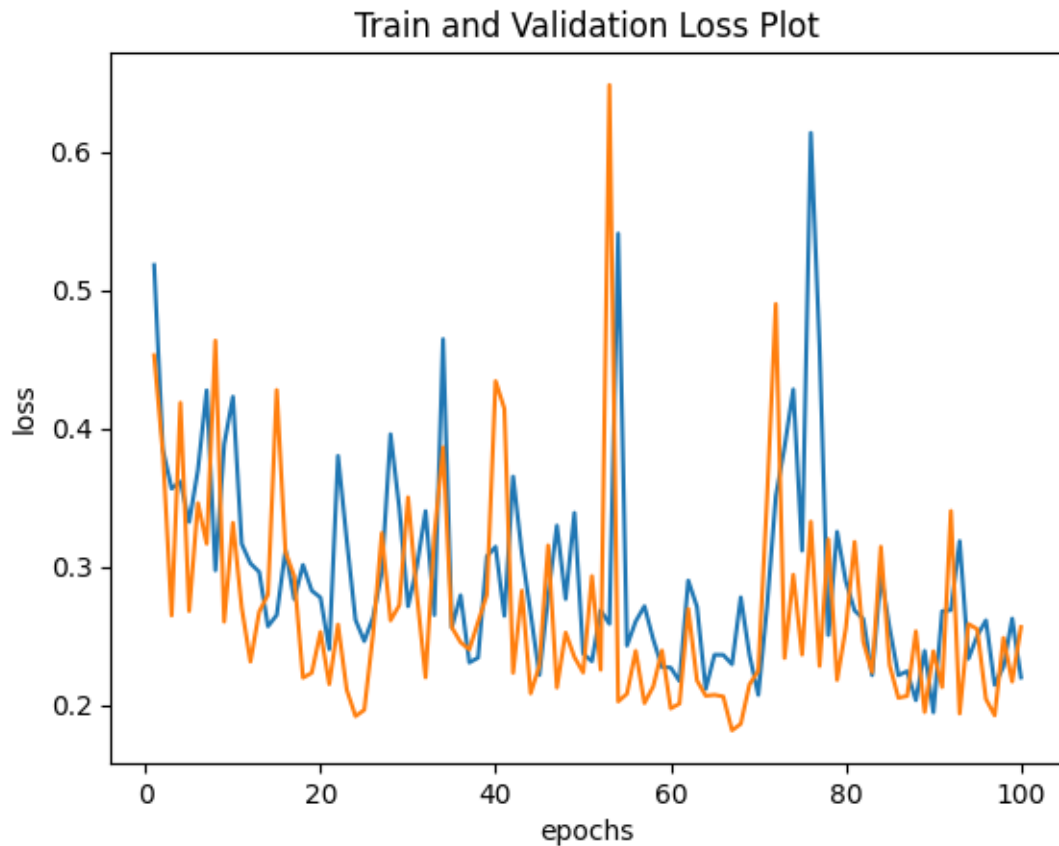
```

```

[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')

```

```
plt.show()
```



Output diatas adalah hasil pelatihan antara train set dengan validation set menggunakan model yang telah dibuat. Dalam hal ini saya menggunakan: * 1 Input layer dengan jumlah 6 neuron, 2 hidden layer dengan jumlah 12 neuron setiap hidden layer-nya, dan 1 output layer dengan jumlah 2 neuron. * Fungsi aktivasi yang digunakan adalah ReLU dengan metode nn.Linear * Jumlah iterasi yang digunakan adalah 100 epoch * Teknik optimasi yang digunakan adalah Adam dengan fungsi loss:Cross Entropy Loss * Besar learning rate adalah 0.2

Hasil diatas merupakan hasil yang cukup baik akan tetapi belum bisa dikatakan sangat baik. Warna biru menandakan training set dan warna orange menandakan validation set. Karena perbedaan loss yang tidak terlalu berbeda jauh antara training set dengan validation set, kita akan menguji model kita ke test set.

```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

Kita akan mengambil model terbaik dari hasil uji diatas.

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))
```

=====

Predicted Class:

```
[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 0 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 0 1 0 1 1 1 0 0 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 0
 1 1 0 0 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 0
 0 1 1 0 1 0 0 0 1 0 0 1 0 1 0 1 0 1 0 1 0 0 1]
```

Ground Truth:

```
[1 1 1 0 0 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]
```

Confusion Matrix:

```
[[48  4]
 [15 67]]
```

Accuracy: 0.8582089552238806

F1 Score: 0.8552998010798523

Classification Report:

	precision	recall	f1-score	support
0	0.76	0.92	0.83	52
1	0.94	0.82	0.88	82
accuracy			0.86	134
macro avg	0.85	0.87	0.86	134
weighted avg	0.87	0.86	0.86	134

Output diatas merupakan hasil penerapan model baseline kepada testing set. Hasil menunjukan performa yang sanga baik, nilai akurasi, presisi, dan recall semua berada diatas 85%. * Accuracy: Secara keseluruhan, seberapa sering mode kita memprediksi setiap observasi dengan tepat? * Presisi: Positive predicted value, ketika observasi di prediksi sebagai kelas 1, berapa kali hal tersebut benar? Berbicara tentang seberapa bermanfaat hasil yang didapatkan. Biasanya presisi yang tinggi dibutuhkan untuk rekomendasi system, e-commerce, dan website. * Recall: True positive rate, ketika pada kenyataanya observasi dikategorikan kedalam kelas 1, seberapa sering itu benar? Bercicara tentang seberapa *complete* hasil kita. Biasanya recall yang tinggi dibutuhkan untuk data medical. * F1-score: Rata-rata hamonic dari presisi dan recall. F1 dipakai ketika nilai true negatif tinggi, atau ketika penambahan data tidak terlalu berpengaruh pada hasil performa.

Saya akan membahas hasil output diatas setelah melakukan tuning hyperparameter.

Pada kesempatan berikutnya saya melakukan tuning hyperparameter dan memodifikasi arsitektur baseline. Saya mencoba 10 kali modifikasi arsitektur beserta tuning hyper parameter. Dari kesepuluh percobaan tersebut didapatkan hasil yang paling memuaskan yaitu:

8 Nomor 1d

[LO 3, LO 4, 15 poin] Setelah mengetahui hasil dari nomor (1c), modifikasi arsitektur pada nomor 1c untuk mendapatkan nilai akurasi optimal yang kalian dapatkan (kalian dapat menambahkan atau mengurangi arsitektur tersebut, atau mengganti hyperparameter, atau menggunakan tuning pada hyperparameter). Jelaskan alasan kalian untuk menggunakan pendekatan yang kalian pilih.

8.1 Modifikasi Arsitektur 1

- Jumlah hidden layer masih sama yakni 2, akan tetapi jumlah neuron di hidden layer pertama dan kedua diubah menjadi 20.
- Optimasi yang digunakan adalah SGD dengan learning rate 0.01
- Jumlah epoch adalah 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 20)
        self.bn1 = nn.BatchNorm1d(20)

        self.fc2 = nn.Linear(20, 20)
        self.bn2 = nn.BatchNorm1d(20)

        self.fc3 = nn.Linear(20, 2)
#total ada 2 hidden layer.

#arsitektur, model yg kita rancang
    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X
```

```
[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
```

```
optimizer = torch.optim.SGD(net.parameters(), lr=0.01)
```

```
[ ]: epochs = 300

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward()
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====
    # validation
    valid_losses = []
    with torch.set_grad_enabled(False):
        for iteration, batch_data in enumerate(valid_loader):
            X_batch, y_batch = batch_data

            out = net(X_batch)
            loss = criterion(out, y_batch.squeeze())
            valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
```



```

print('validation loss: {:.10.8f}'.format(valid_mean_loss))

valid_mean_losses.append(valid_mean_loss)

if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
    valid_best_loss = valid_mean_loss
    torch.save(net.state_dict(), "best_model.pth")
    best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.45553604
validation loss: 0.40837893
=====
Epoch 1
training loss: 0.37022632
validation loss: 0.37232083
=====
Epoch 2
training loss: 0.33729371
validation loss: 0.34833816
=====
Epoch 3
training loss: 0.33376542
validation loss: 0.34124485
=====
Epoch 4
training loss: 0.29554191
validation loss: 0.31201831
=====
Epoch 5
training loss: 0.30351612
validation loss: 0.31221202
=====
Epoch 6
training loss: 0.26308605
validation loss: 0.25674456
=====
Epoch 7
training loss: 0.24523143
validation loss: 0.27808720
=====
Epoch 8
training loss: 0.23852459
validation loss: 0.27349529
=====

```

```
Epoch 9
training loss: 0.21555392
validation loss: 0.23131469
=====
Epoch 10
training loss: 0.22944969
validation loss: 0.25057793
=====
Epoch 11
training loss: 0.21942605
validation loss: 0.22603102
=====
Epoch 12
training loss: 0.23373507
validation loss: 0.31309319
=====
Epoch 13
training loss: 0.23348345
validation loss: 0.26482266
=====
Epoch 14
training loss: 0.22044796
validation loss: 0.25336629
=====
Epoch 15
training loss: 0.19631176
validation loss: 0.21342738
=====
Epoch 16
training loss: 0.20615347
validation loss: 0.22016498
=====
Epoch 17
training loss: 0.21991928
validation loss: 0.22205168
=====
Epoch 18
training loss: 0.18826841
validation loss: 0.22295330
=====
Epoch 19
training loss: 0.19534844
validation loss: 0.22214150
=====
Epoch 20
training loss: 0.20281500
validation loss: 0.21757971
=====
```

```
Epoch 21
training loss: 0.21176197
validation loss: 0.25805593
=====
Epoch 22
training loss: 0.19791992
validation loss: 0.17554094
=====
Epoch 23
training loss: 0.20844391
validation loss: 0.22374584
=====
Epoch 24
training loss: 0.21467789
validation loss: 0.22974266
=====
Epoch 25
training loss: 0.20508491
validation loss: 0.18974288
=====
Epoch 26
training loss: 0.19653773
validation loss: 0.20427123
=====
Epoch 27
training loss: 0.20848310
validation loss: 0.20018798
=====
Epoch 28
training loss: 0.18523012
validation loss: 0.23348384
=====
Epoch 29
training loss: 0.18941005
validation loss: 0.21343102
=====
Epoch 30
training loss: 0.20008230
validation loss: 0.19597042
=====
Epoch 31
training loss: 0.18609317
validation loss: 0.18881261
=====
Epoch 32
training loss: 0.18766688
validation loss: 0.26368344
=====
```

```

Epoch 33
training loss: 0.17488436
validation loss: 0.20797022
=====
Epoch 34
training loss: 0.18358155
validation loss: 0.23932415
=====
Epoch 35
training loss: 0.18403322
validation loss: 0.20772621
=====
Epoch 36
training loss: 0.18817009
validation loss: 0.19124271
=====
Epoch 37
training loss: 0.21791393
validation loss: 0.20875719
=====
Epoch 38
training loss: 0.16798282
validation loss: 0.16981828
=====
Epoch 39
training loss: 0.18766856
validation loss: 0.17370945
=====
Epoch 40
training loss: 0.17614694
validation loss: 0.23579133
=====
Epoch 41
training loss: 0.18277043
validation loss: 0.20821880
=====
Epoch 42
training loss: 0.18542467
validation loss: 0.19684625
=====
Epoch 43
training loss: 0.18038242
validation loss: 0.16035564
=====
Epoch 44
training loss: 0.19305781
validation loss: 0.19352634
=====

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```
Epoch 45
training loss: 0.16232699
validation loss: 0.17515436
=====
Epoch 46
training loss: 0.17692785
validation loss: 0.18782440
=====
Epoch 47
training loss: 0.17121693
validation loss: 0.17863292
=====
Epoch 48
training loss: 0.17856880
validation loss: 0.19901399
=====
Epoch 49
training loss: 0.15485857
validation loss: 0.16484971
=====
Epoch 50
training loss: 0.19635713
validation loss: 0.17318371
=====
Epoch 51
training loss: 0.17753184
validation loss: 0.19290864
=====
Epoch 52
training loss: 0.17891206
validation loss: 0.20331757
=====
Epoch 53
training loss: 0.21014541
validation loss: 0.16954090
=====
Epoch 54
training loss: 0.17011502
validation loss: 0.17061795
=====
Epoch 55
training loss: 0.16123855
validation loss: 0.18618809
=====
Epoch 56
training loss: 0.17135122
validation loss: 0.16500115
=====
```

```
Epoch 57
training loss: 0.16328436
validation loss: 0.16111305
=====
Epoch 58
training loss: 0.15498030
validation loss: 0.18053029
=====
Epoch 59
training loss: 0.14004412
validation loss: 0.20877320
=====
Epoch 60
training loss: 0.14678808
validation loss: 0.17493862
=====
Epoch 61
training loss: 0.15364265
validation loss: 0.16830002
=====
Epoch 62
training loss: 0.15720107
validation loss: 0.16558647
=====
Epoch 63
training loss: 0.19754267
validation loss: 0.16510333
=====
Epoch 64
training loss: 0.14710508
validation loss: 0.17387001
=====
Epoch 65
training loss: 0.15683089
validation loss: 0.16601834
=====
Epoch 66
training loss: 0.13998500
validation loss: 0.16040939
=====
Epoch 67
training loss: 0.16578178
validation loss: 0.15026709
=====
Epoch 68
training loss: 0.15719675
validation loss: 0.15754877
=====
```

```

Epoch 69
training loss: 0.15928556
validation loss: 0.15265137
=====
Epoch 70
training loss: 0.13875948
validation loss: 0.17125192
=====
Epoch 71
training loss: 0.14121854
validation loss: 0.15770498
=====
Epoch 72
training loss: 0.16494152
validation loss: 0.17345059
=====
Epoch 73
training loss: 0.13564657
validation loss: 0.15929450
=====
Epoch 74
training loss: 0.15900247
validation loss: 0.21914637
=====
Epoch 75
training loss: 0.18420690
validation loss: 0.15216365
=====
Epoch 76
training loss: 0.16399100
validation loss: 0.14116058
=====
Epoch 77
training loss: 0.17957023
validation loss: 0.15388060
=====
Epoch 78
training loss: 0.16603483
validation loss: 0.16420844
=====
Epoch 79
training loss: 0.18019161
validation loss: 0.14884935
=====
Epoch 80
training loss: 0.17879578
validation loss: 0.16073763
=====

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```
Epoch 81
training loss: 0.17801303
validation loss: 0.24985148
=====
Epoch 82
training loss: 0.16523570
validation loss: 0.17420512
=====
Epoch 83
training loss: 0.17159931
validation loss: 0.17047983
=====
Epoch 84
training loss: 0.15353914
validation loss: 0.15026304
=====
Epoch 85
training loss: 0.16086496
validation loss: 0.15266690
=====
Epoch 86
training loss: 0.17089374
validation loss: 0.16539101
=====
Epoch 87
training loss: 0.15204993
validation loss: 0.14395317
=====
Epoch 88
training loss: 0.18879808
validation loss: 0.14189045
=====
Epoch 89
training loss: 0.14594373
validation loss: 0.13874285
=====
Epoch 90
training loss: 0.13405053
validation loss: 0.13620426
=====
Epoch 91
training loss: 0.17075358
validation loss: 0.14216593
=====
Epoch 92
training loss: 0.17368139
validation loss: 0.14654988
=====
```



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Epoch 93
training loss: 0.15649924
validation loss: 0.14370970
=====
Epoch 94
training loss: 0.15660025
validation loss: 0.16101909
=====
Epoch 95
training loss: 0.13902949
validation loss: 0.16743062
=====
Epoch 96
training loss: 0.14387089
validation loss: 0.13801908
=====
Epoch 97
training loss: 0.15662464
validation loss: 0.14734386
=====
Epoch 98
training loss: 0.12575863
validation loss: 0.15565662
=====
Epoch 99
training loss: 0.16692910
validation loss: 0.14188917
=====
Epoch 100
training loss: 0.16541876
validation loss: 0.15769349
=====
Epoch 101
training loss: 0.15604523
validation loss: 0.13881387
=====
Epoch 102
training loss: 0.17078379
validation loss: 0.18552014
=====
Epoch 103
training loss: 0.14094159
validation loss: 0.14250749
=====
Epoch 104
training loss: 0.14914690
validation loss: 0.14602114
=====
```

```
Epoch 105
training loss: 0.16714945
validation loss: 0.17706284
=====
Epoch 106
training loss: 0.15416864
validation loss: 0.14935654
=====
Epoch 107
training loss: 0.18172322
validation loss: 0.13262995
=====
Epoch 108
training loss: 0.15926801
validation loss: 0.16878644
=====
Epoch 109
training loss: 0.13953584
validation loss: 0.15321282
=====
Epoch 110
training loss: 0.13642651
validation loss: 0.14275683
=====
Epoch 111
training loss: 0.16592808
validation loss: 0.15347472
=====
Epoch 112
training loss: 0.14465046
validation loss: 0.16249584
=====
Epoch 113
training loss: 0.14694858
validation loss: 0.15538482
=====
Epoch 114
training loss: 0.12988076
validation loss: 0.14733636
=====
Epoch 115
training loss: 0.15079148
validation loss: 0.13293245
=====
Epoch 116
training loss: 0.13659965
validation loss: 0.14573404
=====
```

```
Epoch 117
training loss: 0.14392565
validation loss: 0.12134700
=====
Epoch 118
training loss: 0.14030470
validation loss: 0.12574171
=====
Epoch 119
training loss: 0.12446063
validation loss: 0.12551941
=====
Epoch 120
training loss: 0.14262758
validation loss: 0.26078856
=====
Epoch 121
training loss: 0.15266787
validation loss: 0.13355277
=====
Epoch 122
training loss: 0.13785221
validation loss: 0.14604661
=====
Epoch 123
training loss: 0.14609367
validation loss: 0.14474466
=====
Epoch 124
training loss: 0.16825840
validation loss: 0.17397718
=====
Epoch 125
training loss: 0.15884824
validation loss: 0.13290052
=====
Epoch 126
training loss: 0.14664190
validation loss: 0.16391616
=====
Epoch 127
training loss: 0.16451883
validation loss: 0.15714008
=====
Epoch 128
training loss: 0.14535020
validation loss: 0.13847513
=====
```

```
Epoch 129
training loss: 0.14683264
validation loss: 0.14211546
=====
Epoch 130
training loss: 0.13811961
validation loss: 0.13177890
=====
Epoch 131
training loss: 0.11766296
validation loss: 0.15829049
=====
Epoch 132
training loss: 0.16599882
validation loss: 0.13714743
=====
Epoch 133
training loss: 0.14247800
validation loss: 0.17054854
=====
Epoch 134
training loss: 0.15224284
validation loss: 0.13615946
=====
Epoch 135
training loss: 0.14649859
validation loss: 0.15143555
=====
Epoch 136
training loss: 0.15125762
validation loss: 0.15369444
=====
Epoch 137
training loss: 0.13762553
validation loss: 0.14007819
=====
Epoch 138
training loss: 0.13581902
validation loss: 0.14691263
=====
Epoch 139
training loss: 0.12288647
validation loss: 0.13109708
=====
Epoch 140
training loss: 0.13465302
validation loss: 0.13384241
=====
```

```
Epoch 141
training loss: 0.15622647
validation loss: 0.21227652
=====
Epoch 142
training loss: 0.14897203
validation loss: 0.14834891
=====
Epoch 143
training loss: 0.14694856
validation loss: 0.13914819
=====
Epoch 144
training loss: 0.15613963
validation loss: 0.13051847
=====
Epoch 145
training loss: 0.14627716
validation loss: 0.14886035
=====
Epoch 146
training loss: 0.14472930
validation loss: 0.14792997
=====
Epoch 147
training loss: 0.13973318
validation loss: 0.13946705
=====
Epoch 148
training loss: 0.14991498
validation loss: 0.12265578
=====
Epoch 149
training loss: 0.15813386
validation loss: 0.13846233
=====
Epoch 150
training loss: 0.12706336
validation loss: 0.13997130
=====
Epoch 151
training loss: 0.14096054
validation loss: 0.12258619
=====
Epoch 152
training loss: 0.13967438
validation loss: 0.11960882
=====
```

Epoch 153
training loss: 0.14478406
validation loss: 0.14047442
=====

Epoch 154
training loss: 0.13320296
validation loss: 0.11857934
=====

Epoch 155
training loss: 0.13193381
validation loss: 0.13068175
=====

Epoch 156
training loss: 0.12598504
validation loss: 0.11708578
=====

Epoch 157
training loss: 0.12492394
validation loss: 0.11689002
=====

Epoch 158
training loss: 0.14681830
validation loss: 0.12074424
=====

Epoch 159
training loss: 0.13796039
validation loss: 0.11566995
=====

Epoch 160
training loss: 0.13019636
validation loss: 0.13028105
=====

Epoch 161
training loss: 0.11088303
validation loss: 0.16510428
=====

Epoch 162
training loss: 0.13426898
validation loss: 0.13249873
=====

Epoch 163
training loss: 0.11515950
validation loss: 0.16905122
=====

Epoch 164
training loss: 0.11814744
validation loss: 0.12044378
=====

```
Epoch 165
training loss: 0.14381327
validation loss: 0.12519534
=====
Epoch 166
training loss: 0.15036632
validation loss: 0.10950196
=====
Epoch 167
training loss: 0.15353721
validation loss: 0.17022534
=====
Epoch 168
training loss: 0.12840135
validation loss: 0.14082904
=====
Epoch 169
training loss: 0.12092198
validation loss: 0.12219006
=====
Epoch 170
training loss: 0.13639490
validation loss: 0.12824488
=====
Epoch 171
training loss: 0.12583724
validation loss: 0.13887148
=====
Epoch 172
training loss: 0.15863371
validation loss: 0.15131555
=====
Epoch 173
training loss: 0.13240781
validation loss: 0.13534483
=====
Epoch 174
training loss: 0.13092390
validation loss: 0.11171440
=====
Epoch 175
training loss: 0.13881162
validation loss: 0.11107069
=====
Epoch 176
training loss: 0.14485726
validation loss: 0.11288014
=====
```

```
Epoch 177
training loss: 0.14776491
validation loss: 0.14252621
=====
Epoch 178
training loss: 0.13579690
validation loss: 0.12739624
=====
Epoch 179
training loss: 0.12507294
validation loss: 0.12391189
=====
Epoch 180
training loss: 0.13770777
validation loss: 0.13263813
=====
Epoch 181
training loss: 0.13716252
validation loss: 0.11868710
=====
Epoch 182
training loss: 0.11615036
validation loss: 0.11613701
=====
Epoch 183
training loss: 0.13351798
validation loss: 0.11712095
=====
Epoch 184
training loss: 0.14034130
validation loss: 0.12868074
=====
Epoch 185
training loss: 0.12384067
validation loss: 0.12573247
=====
Epoch 186
training loss: 0.13693729
validation loss: 0.13599470
=====
Epoch 187
training loss: 0.14930262
validation loss: 0.14654465
=====
Epoch 188
training loss: 0.14907470
validation loss: 0.14247383
=====
```



```
Epoch 189
training loss: 0.13842137
validation loss: 0.18383080
=====
Epoch 190
training loss: 0.15150231
validation loss: 0.14091605
=====
Epoch 191
training loss: 0.13382697
validation loss: 0.12352458
=====
Epoch 192
training loss: 0.14739828
validation loss: 0.11591753
=====
Epoch 193
training loss: 0.12866649
validation loss: 0.09573042
=====
Epoch 194
training loss: 0.12005274
validation loss: 0.17248954
=====
Epoch 195
training loss: 0.15108408
validation loss: 0.12377601
=====
Epoch 196
training loss: 0.14782245
validation loss: 0.10942613
=====
Epoch 197
training loss: 0.14591993
validation loss: 0.12334912
=====
Epoch 198
training loss: 0.13113013
validation loss: 0.09523674
=====
Epoch 199
training loss: 0.12873860
validation loss: 0.11768410
=====
Epoch 200
training loss: 0.15574782
validation loss: 0.10991011
=====
```

Epoch 201
training loss: 0.14359759
validation loss: 0.12509668
=====

Epoch 202
training loss: 0.15389788
validation loss: 0.11959954
=====

Epoch 203
training loss: 0.12495270
validation loss: 0.11436555
=====

Epoch 204
training loss: 0.14951433
validation loss: 0.11119048
=====

Epoch 205
training loss: 0.12407418
validation loss: 0.09328815
=====

Epoch 206
training loss: 0.11468875
validation loss: 0.10877952
=====

Epoch 207
training loss: 0.15972513
validation loss: 0.11681171
=====

Epoch 208
training loss: 0.13141190
validation loss: 0.12391961
=====

Epoch 209
training loss: 0.13953055
validation loss: 0.11979409
=====

Epoch 210
training loss: 0.15671200
validation loss: 0.12103597
=====

Epoch 211
training loss: 0.14562814
validation loss: 0.10812467
=====

Epoch 212
training loss: 0.12582083
validation loss: 0.12561472
=====

Epoch 213
training loss: 0.13505520
validation loss: 0.13325812
=====

Epoch 214
training loss: 0.11584084
validation loss: 0.11633936
=====

Epoch 215
training loss: 0.11151495
validation loss: 0.12562482
=====

Epoch 216
training loss: 0.12208529
validation loss: 0.14026788
=====

Epoch 217
training loss: 0.12518542
validation loss: 0.10812234
=====

Epoch 218
training loss: 0.14378512
validation loss: 0.13001594
=====

Epoch 219
training loss: 0.14190032
validation loss: 0.11484640
=====

Epoch 220
training loss: 0.11329319
validation loss: 0.10998268
=====

Epoch 221
training loss: 0.12981971
validation loss: 0.12565584
=====

Epoch 222
training loss: 0.13112937
validation loss: 0.15284549
=====

Epoch 223
training loss: 0.12752254
validation loss: 0.14523993
=====

Epoch 224
training loss: 0.13507971
validation loss: 0.10928307
=====

```
Epoch 225
training loss: 0.14111418
validation loss: 0.15170705
=====
Epoch 226
training loss: 0.13123503
validation loss: 0.12704688
=====
Epoch 227
training loss: 0.12320405
validation loss: 0.14488280
=====
Epoch 228
training loss: 0.10487241
validation loss: 0.12996712
=====
Epoch 229
training loss: 0.12759052
validation loss: 0.13079941
=====
Epoch 230
training loss: 0.12966928
validation loss: 0.13365802
=====
Epoch 231
training loss: 0.15571132
validation loss: 0.11643293
=====
Epoch 232
training loss: 0.13672867
validation loss: 0.12304764
=====
Epoch 233
training loss: 0.14371943
validation loss: 0.12089434
=====
Epoch 234
training loss: 0.11657400
validation loss: 0.11606576
=====
Epoch 235
training loss: 0.11639131
validation loss: 0.10378651
=====
Epoch 236
training loss: 0.11434121
validation loss: 0.12139745
=====
```

```

Epoch 237
training loss: 0.16371274
validation loss: 0.11906388
=====
Epoch 238
training loss: 0.11980657
validation loss: 0.11360556
=====
Epoch 239
training loss: 0.14395358
validation loss: 0.12528181
=====
Epoch 240
training loss: 0.12904567
validation loss: 0.15294799
=====
Epoch 241
training loss: 0.15140875
validation loss: 0.11667805
=====
Epoch 242
training loss: 0.13075517
validation loss: 0.23528120
=====
Epoch 243
training loss: 0.14862429
validation loss: 0.09577560
=====
Epoch 244
training loss: 0.11932647
validation loss: 0.10392193
=====
Epoch 245
training loss: 0.10643779
validation loss: 0.10464459
=====
Epoch 246
training loss: 0.14262116
validation loss: 0.12633379
=====
Epoch 247
training loss: 0.11509552
validation loss: 0.11722659
=====
Epoch 248
training loss: 0.13641624
validation loss: 0.10506023
=====

```

```
Epoch 249
training loss: 0.13597916
validation loss: 0.12756069
=====
Epoch 250
training loss: 0.13287458
validation loss: 0.11125619
=====
Epoch 251
training loss: 0.11768095
validation loss: 0.13229275
=====
Epoch 252
training loss: 0.12919164
validation loss: 0.13487390
=====
Epoch 253
training loss: 0.13826698
validation loss: 0.11697827
=====
Epoch 254
training loss: 0.15728936
validation loss: 0.11326181
=====
Epoch 255
training loss: 0.11059441
validation loss: 0.11646395
=====
Epoch 256
training loss: 0.14185375
validation loss: 0.12239460
=====
Epoch 257
training loss: 0.12827513
validation loss: 0.11356895
=====
Epoch 258
training loss: 0.13000321
validation loss: 0.11182129
=====
Epoch 259
training loss: 0.10911209
validation loss: 0.11406199
=====
Epoch 260
training loss: 0.13845709
validation loss: 0.11551098
=====
```

```

Epoch 261
training loss: 0.12609059
validation loss: 0.10131657
=====
Epoch 262
training loss: 0.10486545
validation loss: 0.09970629
=====
Epoch 263
training loss: 0.13786364
validation loss: 0.11986130
=====
Epoch 264
training loss: 0.14288786
validation loss: 0.12149411
=====
Epoch 265
training loss: 0.11398632
validation loss: 0.12080791
=====
Epoch 266
training loss: 0.10455069
validation loss: 0.09897681
=====
Epoch 267
training loss: 0.10479508
validation loss: 0.11166797
=====
Epoch 268
training loss: 0.14967956
validation loss: 0.12939104
=====
Epoch 269
training loss: 0.11376385
validation loss: 0.11603447
=====
Epoch 270
training loss: 0.11446910
validation loss: 0.11539578
=====
Epoch 271
training loss: 0.12575935
validation loss: 0.08892047
=====
Epoch 272
training loss: 0.11586001
validation loss: 0.09052346
=====

```

```
Epoch 273
training loss: 0.11577997
validation loss: 0.12243055
=====
Epoch 274
training loss: 0.11254770
validation loss: 0.10168629
=====
Epoch 275
training loss: 0.14311470
validation loss: 0.11731762
=====
Epoch 276
training loss: 0.13261043
validation loss: 0.11209070
=====
Epoch 277
training loss: 0.10869878
validation loss: 0.10669706
=====
Epoch 278
training loss: 0.12669678
validation loss: 0.09307823
=====
Epoch 279
training loss: 0.12579693
validation loss: 0.09552715
=====
Epoch 280
training loss: 0.10915531
validation loss: 0.11659359
=====
Epoch 281
training loss: 0.12021657
validation loss: 0.11435956
=====
Epoch 282
training loss: 0.13783862
validation loss: 0.10349716
=====
Epoch 283
training loss: 0.11474144
validation loss: 0.11033566
=====
Epoch 284
training loss: 0.10466936
validation loss: 0.11268834
=====
```


Epoch 285
training loss: 0.10859305
validation loss: 0.10294453
=====

Epoch 286
training loss: 0.12186884
validation loss: 0.10270611
=====

Epoch 287
training loss: 0.12337052
validation loss: 0.10424218
=====

Epoch 288
training loss: 0.13051115
validation loss: 0.09639846
=====

Epoch 289
training loss: 0.13464077
validation loss: 0.09965862
=====

Epoch 290
training loss: 0.08946843
validation loss: 0.10627729
=====

Epoch 291
training loss: 0.11014186
validation loss: 0.10714588
=====

Epoch 292
training loss: 0.12529412
validation loss: 0.19431885
=====

Epoch 293
training loss: 0.15359780
validation loss: 0.14744042
=====

Epoch 294
training loss: 0.13870832
validation loss: 0.11917609
=====

Epoch 295
training loss: 0.10512275
validation loss: 0.11674797
=====

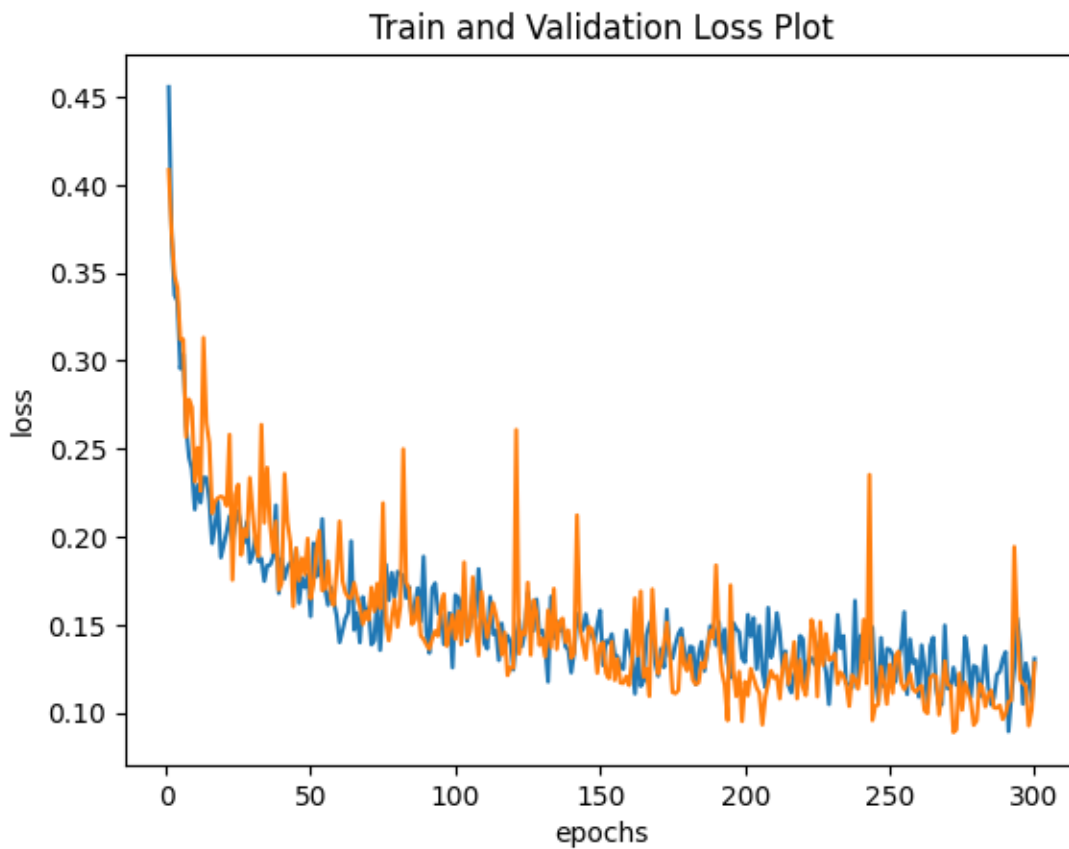
Epoch 296
training loss: 0.12816770
validation loss: 0.11516786
=====

Epoch 297
training loss: 0.11925351
validation loss: 0.09273795
=====

Epoch 298
training loss: 0.10668233
validation loss: 0.10152344
=====

Epoch 299
training loss: 0.13078167
validation loss: 0.12828121

```
[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1, epochs+1), train_mean_losses)
    plt.plot(range(1, epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()
```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))
```

=====

Predicted Class:

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 0 0 1

```

0 1 1 0 1 1 1 0 1 1 1 0 0 1 1 0 0 1 1 1 1 0 1 1 1 1 1 1 1 0 0 1 1 1 1 0
1 1 0 1 0 1 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 0 0 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

Confusion Matrix:

```

[[48  4]
 [ 7 75]]

```

Accuracy: 0.917910447761194

F1 Score: 0.9144366401578916

Classification Report:

	precision	recall	f1-score	support
0	0.87	0.92	0.90	52
1	0.95	0.91	0.93	82
accuracy			0.92	134
macro avg	0.91	0.92	0.91	134
weighted avg	0.92	0.92	0.92	134

9 Nomor 1e

[LO 3, LO 4, 5 poin] Lakukan evaluasi unjuk kerja kedua arsitektur di atas pada test set dengan mencari nilai accuracy, precision, recall dan F1-Score. Dan berikan penjelasan mengenai hasilnya dengan rinci.

9.1 Perbandingan Arsitektur Baseline dengan Arsitektur Modifikasi

Diatas merupakan percobaan terbaik dari kesepuluh eksperimen yang telah dilakukan. Adapun perubahan dari arsitektur baseline yakni: * Jumlah hidden layer sama yaitu 2, akan tetapi pada kedua layer, jumlah neuron berubah menjadi 20 neuron. * Learning rate diturunkan dari 0.2 sampai 0.01 * Jumlah iterasi/epoch ditambah dari 100 menjadi 300 * Untuk fungsi optimasi menggunakan SGD, yaitu menggunakan ReLU function.

Dari hasil diatas terjadi peningkatan performa yang cukup signifikan, dari yang awalnya memiliki akurasi sebesar 86%, setelah dilakukan tuning parameter dan modifikasi arsitektur, akurasi meningkat menjadi 92%. Hal yang sama terjadi pada nilai f1-score yang semula bernilai 86% meningkat menjadi 92%, nilai precision yang semula bernilai 85% meningkat menjadi 91%, serta nilai recall yang semula bernilai 87% meningkat menjadi 92%. Hal ini berarti model modifikasi sudah berjalan dengan optimum ketimbang model arsitektur baseline.

Berikut merupakan penjelasan mengapa model modifikasi bisa mendapatkan akurasi yang cukup tinggi:

- * Menambah jumlah neuron dapat meningkatkan kemampuan model untuk menemukan pola-pola yang lebih kompleks sehingga meningkatkan performa data. Dengan meningkatkan neuron, model dapat mempelajari pola yang lebih kompleks dan data yang lebih rumit. Akan tetapi peningkatan jumlah neuron yang terlalu banyak dapat menuju overfitting, sehingga penambahan jumlah neuron harus dipertimbangkan baik baik.
- * Learning rate dan jumlah epoch. Learning rate dan jumlah epoch merupakan dua hyperparameter yang sangat penting dalam proses pelatihan neural network. Learning rate akan berpengaruh pada perubahan bobot model setiap kali diupdate, sedangkan epoch menentukan seberapa sering model melihat dataset training selama proses pelatihan. Pada model base arsitektur sebelumnya, saya menggunakan learning rate sebesar 0.2, mungkin learning rate tersebut cukup besar sehingga model melompati titik minimum loss dan tidak dapat kembali menemukan titik minimum global. Selain itu epoch yang kurang cukup banyak mungkin membuat model tidak memiliki cukup waktu untuk mempelajari data yang ada. Oleh karena itu, melalui berbagai eksperimen saya menurunkan learning rate menjadi 0.01 (jangan terlalu kecil karena akan memakan waktu yang lama) serta menaikkan jumlah epoch, dengan adanya kedua ini, mungkin model yang dibuat dapat menemukan nilai optimal dari bobotnya tanpa terlalu cepat atau lambat sehingga menghasilkan performa yang cukup memuaskan.

Kemudian, baik pada model arsitektur base dengan model arsitektur setelah modifikasi, tidak terlalu terlihat pola overfitting ataupun underfitting. Akan tetapi pada model setelah dilakukan tuning, nilai loss antara training dengan validasi nampak lebih berdekatan dan mengalami penurunan loss yang perlahan tapi konsisten. Hal ini berbeda dengan nilai loss pada training dan validasi set di model sebelumnya yang cenderung lebih tidak stabil dan kurang terlihat perkembangannya. Hal ini dapat berarti bahwa model secara bertahap menyesuaikan diri dengan data pelatihan dan semakin akurat dalam memprediksi nilai target.

Contoh model yang overfit terlihat pada modifikasi arsitektur 5. Pada modifikasi arsitektur tersebut terlihat bahwa antara loss train set (biru) dan validation set (orange) tidak berdempetan sama sekali. Garis biru selalu berada jauh di bawah garis orange. Ini berarti bahwa model bekerja dengan baik, menghasilkan loss yang semakin kecil hanya pada train set.

10 Nomor 1f

<https://drive.google.com/drive/folders/1iXpxIgVLqB1G-cWYxDCVfIwRd05f-k?usp=sharing>

11 Modifikasi Arsitektur 2

- Jumlah hidden layer 1 dengan jumlah neuron 16 pada hidden layer tersebut
- Optimasi yang digunakan adalah SGD dengan learning rate 0.1
- Jumlah epoch adalah 400

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 16)
        self.bn1 = nn.BatchNorm1d(16)

        self.fc2 = nn.Linear(16, 2)

#arsitektur, model yg kita rancang
    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)

        return X
```

```
[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.1)
```

```
[ ]: epochs = 400

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data
```

```

optimizer.zero_grad()

out = net(X_batch)
loss = criterion(out, y_batch.squeeze())

loss.backward()
optimizer.step()

train_losses.append(loss)

train_mean_loss = torch.mean(torch.stack(train_losses))
print('training loss: {:.10.8f}'.format(train_mean_loss))

train_mean_losses.append(train_mean_loss)

#=====
# validation
valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

valid_mean_loss = torch.mean(torch.stack(valid_losses))
print('validation loss: {:.10.8f}'.format(valid_mean_loss))

valid_mean_losses.append(valid_mean_loss)

if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
    valid_best_loss = valid_mean_loss
    torch.save(net.state_dict(), "best_model.pth")
    best_epoch = i
#=====

```

```

=====
Epoch 0

```

```

training loss: 0.37094828
validation loss: 0.35139602

```

```

=====
Epoch 1

```

```

training loss: 0.32610264
validation loss: 0.28421313

```

```

=====
Epoch 2

```

```
training loss: 0.27613422
validation loss: 0.40950888
=====
Epoch 3
training loss: 0.28877994
validation loss: 0.29952717
=====
Epoch 4
training loss: 0.26020467
validation loss: 0.25451851
=====
Epoch 5
training loss: 0.25781599
validation loss: 0.27470535
=====
Epoch 6
training loss: 0.27913594
validation loss: 0.29666698
=====
Epoch 7
training loss: 0.24742590
validation loss: 0.24806392
=====
Epoch 8
training loss: 0.26162255
validation loss: 0.28125936
=====
Epoch 9
training loss: 0.27515411
validation loss: 0.26560751
=====
Epoch 10
training loss: 0.26785627
validation loss: 0.29949275
=====
Epoch 11
training loss: 0.27936235
validation loss: 0.34325838
=====
Epoch 12
training loss: 0.24138848
validation loss: 0.24769658
=====
Epoch 13
training loss: 0.25028539
validation loss: 0.23460236
=====
Epoch 14
```



```

training loss: 0.24544643
validation loss: 0.22076857
=====
Epoch 15
training loss: 0.25344878
validation loss: 0.21087778
=====
Epoch 16
training loss: 0.24910952
validation loss: 0.23342471
=====
Epoch 17
training loss: 0.24106151
validation loss: 0.21513999
=====
Epoch 18
training loss: 0.22107531
validation loss: 0.22044712
=====
Epoch 19
training loss: 0.27209410
validation loss: 0.19159487
=====
Epoch 20
training loss: 0.23570082
validation loss: 0.20395559
=====
Epoch 21
training loss: 0.20507626
validation loss: 0.23066397
=====
Epoch 22
training loss: 0.20859730
validation loss: 0.21744542
=====
Epoch 23
training loss: 0.22964323
validation loss: 0.25302419
=====
Epoch 24
training loss: 0.21388412
validation loss: 0.18397908
=====
Epoch 25
training loss: 0.25294325
validation loss: 0.19887321
=====
Epoch 26

```

```
training loss: 0.23963217
validation loss: 0.19246462
=====
Epoch 27
training loss: 0.22256328
validation loss: 0.20286793
=====
Epoch 28
training loss: 0.22431678
validation loss: 0.38683546
=====
Epoch 29
training loss: 0.22585475
validation loss: 0.21081014
=====
Epoch 30
training loss: 0.23577245
validation loss: 0.19820003
=====
Epoch 31
training loss: 0.21695031
validation loss: 0.19084272
=====
Epoch 32
training loss: 0.24479809
validation loss: 0.32030568
=====
Epoch 33
training loss: 0.20798358
validation loss: 0.33516622
=====
Epoch 34
training loss: 0.21992733
validation loss: 0.20752680
=====
Epoch 35
training loss: 0.21911925
validation loss: 0.23290642
=====
Epoch 36
training loss: 0.21653025
validation loss: 0.25727886
=====
Epoch 37
training loss: 0.23385490
validation loss: 0.31671464
=====
Epoch 38
```

```
training loss: 0.24045016
validation loss: 0.31291935
=====
Epoch 39
training loss: 0.23794170
validation loss: 0.22884402
=====
Epoch 40
training loss: 0.22610627
validation loss: 0.19117887
=====
Epoch 41
training loss: 0.21906909
validation loss: 0.20301372
=====
Epoch 42
training loss: 0.21334860
validation loss: 0.20396735
=====
Epoch 43
training loss: 0.20402786
validation loss: 0.20091653
=====
Epoch 44
training loss: 0.20970912
validation loss: 0.21854405
=====
Epoch 45
training loss: 0.21281454
validation loss: 0.23255964
=====
Epoch 46
training loss: 0.22072823
validation loss: 0.19096009
=====
Epoch 47
training loss: 0.23033707
validation loss: 0.22293295
=====
Epoch 48
training loss: 0.23253326
validation loss: 0.28787807
=====
Epoch 49
training loss: 0.22550757
validation loss: 0.19108060
=====
Epoch 50
```

```
training loss: 0.22484232
validation loss: 0.22907346
=====
Epoch 51
training loss: 0.22712828
validation loss: 0.27319539
=====
Epoch 52
training loss: 0.23669425
validation loss: 0.21142149
=====
Epoch 53
training loss: 0.21005887
validation loss: 0.21283896
=====
Epoch 54
training loss: 0.20843206
validation loss: 0.22683136
=====
Epoch 55
training loss: 0.20714442
validation loss: 0.20410982
=====
Epoch 56
training loss: 0.21403788
validation loss: 0.23560899
=====
Epoch 57
training loss: 0.23146626
validation loss: 0.22398835
=====
Epoch 58
training loss: 0.22912718
validation loss: 0.24966833
=====
Epoch 59
training loss: 0.20328867
validation loss: 0.19760594
=====
Epoch 60
training loss: 0.19332980
validation loss: 0.20891845
=====
Epoch 61
training loss: 0.21921895
validation loss: 0.27583686
=====
Epoch 62
```

```
training loss: 0.20976347
validation loss: 0.23849893
=====
Epoch 63
training loss: 0.20661213
validation loss: 0.24183966
=====
Epoch 64
training loss: 0.21087371
validation loss: 0.23243162
=====
Epoch 65
training loss: 0.19546801
validation loss: 0.17771809
=====
Epoch 66
training loss: 0.20499606
validation loss: 0.26503849
=====
Epoch 67
training loss: 0.18854044
validation loss: 0.18464783
=====
Epoch 68
training loss: 0.21028757
validation loss: 0.22341439
=====
Epoch 69
training loss: 0.21478167
validation loss: 0.21898438
=====
Epoch 70
training loss: 0.18940659
validation loss: 0.19978906
=====
Epoch 71
training loss: 0.18310714
validation loss: 0.21261914
=====
Epoch 72
training loss: 0.19284509
validation loss: 0.18569058
=====
Epoch 73
training loss: 0.21261472
validation loss: 0.48181516
=====
Epoch 74
```

```
training loss: 0.21082842
validation loss: 0.20643054
=====
Epoch 75
training loss: 0.23599142
validation loss: 0.48892254
=====
Epoch 76
training loss: 0.20621347
validation loss: 0.22560936
=====
Epoch 77
training loss: 0.20000210
validation loss: 0.24007097
=====
Epoch 78
training loss: 0.20630744
validation loss: 0.24475853
=====
Epoch 79
training loss: 0.19325364
validation loss: 0.25867009
=====
Epoch 80
training loss: 0.18788016
validation loss: 0.42182025
=====
Epoch 81
training loss: 0.22149776
validation loss: 0.19311404
=====
Epoch 82
training loss: 0.19941963
validation loss: 0.22892721
=====
Epoch 83
training loss: 0.19789131
validation loss: 0.21009970
=====
Epoch 84
training loss: 0.17617302
validation loss: 0.20243536
=====
Epoch 85
training loss: 0.20243548
validation loss: 0.23991832
=====
Epoch 86
```

```
training loss: 0.19804731
validation loss: 0.23833986
=====
Epoch 87
training loss: 0.21094631
validation loss: 0.28395346
=====
Epoch 88
training loss: 0.20549390
validation loss: 0.23581180
=====
Epoch 89
training loss: 0.17972852
validation loss: 0.22200707
=====
Epoch 90
training loss: 0.19835050
validation loss: 0.25624675
=====
Epoch 91
training loss: 0.25693431
validation loss: 0.34884378
=====
Epoch 92
training loss: 0.24168433
validation loss: 0.25821120
=====
Epoch 93
training loss: 0.19960187
validation loss: 0.27410829
=====
Epoch 94
training loss: 0.21338913
validation loss: 0.26483300
=====
Epoch 95
training loss: 0.20411971
validation loss: 0.30974609
=====
Epoch 96
training loss: 0.20304668
validation loss: 0.26459897
=====
Epoch 97
training loss: 0.22203141
validation loss: 0.35392308
=====
Epoch 98
```

```
training loss: 0.21460874
validation loss: 0.23673461
=====
Epoch 99
training loss: 0.21389279
validation loss: 0.23717587
=====
Epoch 100
training loss: 0.23929000
validation loss: 0.24890362
=====
Epoch 101
training loss: 0.19998352
validation loss: 0.35660240
=====
Epoch 102
training loss: 0.20339979
validation loss: 0.26913846
=====
Epoch 103
training loss: 0.19107513
validation loss: 0.23590183
=====
Epoch 104
training loss: 0.19783778
validation loss: 0.21804346
=====
Epoch 105
training loss: 0.21138971
validation loss: 0.27720320
=====
Epoch 106
training loss: 0.22707343
validation loss: 0.22816901
=====
Epoch 107
training loss: 0.18227479
validation loss: 0.21695961
=====
Epoch 108
training loss: 0.25309265
validation loss: 0.63426739
=====
Epoch 109
training loss: 0.24232851
validation loss: 0.22582518
=====
Epoch 110
```



```
training loss: 0.20607494
validation loss: 0.20437936
=====
Epoch 111
training loss: 0.18588817
validation loss: 0.22651441
=====
Epoch 112
training loss: 0.21967353
validation loss: 0.22434774
=====
Epoch 113
training loss: 0.21960852
validation loss: 0.20696598
=====
Epoch 114
training loss: 0.21376118
validation loss: 0.20890044
=====
Epoch 115
training loss: 0.19625318
validation loss: 0.21294802
=====
Epoch 116
training loss: 0.20836242
validation loss: 0.20640892
=====
Epoch 117
training loss: 0.21240950
validation loss: 0.20765828
=====
Epoch 118
training loss: 0.19013856
validation loss: 0.21559435
=====
Epoch 119
training loss: 0.19860360
validation loss: 0.20887992
=====
Epoch 120
training loss: 0.19925299
validation loss: 0.21943511
=====
Epoch 121
training loss: 0.18111899
validation loss: 0.24675193
=====
Epoch 122
```

```
training loss: 0.19990341
validation loss: 0.20160916
=====
Epoch 123
training loss: 0.20799100
validation loss: 0.36043549
=====
Epoch 124
training loss: 0.20110844
validation loss: 0.23731890
=====
Epoch 125
training loss: 0.21844794
validation loss: 0.19778094
=====
Epoch 126
training loss: 0.21347710
validation loss: 0.19782819
=====
Epoch 127
training loss: 0.21992607
validation loss: 0.17884219
=====
Epoch 128
training loss: 0.22567959
validation loss: 0.23980075
=====
Epoch 129
training loss: 0.21982089
validation loss: 0.19476117
=====
Epoch 130
training loss: 0.24541205
validation loss: 0.26700753
=====
Epoch 131
training loss: 0.20127097
validation loss: 0.29189071
=====
Epoch 132
training loss: 0.22063008
validation loss: 0.22660904
=====
Epoch 133
training loss: 0.21603137
validation loss: 0.21055025
=====
Epoch 134
```

```
training loss: 0.21688683
validation loss: 0.31146201
=====
Epoch 135
training loss: 0.23179992
validation loss: 0.23819290
=====
Epoch 136
training loss: 0.20158739
validation loss: 0.25253078
=====
Epoch 137
training loss: 0.20326346
validation loss: 0.21941032
=====
Epoch 138
training loss: 0.19926949
validation loss: 0.21552353
=====
Epoch 139
training loss: 0.20950444
validation loss: 0.20354834
=====
Epoch 140
training loss: 0.17765093
validation loss: 0.19667700
=====
Epoch 141
training loss: 0.18991193
validation loss: 0.19342627
=====
Epoch 142
training loss: 0.19052988
validation loss: 0.22265650
=====
Epoch 143
training loss: 0.19521800
validation loss: 0.34653255
=====
Epoch 144
training loss: 0.20684060
validation loss: 0.19666323
=====
Epoch 145
training loss: 0.23908135
validation loss: 0.21842135
=====
Epoch 146
```

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training loss: 0.19755164
validation loss: 0.20830652
=====
Epoch 147
training loss: 0.20059583
validation loss: 0.19055298
=====
Epoch 148
training loss: 0.21837769
validation loss: 0.36214992
=====
Epoch 149
training loss: 0.17105189
validation loss: 0.21547231
=====
Epoch 150
training loss: 0.18179744
validation loss: 0.22533303
=====
Epoch 151
training loss: 0.17230748
validation loss: 0.21300590
=====
Epoch 152
training loss: 0.18186273
validation loss: 0.23317590
=====
Epoch 153
training loss: 0.21232735
validation loss: 0.22140770
=====
Epoch 154
training loss: 0.19947194
validation loss: 0.20839784
=====
Epoch 155
training loss: 0.19523519
validation loss: 0.21332170
=====
Epoch 156
training loss: 0.19399138
validation loss: 0.20015563
=====
Epoch 157
training loss: 0.19404015
validation loss: 0.21951996
=====
Epoch 158

```

```
training loss: 0.20202780
validation loss: 0.25646907
=====
Epoch 159
training loss: 0.18926404
validation loss: 0.36691085
=====
Epoch 160
training loss: 0.20132089
validation loss: 0.42768675
=====
Epoch 161
training loss: 0.20398910
validation loss: 0.26722410
=====
Epoch 162
training loss: 0.20898178
validation loss: 0.23807035
=====
Epoch 163
training loss: 0.19009234
validation loss: 0.22336107
=====
Epoch 164
training loss: 0.19591060
validation loss: 0.32341111
=====
Epoch 165
training loss: 0.19305930
validation loss: 0.37267619
=====
Epoch 166
training loss: 0.20466359
validation loss: 0.24772449
=====
Epoch 167
training loss: 0.21470661
validation loss: 0.32031575
=====
Epoch 168
training loss: 0.23790644
validation loss: 0.42806241
=====
Epoch 169
training loss: 0.22027989
validation loss: 0.23980385
=====
Epoch 170
```

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training loss: 0.21349180
validation loss: 0.20127957
=====
Epoch 171
training loss: 0.18653120
validation loss: 0.21551980
=====
Epoch 172
training loss: 0.18760632
validation loss: 0.25157705
=====
Epoch 173
training loss: 0.21202819
validation loss: 0.20986871
=====
Epoch 174
training loss: 0.22822978
validation loss: 0.24004482
=====
Epoch 175
training loss: 0.20672984
validation loss: 0.18463469
=====
Epoch 176
training loss: 0.18974766
validation loss: 0.18631202
=====
Epoch 177
training loss: 0.20770620
validation loss: 0.20819049
=====
Epoch 178
training loss: 0.19821261
validation loss: 0.24348387
=====
Epoch 179
training loss: 0.19614102
validation loss: 0.21030822
=====
Epoch 180
training loss: 0.18455803
validation loss: 0.26791501
=====
Epoch 181
training loss: 0.19194674
validation loss: 0.20637889
=====
Epoch 182

```

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training loss: 0.19743775
validation loss: 0.20499563
=====
Epoch 183
training loss: 0.20593987
validation loss: 0.23910275
=====
Epoch 184
training loss: 0.19782954
validation loss: 0.37232363
=====
Epoch 185
training loss: 0.20226520
validation loss: 0.20392720
=====
Epoch 186
training loss: 0.17987178
validation loss: 0.19573207
=====
Epoch 187
training loss: 0.20302622
validation loss: 0.25545406
=====
Epoch 188
training loss: 0.21683031
validation loss: 0.19412360
=====
Epoch 189
training loss: 0.20465669
validation loss: 0.23635206
=====
Epoch 190
training loss: 0.17030801
validation loss: 0.20345835
=====
Epoch 191
training loss: 0.21758522
validation loss: 0.29079279
=====
Epoch 192
training loss: 0.18408479
validation loss: 0.18861660
=====
Epoch 193
training loss: 0.24709649
validation loss: 0.43722761
=====
Epoch 194

```

```
training loss: 0.20147753
validation loss: 0.22202404
=====
Epoch 195
training loss: 0.19611302
validation loss: 0.23007409
=====
Epoch 196
training loss: 0.18740657
validation loss: 0.23235038
=====
Epoch 197
training loss: 0.18880163
validation loss: 0.23295817
=====
Epoch 198
training loss: 0.20245439
validation loss: 0.19606066
=====
Epoch 199
training loss: 0.18887857
validation loss: 0.20309336
=====
Epoch 200
training loss: 0.21113603
validation loss: 0.38449281
=====
Epoch 201
training loss: 0.20102549
validation loss: 0.20391347
=====
Epoch 202
training loss: 0.18883447
validation loss: 0.20888050
=====
Epoch 203
training loss: 0.19323029
validation loss: 0.23045941
=====
Epoch 204
training loss: 0.18289995
validation loss: 0.20313828
=====
Epoch 205
training loss: 0.21772943
validation loss: 0.49166062
=====
Epoch 206
```



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training loss: 0.25682634
validation loss: 0.27722442
=====
Epoch 207
training loss: 0.20044610
validation loss: 0.21256922
=====
Epoch 208
training loss: 0.19773279
validation loss: 0.23095827
=====
Epoch 209
training loss: 0.20290680
validation loss: 0.34357160
=====
Epoch 210
training loss: 0.17261267
validation loss: 0.26177925
=====
Epoch 211
training loss: 0.20169079
validation loss: 0.31192812
=====
Epoch 212
training loss: 0.23439865
validation loss: 0.33070433
=====
Epoch 213
training loss: 0.18179102
validation loss: 0.25168133
=====
Epoch 214
training loss: 0.18396369
validation loss: 0.20206179
=====
Epoch 215
training loss: 0.18366508
validation loss: 0.20522134
=====
Epoch 216
training loss: 0.19418478
validation loss: 0.20661499
=====
Epoch 217
training loss: 0.18978769
validation loss: 0.20028424
=====
Epoch 218

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```
training loss: 0.20755541
validation loss: 0.45041889
=====
Epoch 219
training loss: 0.20753767
validation loss: 0.30178037
=====
Epoch 220
training loss: 0.18501398
validation loss: 0.23415269
=====
Epoch 221
training loss: 0.20837195
validation loss: 0.18408224
=====
Epoch 222
training loss: 0.20396902
validation loss: 0.21093249
=====
Epoch 223
training loss: 0.20117556
validation loss: 0.19530842
=====
Epoch 224
training loss: 0.18407713
validation loss: 0.20884641
=====
Epoch 225
training loss: 0.20242406
validation loss: 0.22394814
=====
Epoch 226
training loss: 0.19909899
validation loss: 0.21338908
=====
Epoch 227
training loss: 0.21036699
validation loss: 0.28921497
=====
Epoch 228
training loss: 0.18293007
validation loss: 0.24188346
=====
Epoch 229
training loss: 0.17484422
validation loss: 0.19298525
=====
Epoch 230
```

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training loss: 0.19283056
validation loss: 0.21848549
=====
Epoch 231
training loss: 0.16501042
validation loss: 0.22462548
=====
Epoch 232
training loss: 0.23673257
validation loss: 1.27353835
=====
Epoch 233
training loss: 0.39192209
validation loss: 0.22988094
=====
Epoch 234
training loss: 0.24636504
validation loss: 0.22559077
=====
Epoch 235
training loss: 0.24094664
validation loss: 0.28892517
=====
Epoch 236
training loss: 0.23066664
validation loss: 0.31386453
=====
Epoch 237
training loss: 0.27251688
validation loss: 0.39604086
=====
Epoch 238
training loss: 0.25385633
validation loss: 0.37409148
=====
Epoch 239
training loss: 0.23174715
validation loss: 0.23331629
=====
Epoch 240
training loss: 0.22578815
validation loss: 0.39131233
=====
Epoch 241
training loss: 0.23632544
validation loss: 0.31351328
=====
Epoch 242

```

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training loss: 0.24910542
validation loss: 0.37631002
=====
Epoch 243
training loss: 0.21553689
validation loss: 0.23359390
=====
Epoch 244
training loss: 0.23866950
validation loss: 0.22339880
=====
Epoch 245
training loss: 0.25549355
validation loss: 0.21796417
=====
Epoch 246
training loss: 0.22626175
validation loss: 0.20892714
=====
Epoch 247
training loss: 0.23311076
validation loss: 0.31693774
=====
Epoch 248
training loss: 0.24434094
validation loss: 0.24988064
=====
Epoch 249
training loss: 0.23278256
validation loss: 0.25210738
=====
Epoch 250
training loss: 0.24745190
validation loss: 0.24576403
=====
Epoch 251
training loss: 0.25607720
validation loss: 0.29793590
=====
Epoch 252
training loss: 0.23451242
validation loss: 0.20696113
=====
Epoch 253
training loss: 0.22319822
validation loss: 0.25621390
=====
Epoch 254

```

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training loss: 0.25618353
validation loss: 0.51362550
=====
Epoch 255
training loss: 0.21513732
validation loss: 0.21289989
=====
Epoch 256
training loss: 0.25062132
validation loss: 0.28160071
=====
Epoch 257
training loss: 0.23321590
validation loss: 0.23804754
=====
Epoch 258
training loss: 0.22352295
validation loss: 0.24090116
=====
Epoch 259
training loss: 0.21437812
validation loss: 0.22933629
=====
Epoch 260
training loss: 0.23084548
validation loss: 0.28173089
=====
Epoch 261
training loss: 0.23527226
validation loss: 1.87526107
=====
Epoch 262
training loss: 0.31202504
validation loss: 0.23849773
=====
Epoch 263
training loss: 0.23269300
validation loss: 0.22576934
=====
Epoch 264
training loss: 0.24520709
validation loss: 0.22062610
=====
Epoch 265
training loss: 0.21474066
validation loss: 0.52528286
=====
Epoch 266

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training loss: 0.23221052
validation loss: 0.25319996
=====
Epoch 267
training loss: 0.21302237
validation loss: 0.18543868
=====
Epoch 268
training loss: 0.20568365
validation loss: 0.24723315
=====
Epoch 269
training loss: 0.22360948
validation loss: 0.39871511
=====
Epoch 270
training loss: 0.24341141
validation loss: 0.38393584
=====
Epoch 271
training loss: 0.20361625
validation loss: 0.21837774
=====
Epoch 272
training loss: 0.21401346
validation loss: 0.21994486
=====
Epoch 273
training loss: 0.21404490
validation loss: 0.32362413
=====
Epoch 274
training loss: 0.20584191
validation loss: 0.50156796
=====
Epoch 275
training loss: 0.23289523
validation loss: 0.23884554
=====
Epoch 276
training loss: 0.22747195
validation loss: 0.20214796
=====
Epoch 277
training loss: 0.21622184
validation loss: 0.20810151
=====
Epoch 278

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```
training loss: 0.25348791
validation loss: 0.24257496
=====
Epoch 279
training loss: 0.23960608
validation loss: 0.34429377
=====
Epoch 280
training loss: 0.25739253
validation loss: 0.30100727
=====
Epoch 281
training loss: 0.24021876
validation loss: 0.24613413
=====
Epoch 282
training loss: 0.23416121
validation loss: 0.20532398
=====
Epoch 283
training loss: 0.20354141
validation loss: 0.22264636
=====
Epoch 284
training loss: 0.21265063
validation loss: 0.22116430
=====
Epoch 285
training loss: 0.26033261
validation loss: 0.35317811
=====
Epoch 286
training loss: 0.26283118
validation loss: 0.17991559
=====
Epoch 287
training loss: 0.22313803
validation loss: 0.18336137
=====
Epoch 288
training loss: 0.25306338
validation loss: 0.19292338
=====
Epoch 289
training loss: 0.24163388
validation loss: 0.20846273
=====
Epoch 290
```

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training loss: 0.22956783
validation loss: 0.20043880
=====
Epoch 291
training loss: 0.23442440
validation loss: 0.22018240
=====
Epoch 292
training loss: 0.20989175
validation loss: 0.19960308
=====
Epoch 293
training loss: 0.24033128
validation loss: 0.34558874
=====
Epoch 294
training loss: 0.21971731
validation loss: 0.19331953
=====
Epoch 295
training loss: 0.20110095
validation loss: 0.20118710
=====
Epoch 296
training loss: 0.21986803
validation loss: 0.18776499
=====
Epoch 297
training loss: 0.22384372
validation loss: 0.20602140
=====
Epoch 298
training loss: 0.20773514
validation loss: 0.38596281
=====
Epoch 299
training loss: 0.22420241
validation loss: 0.35152417
=====
Epoch 300
training loss: 0.20134625
validation loss: 0.29135245
=====
Epoch 301
training loss: 0.22042164
validation loss: 0.21450929
=====
Epoch 302

```



```
training loss: 0.22124201
validation loss: 0.21547596
=====
Epoch 303
training loss: 0.23140281
validation loss: 0.36902237
=====
Epoch 304
training loss: 0.23639475
validation loss: 0.21372135
=====
Epoch 305
training loss: 0.21806765
validation loss: 0.18645945
=====
Epoch 306
training loss: 0.23780507
validation loss: 0.18268204
=====
Epoch 307
training loss: 0.21783444
validation loss: 0.24947397
=====
Epoch 308
training loss: 0.21252868
validation loss: 0.19819714
=====
Epoch 309
training loss: 0.24357921
validation loss: 0.30665284
=====
Epoch 310
training loss: 0.21981040
validation loss: 0.23698628
=====
Epoch 311
training loss: 0.24482204
validation loss: 0.23100568
=====
Epoch 312
training loss: 0.24845655
validation loss: 0.19592842
=====
Epoch 313
training loss: 0.24766533
validation loss: 0.17392197
=====
Epoch 314
```

```

training loss: 0.24430442
validation loss: 0.20171520
=====
Epoch 315
training loss: 0.23470274
validation loss: 0.21866408
=====
Epoch 316
training loss: 0.28432745
validation loss: 0.32114366
=====
Epoch 317
training loss: 0.22119011
validation loss: 0.23460375
=====
Epoch 318
training loss: 0.23361620
validation loss: 0.32101586
=====
Epoch 319
training loss: 0.19947992
validation loss: 0.21164049
=====
Epoch 320
training loss: 0.22027865
validation loss: 0.18669029
=====
Epoch 321
training loss: 0.20602761
validation loss: 0.30934769
=====
Epoch 322
training loss: 0.22069760
validation loss: 0.22665286
=====
Epoch 323
training loss: 0.21271619
validation loss: 0.18529156
=====
Epoch 324
training loss: 0.23997197
validation loss: 0.18655176
=====
Epoch 325
training loss: 0.23180345
validation loss: 0.42984840
=====
Epoch 326

```

```

training loss: 0.22810736
validation loss: 0.21605840
=====
Epoch 327
training loss: 0.24276567
validation loss: 0.24930584
=====
Epoch 328
training loss: 0.24468137
validation loss: 0.36582857
=====
Epoch 329
training loss: 0.24357215
validation loss: 0.33129737
=====
Epoch 330
training loss: 0.22975099
validation loss: 0.30414385
=====
Epoch 331
training loss: 0.24037825
validation loss: 0.19499880
=====
Epoch 332
training loss: 0.22020444
validation loss: 0.30590415
=====
Epoch 333
training loss: 0.22026493
validation loss: 0.26249894
=====
Epoch 334
training loss: 0.19201438
validation loss: 0.20309295
=====
Epoch 335
training loss: 0.21374419
validation loss: 0.22023977
=====
Epoch 336
training loss: 0.21090016
validation loss: 0.19746865
=====
Epoch 337
training loss: 0.24494796
validation loss: 0.21435896
=====
Epoch 338

```

```
training loss: 0.24436809
validation loss: 0.19576545
=====
Epoch 339
training loss: 0.22673091
validation loss: 0.19759022
=====
Epoch 340
training loss: 0.23396033
validation loss: 0.26380029
=====
Epoch 341
training loss: 0.22897489
validation loss: 0.23976614
=====
Epoch 342
training loss: 0.24344404
validation loss: 0.27686116
=====
Epoch 343
training loss: 0.23810384
validation loss: 0.21216625
=====
Epoch 344
training loss: 0.20663501
validation loss: 0.20427564
=====
Epoch 345
training loss: 0.22133490
validation loss: 0.20135263
=====
Epoch 346
training loss: 0.23555130
validation loss: 0.17436436
=====
Epoch 347
training loss: 0.22376120
validation loss: 0.19106832
=====
Epoch 348
training loss: 0.23313823
validation loss: 0.17974046
=====
Epoch 349
training loss: 0.20303832
validation loss: 0.19110847
=====
Epoch 350
```

```
training loss: 0.23265904
validation loss: 0.17243950
=====
Epoch 351
training loss: 0.24999638
validation loss: 0.34385854
=====
Epoch 352
training loss: 0.24053812
validation loss: 0.26329026
=====
Epoch 353
training loss: 0.24353680
validation loss: 0.22184536
=====
Epoch 354
training loss: 0.21267010
validation loss: 0.18487117
=====
Epoch 355
training loss: 0.22405255
validation loss: 0.19583449
=====
Epoch 356
training loss: 0.19844189
validation loss: 0.23353764
=====
Epoch 357
training loss: 0.20420729
validation loss: 0.16558634
=====
Epoch 358
training loss: 0.24423677
validation loss: 0.52512926
=====
Epoch 359
training loss: 0.22198609
validation loss: 0.20440914
=====
Epoch 360
training loss: 0.20240207
validation loss: 0.19264068
=====
Epoch 361
training loss: 0.22808807
validation loss: 0.21714465
=====
Epoch 362
```

```
training loss: 0.19376393
validation loss: 0.20099738
=====
Epoch 363
training loss: 0.23516980
validation loss: 0.48405689
=====
Epoch 364
training loss: 0.21196705
validation loss: 0.19648628
=====
Epoch 365
training loss: 0.20267718
validation loss: 0.24635853
=====
Epoch 366
training loss: 0.25650382
validation loss: 0.25823542
=====
Epoch 367
training loss: 0.22796145
validation loss: 0.19162603
=====
Epoch 368
training loss: 0.23281880
validation loss: 0.16585891
=====
Epoch 369
training loss: 0.21567151
validation loss: 0.24955085
=====
Epoch 370
training loss: 0.24645707
validation loss: 0.39467934
=====
Epoch 371
training loss: 0.22703114
validation loss: 0.20713420
=====
Epoch 372
training loss: 0.27874807
validation loss: 0.23426291
=====
Epoch 373
training loss: 0.21914126
validation loss: 0.18629909
=====
Epoch 374
```

```

training loss: 0.23126526
validation loss: 0.17327268
=====
Epoch 375
training loss: 0.23003295
validation loss: 0.20115209
=====
Epoch 376
training loss: 0.27241376
validation loss: 0.36950266
=====
Epoch 377
training loss: 0.22261544
validation loss: 0.24651177
=====
Epoch 378
training loss: 0.19571635
validation loss: 0.19192807
=====
Epoch 379
training loss: 0.22963078
validation loss: 0.19345616
=====
Epoch 380
training loss: 0.19954953
validation loss: 0.19137958
=====
Epoch 381
training loss: 0.21055740
validation loss: 0.20444575
=====
Epoch 382
training loss: 0.21789713
validation loss: 0.18712759
=====
Epoch 383
training loss: 0.19786705
validation loss: 0.22049244
=====
Epoch 384
training loss: 0.22554289
validation loss: 0.22475682
=====
Epoch 385
training loss: 0.22401094
validation loss: 0.34128502
=====
Epoch 386

```

```

training loss: 0.22514635
validation loss: 0.31982875
=====
Epoch 387
training loss: 0.25029033
validation loss: 0.25569984
=====
Epoch 388
training loss: 0.20444120
validation loss: 0.18448889
=====
Epoch 389
training loss: 0.21465047
validation loss: 0.18796834
=====
Epoch 390
training loss: 0.21005829
validation loss: 0.20141698
=====
Epoch 391
training loss: 0.21989636
validation loss: 0.17430104
=====
Epoch 392
training loss: 0.24360251
validation loss: 0.20328932
=====
Epoch 393
training loss: 0.20899874
validation loss: 0.17593914
=====
Epoch 394
training loss: 0.23461992
validation loss: 0.29545787
=====
Epoch 395
training loss: 0.21631439
validation loss: 0.24088748
=====
Epoch 396
training loss: 0.21550490
validation loss: 0.29965290
=====
Epoch 397
training loss: 0.23629181
validation loss: 0.21535096
=====
Epoch 398

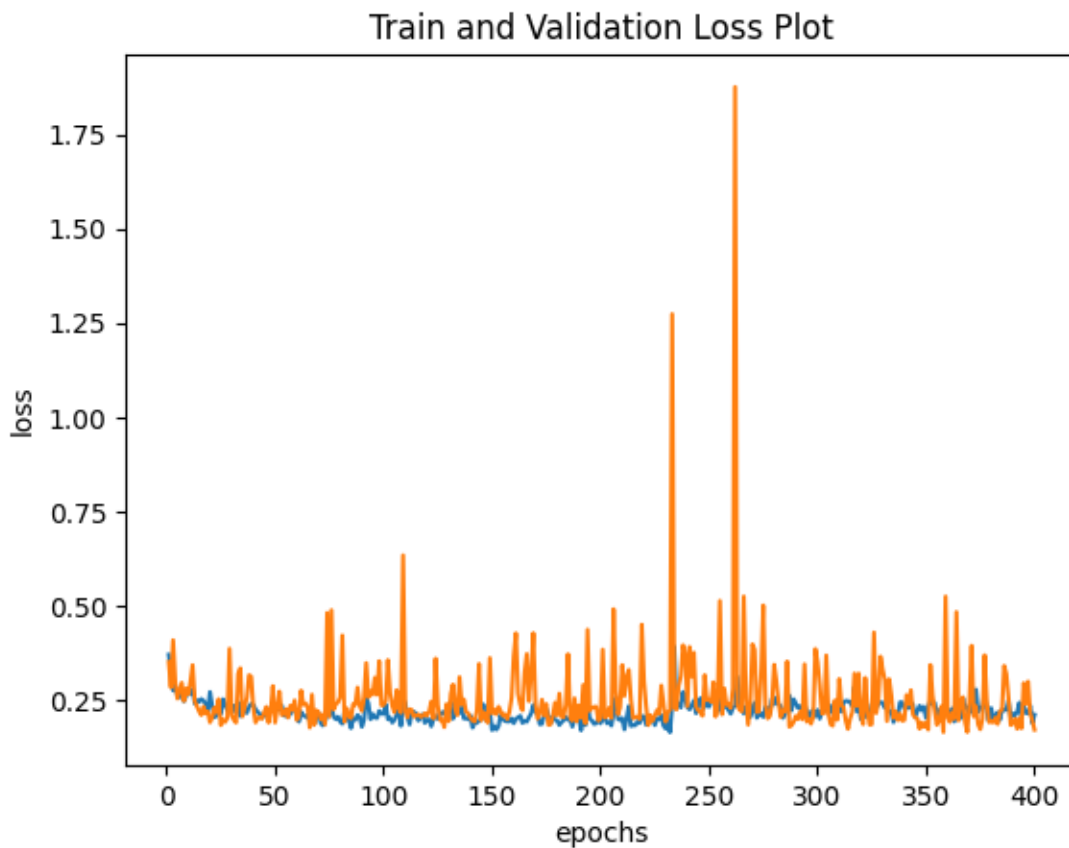
```



```
training loss: 0.18945558
validation loss: 0.19659713
```

```
=====
Epoch 399
training loss: 0.21188951
validation loss: 0.17185679
```

```
[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()
```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))
```

=====

Predicted Class:

```
[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 0 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 0 1 0 1 1 1 0 1 1 1 0 0 1 1 1 1 0 1 1 1 1 1 1 0 0 0 1 1 1 0 1
 1 1 0 0 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 0 1 0 1 0 0 0 1 0 0 1 0 1 0 1 0 1 0 1 0 0 1]
```

Ground Truth:

```
[1 1 1 0 0 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]
```

Confusion Matrix:

```
[[48  4]
 [13 69]]
```

Accuracy: 0.8731343283582089

F1 Score: 0.8699400513845276

Classification Report:

	precision	recall	f1-score	support
0	0.79	0.92	0.85	52
1	0.95	0.84	0.89	82
accuracy			0.87	134
macro avg	0.87	0.88	0.87	134
weighted avg	0.88	0.87	0.87	134

12 Modifikasi Arsitektur 3

- Hidden layer berjumlah 3, dengan jumlah neuron di masing-masing hidden layer sebanyak 16 neuron
- Optimasi yang digunakan adalah SGD dengan learning rate=0.5
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 12)
        self.bn1 = nn.BatchNorm1d(12)

        self.fc2 = nn.Linear(12, 12)
        self.bn2 = nn.BatchNorm1d(12)
```

```

        self.fc3 = nn.Linear(12, 12)
        self.bn3 = nn.BatchNorm1d(12)

        self.fc4 = nn.Linear(12, 2)
#total ada 2 hidden layer.

#arsitektur, model yg kita rancang
    def forward(self, X):
        X = self.fc1(X) #fc1 --> linier, perceptron biasa. dense dlm
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)
        X = F.relu(X)
        X = self.bn3(X)
        X = self.fc4(X)

    return X

```

```

[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.5)

```

```

[ ]: epochs = 500 #jumlah epoch 300 epoch

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

```

```

for iteration, batch_data in enumerate(train_loader):
    X_batch, y_batch = batch_data

    optimizer.zero_grad()

    out = net(X_batch)
    loss = criterion(out, y_batch.squeeze())

    loss.backward()    # perhitungan backpropagation
    optimizer.step()

    train_losses.append(loss)    #memperbaharui setiao weight atau bbot

train_mean_loss = torch.mean(torch.stack(train_losses))
print('training loss: {:.10.8f}'.format(train_mean_loss))

train_mean_losses.append(train_mean_loss)

#=====
# validation#setiap epoch lakukan validation
valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0

```

```

training loss: 0.40107766

```

```

validation loss: 0.45305672
=====

```

```

Epoch 1

```

```

training loss: 0.32703072

```

```

validation loss: 0.62668830
=====
Epoch 2
training loss: 0.36042070
validation loss: 0.43439862
=====
Epoch 3
training loss: 0.30474421
validation loss: 0.21988975
=====
Epoch 4
training loss: 0.27604687
validation loss: 0.26239783
=====
Epoch 5
training loss: 0.29118446
validation loss: 0.24153706
=====
Epoch 6
training loss: 0.23241775
validation loss: 0.29505605
=====
Epoch 7
training loss: 0.29306990
validation loss: 0.38701931
=====
Epoch 8
training loss: 0.28264740
validation loss: 0.26919794
=====
Epoch 9
training loss: 0.25887719
validation loss: 0.18836743
=====
Epoch 10
training loss: 0.23841399
validation loss: 0.22614947
=====
Epoch 11
training loss: 0.25032613
validation loss: 0.30327496
=====
Epoch 12
training loss: 0.24634504
validation loss: 0.41075492
=====
Epoch 13
training loss: 0.24419001

```

```

validation loss: 0.30292913
=====
Epoch 14
training loss: 0.22423561
validation loss: 0.48254937
=====
Epoch 15
training loss: 0.23543954
validation loss: 0.21408474
=====
Epoch 16
training loss: 0.23962462
validation loss: 0.19345005
=====
Epoch 17
training loss: 0.23626757
validation loss: 0.76693594
=====
Epoch 18
training loss: 0.25848484
validation loss: 0.32667816
=====
Epoch 19
training loss: 0.22958852
validation loss: 0.22193350
=====
Epoch 20
training loss: 0.19504319
validation loss: 0.27877811
=====
Epoch 21
training loss: 0.24750745
validation loss: 0.35482728
=====
Epoch 22
training loss: 0.18890086
validation loss: 0.27904594
=====
Epoch 23
training loss: 0.19249170
validation loss: 0.20981282
=====
Epoch 24
training loss: 0.26684475
validation loss: 0.40027016
=====
Epoch 25
training loss: 0.25340909

```

```
validation loss: 0.26355264
=====
Epoch 26
training loss: 0.24656320
validation loss: 0.55433899
=====
Epoch 27
training loss: 0.24617182
validation loss: 0.36733121
=====
Epoch 28
training loss: 0.25471288
validation loss: 0.38116342
=====
Epoch 29
training loss: 0.21258374
validation loss: 0.19107302
=====
Epoch 30
training loss: 0.22864050
validation loss: 0.33472183
=====
Epoch 31
training loss: 0.23545727
validation loss: 0.25560716
=====
Epoch 32
training loss: 0.21388955
validation loss: 0.25853091
=====
Epoch 33
training loss: 0.23925193
validation loss: 0.26342052
=====
Epoch 34
training loss: 0.22448060
validation loss: 0.33963990
=====
Epoch 35
training loss: 0.20740518
validation loss: 0.22746836
=====
Epoch 36
training loss: 0.19755113
validation loss: 0.24751206
=====
Epoch 37
training loss: 0.19096382
```



```

validation loss: 0.33875287
=====
Epoch 38
training loss: 0.20919235
validation loss: 0.28793633
=====
Epoch 39
training loss: 0.22024001
validation loss: 0.25238380
=====
Epoch 40
training loss: 0.22619610
validation loss: 0.27464411
=====
Epoch 41
training loss: 0.18590929
validation loss: 0.23660697
=====
Epoch 42
training loss: 0.19951890
validation loss: 0.20947935
=====
Epoch 43
training loss: 0.24005841
validation loss: 0.44533432
=====
Epoch 44
training loss: 0.24198735
validation loss: 0.54980356
=====
Epoch 45
training loss: 0.19221191
validation loss: 0.17153881
=====
Epoch 46
training loss: 0.20941390
validation loss: 0.41693926
=====
Epoch 47
training loss: 0.23037127
validation loss: 0.33081061
=====
Epoch 48
training loss: 0.22411618
validation loss: 0.23106380
=====
Epoch 49
training loss: 0.19298792

```

```
validation loss: 0.17308772
=====
Epoch 50
training loss: 0.20963779
validation loss: 0.21529508
=====
Epoch 51
training loss: 0.21199328
validation loss: 0.37518379
=====
Epoch 52
training loss: 0.20494136
validation loss: 0.19762519
=====
Epoch 53
training loss: 0.18627866
validation loss: 0.23434943
=====
Epoch 54
training loss: 0.18439816
validation loss: 0.19637559
=====
Epoch 55
training loss: 0.19316909
validation loss: 0.19252518
=====
Epoch 56
training loss: 0.20632617
validation loss: 0.21472843
=====
Epoch 57
training loss: 0.22988524
validation loss: 0.33215749
=====
Epoch 58
training loss: 0.31593412
validation loss: 0.30109322
=====
Epoch 59
training loss: 0.31683433
validation loss: 0.41249272
=====
Epoch 60
training loss: 0.24971724
validation loss: 0.41167274
=====
Epoch 61
training loss: 0.21634723
```

```

validation loss: 0.21631454
=====
Epoch 62
training loss: 0.21565984
validation loss: 0.31981665
=====
Epoch 63
training loss: 0.22061452
validation loss: 0.29547107
=====
Epoch 64
training loss: 0.23527223
validation loss: 0.26402363
=====
Epoch 65
training loss: 0.24926011
validation loss: 1.27392864
=====
Epoch 66
training loss: 0.28750509
validation loss: 0.33213457
=====
Epoch 67
training loss: 0.20543948
validation loss: 0.25173140
=====
Epoch 68
training loss: 0.21351779
validation loss: 0.37464687
=====
Epoch 69
training loss: 0.23041704
validation loss: 0.23349941
=====
Epoch 70
training loss: 0.19624984
validation loss: 0.18667433
=====
Epoch 71
training loss: 0.22070786
validation loss: 0.30796218
=====
Epoch 72
training loss: 0.19957870
validation loss: 0.22553237
=====
Epoch 73
training loss: 0.20622648

```

```

validation loss: 0.18352482
=====
Epoch 74
training loss: 0.19677223
validation loss: 0.21584073
=====
Epoch 75
training loss: 0.17816487
validation loss: 0.36109588
=====
Epoch 76
training loss: 0.22677089
validation loss: 0.31726831
=====
Epoch 77
training loss: 0.19545272
validation loss: 0.26493132
=====
Epoch 78
training loss: 0.21283847
validation loss: 0.22345226
=====
Epoch 79
training loss: 0.20482998
validation loss: 0.25818288
=====
Epoch 80
training loss: 0.17877643
validation loss: 0.19006458
=====
Epoch 81
training loss: 0.19388701
validation loss: 0.47621584
=====
Epoch 82
training loss: 0.21000983
validation loss: 0.47740272
=====
Epoch 83
training loss: 0.20427078
validation loss: 0.18421006
=====
Epoch 84
training loss: 0.20058168
validation loss: 0.43001592
=====
Epoch 85
training loss: 0.19326274

```

```
validation loss: 0.22663350
=====
Epoch 86
training loss: 0.17533636
validation loss: 0.19712742
=====
Epoch 87
training loss: 0.17949615
validation loss: 0.19622533
=====
Epoch 88
training loss: 0.20903015
validation loss: 0.57114983
=====
Epoch 89
training loss: 0.22399558
validation loss: 0.21868548
=====
Epoch 90
training loss: 0.21684387
validation loss: 0.63290960
=====
Epoch 91
training loss: 0.24191459
validation loss: 0.36736920
=====
Epoch 92
training loss: 0.21306780
validation loss: 0.23300046
=====
Epoch 93
training loss: 0.19378771
validation loss: 0.25047150
=====
Epoch 94
training loss: 0.16542679
validation loss: 0.23829895
=====
Epoch 95
training loss: 0.18479270
validation loss: 0.27889493
=====
Epoch 96
training loss: 0.20564246
validation loss: 0.20555109
=====
Epoch 97
training loss: 0.18350770
```

```
validation loss: 0.27824250
=====
Epoch 98
training loss: 0.20316334
validation loss: 0.46404552
=====
Epoch 99
training loss: 0.17770648
validation loss: 0.19446762
=====
Epoch 100
training loss: 0.19612096
validation loss: 0.29201928
=====
Epoch 101
training loss: 0.17882687
validation loss: 0.47013783
=====
Epoch 102
training loss: 0.19830623
validation loss: 0.19620356
=====
Epoch 103
training loss: 0.21240145
validation loss: 0.21990488
=====
Epoch 104
training loss: 0.19573925
validation loss: 0.21611209
=====
Epoch 105
training loss: 0.16285941
validation loss: 0.29158425
=====
Epoch 106
training loss: 0.19574727
validation loss: 0.20200486
=====
Epoch 107
training loss: 0.17608991
validation loss: 0.27670842
=====
Epoch 108
training loss: 0.18909335
validation loss: 0.22488365
=====
Epoch 109
training loss: 0.18236379
```

```

validation loss: 0.36180627
=====
Epoch 110
training loss: 0.18843748
validation loss: 0.21623886
=====
Epoch 111
training loss: 0.19151080
validation loss: 0.28982106
=====
Epoch 112
training loss: 0.18523835
validation loss: 0.23546493
=====
Epoch 113
training loss: 0.17893592
validation loss: 0.23722927
=====
Epoch 114
training loss: 0.16218989
validation loss: 0.23155473
=====
Epoch 115
training loss: 0.17565151
validation loss: 0.26816663
=====
Epoch 116
training loss: 0.17279823
validation loss: 0.24824852
=====
Epoch 117
training loss: 0.18457288
validation loss: 0.20040508
=====
Epoch 118
training loss: 0.17502140
validation loss: 0.21381380
=====
Epoch 119
training loss: 0.18677288
validation loss: 0.20051113
=====
Epoch 120
training loss: 0.16450538
validation loss: 0.50531811
=====
Epoch 121
training loss: 0.18665954

```

```

validation loss: 0.19809742
=====
Epoch 122
training loss: 0.16924901
validation loss: 0.35685530
=====
Epoch 123
training loss: 0.19748217
validation loss: 0.17552163
=====
Epoch 124
training loss: 0.17294736
validation loss: 0.19061495
=====
Epoch 125
training loss: 0.16831101
validation loss: 0.25176701
=====
Epoch 126
training loss: 0.19727999
validation loss: 0.53304404
=====
Epoch 127
training loss: 0.19005896
validation loss: 0.33147696
=====
Epoch 128
training loss: 0.16559194
validation loss: 0.29702270
=====
Epoch 129
training loss: 0.17794779
validation loss: 0.23044764
=====
Epoch 130
training loss: 0.18535955
validation loss: 0.31924912
=====
Epoch 131
training loss: 0.18083583
validation loss: 0.26422298
=====
Epoch 132
training loss: 0.16942643
validation loss: 0.25733024
=====
Epoch 133
training loss: 0.18532695

```



```
validation loss: 0.39364612
=====
Epoch 134
training loss: 0.18801592
validation loss: 0.25258571
=====
Epoch 135
training loss: 0.15454634
validation loss: 0.21248238
=====
Epoch 136
training loss: 0.16353448
validation loss: 0.39920774
=====
Epoch 137
training loss: 0.27862969
validation loss: 0.24574226
=====
Epoch 138
training loss: 0.23615418
validation loss: 0.19603102
=====
Epoch 139
training loss: 0.21902016
validation loss: 0.33031744
=====
Epoch 140
training loss: 0.24028848
validation loss: 0.21445596
=====
Epoch 141
training loss: 0.21750946
validation loss: 0.31510088
=====
Epoch 142
training loss: 0.21000695
validation loss: 0.25363100
=====
Epoch 143
training loss: 0.18266489
validation loss: 0.18896419
=====
Epoch 144
training loss: 0.21368091
validation loss: 0.26351827
=====
Epoch 145
training loss: 0.21794929
```

```
validation loss: 0.27886546
=====
Epoch 146
training loss: 0.19214357
validation loss: 0.17212856
=====
Epoch 147
training loss: 0.16117777
validation loss: 0.20639145
=====
Epoch 148
training loss: 0.22310691
validation loss: 0.24778074
=====
Epoch 149
training loss: 0.20633036
validation loss: 0.28334066
=====
Epoch 150
training loss: 0.16984655
validation loss: 0.17339495
=====
Epoch 151
training loss: 0.20313656
validation loss: 0.18381426
=====
Epoch 152
training loss: 0.20675297
validation loss: 0.35542649
=====
Epoch 153
training loss: 0.19717585
validation loss: 0.24009001
=====
Epoch 154
training loss: 0.19892608
validation loss: 0.22037289
=====
Epoch 155
training loss: 0.16642505
validation loss: 0.21982607
=====
Epoch 156
training loss: 0.19813210
validation loss: 0.38702139
=====
Epoch 157
training loss: 0.18957710
```

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validation loss: 0.38664082
=====
Epoch 158
training loss: 0.17989127
validation loss: 0.21717364
=====
Epoch 159
training loss: 0.17765914
validation loss: 0.23175043
=====
Epoch 160
training loss: 0.18223670
validation loss: 0.24916396
=====
Epoch 161
training loss: 0.18477426
validation loss: 0.18688661
=====
Epoch 162
training loss: 0.20644023
validation loss: 0.43466145
=====
Epoch 163
training loss: 0.19243084
validation loss: 0.17778097
=====
Epoch 164
training loss: 0.14623073
validation loss: 0.21063861
=====
Epoch 165
training loss: 0.19625598
validation loss: 0.20222850
=====
Epoch 166
training loss: 0.17374916
validation loss: 0.19536737
=====
Epoch 167
training loss: 0.20933756
validation loss: 0.24330240
=====
Epoch 168
training loss: 0.23068270
validation loss: 0.23217380
=====
Epoch 169
training loss: 0.17461106

```

```
validation loss: 0.21972936
=====
Epoch 170
training loss: 0.18213275
validation loss: 0.22286253
=====
Epoch 171
training loss: 0.15651621
validation loss: 0.26168531
=====
Epoch 172
training loss: 0.16272071
validation loss: 0.19993770
=====
Epoch 173
training loss: 0.17308812
validation loss: 0.23643835
=====
Epoch 174
training loss: 0.16500184
validation loss: 0.15157244
=====
Epoch 175
training loss: 0.19262289
validation loss: 0.20889923
=====
Epoch 176
training loss: 0.18766092
validation loss: 0.21204300
=====
Epoch 177
training loss: 0.18529077
validation loss: 0.25794595
=====
Epoch 178
training loss: 0.15941040
validation loss: 0.22608106
=====
Epoch 179
training loss: 0.21811235
validation loss: 0.34391230
=====
Epoch 180
training loss: 0.18834896
validation loss: 0.18901323
=====
Epoch 181
training loss: 0.19096832
```

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validation loss: 0.18313062
=====
Epoch 182
training loss: 0.21524528
validation loss: 0.23002465
=====
Epoch 183
training loss: 0.18486945
validation loss: 0.25429317
=====
Epoch 184
training loss: 0.19105960
validation loss: 0.21540758
=====
Epoch 185
training loss: 0.15262562
validation loss: 0.18606417
=====
Epoch 186
training loss: 0.17753254
validation loss: 0.21041223
=====
Epoch 187
training loss: 0.17467400
validation loss: 0.17683364
=====
Epoch 188
training loss: 0.25527877
validation loss: 0.32688215
=====
Epoch 189
training loss: 0.19571862
validation loss: 0.26019859
=====
Epoch 190
training loss: 0.19370149
validation loss: 0.20476778
=====
Epoch 191
training loss: 0.18859766
validation loss: 0.17954794
=====
Epoch 192
training loss: 0.20573193
validation loss: 0.38375589
=====
Epoch 193
training loss: 0.20205095

```

```
validation loss: 0.59256303
=====
Epoch 194
training loss: 0.16970962
validation loss: 0.17612170
=====
Epoch 195
training loss: 0.16584681
validation loss: 0.26272532
=====
Epoch 196
training loss: 0.18281281
validation loss: 0.19306369
=====
Epoch 197
training loss: 0.20905828
validation loss: 1.43181276
=====
Epoch 198
training loss: 0.19987556
validation loss: 0.15849519
=====
Epoch 199
training loss: 0.18730800
validation loss: 0.16203780
=====
Epoch 200
training loss: 0.18483999
validation loss: 0.23705401
=====
Epoch 201
training loss: 0.21175799
validation loss: 0.16481501
=====
Epoch 202
training loss: 0.19223155
validation loss: 0.19432890
=====
Epoch 203
training loss: 0.19191097
validation loss: 0.18068913
=====
Epoch 204
training loss: 0.17528602
validation loss: 0.19423123
=====
Epoch 205
training loss: 0.17086144
```

```
validation loss: 0.16586183
=====
Epoch 206
training loss: 0.18810926
validation loss: 0.16406257
=====
Epoch 207
training loss: 0.17859355
validation loss: 0.25978094
=====
Epoch 208
training loss: 0.17582403
validation loss: 0.15866822
=====
Epoch 209
training loss: 0.17302813
validation loss: 0.17831953
=====
Epoch 210
training loss: 0.18865712
validation loss: 0.17806935
=====
Epoch 211
training loss: 0.17984803
validation loss: 0.35519129
=====
Epoch 212
training loss: 0.17321365
validation loss: 0.15566733
=====
Epoch 213
training loss: 0.14836533
validation loss: 0.19072309
=====
Epoch 214
training loss: 0.18268979
validation loss: 0.19475432
=====
Epoch 215
training loss: 0.16770960
validation loss: 0.16889325
=====
Epoch 216
training loss: 0.15390493
validation loss: 0.14802647
=====
Epoch 217
training loss: 0.21088670
```

```

validation loss: 0.18738610
=====
Epoch 218
training loss: 0.15117605
validation loss: 0.18996763
=====
Epoch 219
training loss: 0.14263952
validation loss: 0.19968027
=====
Epoch 220
training loss: 0.17813164
validation loss: 0.23620227
=====
Epoch 221
training loss: 0.17235810
validation loss: 0.15212917
=====
Epoch 222
training loss: 0.17651649
validation loss: 0.20831920
=====
Epoch 223
training loss: 0.17260410
validation loss: 0.22674213
=====
Epoch 224
training loss: 0.17960075
validation loss: 0.25887802
=====
Epoch 225
training loss: 0.16846979
validation loss: 0.21568111
=====
Epoch 226
training loss: 0.17382215
validation loss: 0.15632680
=====
Epoch 227
training loss: 0.16478923
validation loss: 0.14375958
=====
Epoch 228
training loss: 0.17452516
validation loss: 0.22610223
=====
Epoch 229
training loss: 0.16849329

```



```
validation loss: 0.19259174
=====
Epoch 230
training loss: 0.20456670
validation loss: 0.32920477
=====
Epoch 231
training loss: 0.16587046
validation loss: 0.25222147
=====
Epoch 232
training loss: 0.18649027
validation loss: 0.22854820
=====
Epoch 233
training loss: 0.16655135
validation loss: 0.18226650
=====
Epoch 234
training loss: 0.14740624
validation loss: 0.18129876
=====
Epoch 235
training loss: 0.20215145
validation loss: 0.19025005
=====
Epoch 236
training loss: 0.17412041
validation loss: 0.20857777
=====
Epoch 237
training loss: 0.17932869
validation loss: 0.22656031
=====
Epoch 238
training loss: 0.17940919
validation loss: 0.22411074
=====
Epoch 239
training loss: 0.18836711
validation loss: 0.16211304
=====
Epoch 240
training loss: 0.15842608
validation loss: 0.26602706
=====
Epoch 241
training loss: 0.17607035
```

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validation loss: 0.19854397
=====
Epoch 242
training loss: 0.17375401
validation loss: 0.26787060
=====
Epoch 243
training loss: 0.18139634
validation loss: 0.24754305
=====
Epoch 244
training loss: 0.18538010
validation loss: 0.29597825
=====
Epoch 245
training loss: 0.20045090
validation loss: 0.67358708
=====
Epoch 246
training loss: 0.17345586
validation loss: 0.16973981
=====
Epoch 247
training loss: 0.13024876
validation loss: 0.36272448
=====
Epoch 248
training loss: 0.16216612
validation loss: 0.19198750
=====
Epoch 249
training loss: 0.17906097
validation loss: 0.21721786
=====
Epoch 250
training loss: 0.17893068
validation loss: 0.24632539
=====
Epoch 251
training loss: 0.17091933
validation loss: 0.27873433
=====
Epoch 252
training loss: 0.17574950
validation loss: 0.30450431
=====
Epoch 253
training loss: 0.15128981

```

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validation loss: 0.17466520
=====
Epoch 254
training loss: 0.15521491
validation loss: 0.28774792
=====
Epoch 255
training loss: 0.17730717
validation loss: 0.56405008
=====
Epoch 256
training loss: 0.16791153
validation loss: 0.18677370
=====
Epoch 257
training loss: 0.17946164
validation loss: 0.22879860
=====
Epoch 258
training loss: 0.16647314
validation loss: 0.19764629
=====
Epoch 259
training loss: 0.19146737
validation loss: 0.27447233
=====
Epoch 260
training loss: 0.15981859
validation loss: 0.14026721
=====
Epoch 261
training loss: 0.18102604
validation loss: 0.28330588
=====
Epoch 262
training loss: 0.17695449
validation loss: 0.18085955
=====
Epoch 263
training loss: 0.16903089
validation loss: 0.15485305
=====
Epoch 264
training loss: 0.15999997
validation loss: 0.19381487
=====
Epoch 265
training loss: 0.19936688

```

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validation loss: 0.16432193
=====
Epoch 266
training loss: 0.21438108
validation loss: 0.17978998
=====
Epoch 267
training loss: 0.19371884
validation loss: 0.85273737
=====
Epoch 268
training loss: 0.15544258
validation loss: 0.17071307
=====
Epoch 269
training loss: 0.16332136
validation loss: 0.19875403
=====
Epoch 270
training loss: 0.18759613
validation loss: 0.19417374
=====
Epoch 271
training loss: 0.15188105
validation loss: 0.21545726
=====
Epoch 272
training loss: 0.20465194
validation loss: 0.60633630
=====
Epoch 273
training loss: 0.18677193
validation loss: 0.64436173
=====
Epoch 274
training loss: 0.14598916
validation loss: 0.18204963
=====
Epoch 275
training loss: 0.16878489
validation loss: 0.28214794
=====
Epoch 276
training loss: 0.18633115
validation loss: 0.39298177
=====
Epoch 277
training loss: 0.17000802

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validation loss: 0.16651559
=====
Epoch 278
training loss: 0.17014483
validation loss: 0.22253545
=====
Epoch 279
training loss: 0.16143878
validation loss: 0.18959369
=====
Epoch 280
training loss: 0.15465033
validation loss: 0.17238554
=====
Epoch 281
training loss: 0.14996350
validation loss: 0.20459533
=====
Epoch 282
training loss: 0.13983519
validation loss: 0.12293227
=====
Epoch 283
training loss: 0.16510360
validation loss: 0.16419929
=====
Epoch 284
training loss: 0.17358468
validation loss: 0.57712859
=====
Epoch 285
training loss: 0.16920312
validation loss: 0.30617240
=====
Epoch 286
training loss: 0.17143431
validation loss: 0.16762383
=====
Epoch 287
training loss: 0.16548976
validation loss: 0.30432659
=====
Epoch 288
training loss: 0.17582525
validation loss: 0.14294603
=====
Epoch 289
training loss: 0.16849890

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```
validation loss: 0.24506482
=====
Epoch 290
training loss: 0.20032790
validation loss: 0.13632861
=====
Epoch 291
training loss: 0.15938301
validation loss: 0.18805313
=====
Epoch 292
training loss: 0.14891644
validation loss: 0.21149595
=====
Epoch 293
training loss: 0.17777812
validation loss: 0.26586455
=====
Epoch 294
training loss: 0.14280505
validation loss: 0.24724877
=====
Epoch 295
training loss: 0.13742189
validation loss: 0.14797078
=====
Epoch 296
training loss: 0.14608623
validation loss: 0.21911514
=====
Epoch 297
training loss: 0.14725111
validation loss: 0.21664497
=====
Epoch 298
training loss: 0.16600688
validation loss: 0.23301703
=====
Epoch 299
training loss: 0.16108046
validation loss: 0.20052682
=====
Epoch 300
training loss: 0.14849867
validation loss: 0.30437535
=====
Epoch 301
training loss: 0.19289720
```

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validation loss: 0.81866932
=====
Epoch 302
training loss: 0.16793717
validation loss: 0.16231027
=====
Epoch 303
training loss: 0.14474756
validation loss: 0.19886434
=====
Epoch 304
training loss: 0.17453678
validation loss: 0.25606334
=====
Epoch 305
training loss: 0.15290347
validation loss: 0.20486271
=====
Epoch 306
training loss: 0.15122589
validation loss: 0.65991819
=====
Epoch 307
training loss: 0.16669108
validation loss: 0.13976924
=====
Epoch 308
training loss: 0.14280398
validation loss: 0.21700472
=====
Epoch 309
training loss: 0.13106102
validation loss: 0.15470642
=====
Epoch 310
training loss: 0.15122028
validation loss: 0.18275285
=====
Epoch 311
training loss: 0.15422475
validation loss: 0.13822660
=====
Epoch 312
training loss: 0.18060204
validation loss: 0.17781563
=====
Epoch 313
training loss: 0.16619912

```

```

validation loss: 0.25607809
=====
Epoch 314
training loss: 0.15992986
validation loss: 0.37715012
=====
Epoch 315
training loss: 0.12259481
validation loss: 0.16308951
=====
Epoch 316
training loss: 0.13868675
validation loss: 0.16102974
=====
Epoch 317
training loss: 0.15180157
validation loss: 0.16666391
=====
Epoch 318
training loss: 0.17536314
validation loss: 0.14118247
=====
Epoch 319
training loss: 0.16050798
validation loss: 0.17872714
=====
Epoch 320
training loss: 0.15144771
validation loss: 0.15056726
=====
Epoch 321
training loss: 0.12623644
validation loss: 0.21154331
=====
Epoch 322
training loss: 0.11387476
validation loss: 0.14351150
=====
Epoch 323
training loss: 0.13414635
validation loss: 0.13282779
=====
Epoch 324
training loss: 0.14192091
validation loss: 0.17609873
=====
Epoch 325
training loss: 0.15595393

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```
validation loss: 0.14650054
=====
Epoch 326
training loss: 0.15181370
validation loss: 0.16974597
=====
Epoch 327
training loss: 0.15752363
validation loss: 0.27093107
=====
Epoch 328
training loss: 0.14477435
validation loss: 0.17392647
=====
Epoch 329
training loss: 0.15625642
validation loss: 0.44151458
=====
Epoch 330
training loss: 0.12611407
validation loss: 0.15585685
=====
Epoch 331
training loss: 0.14774026
validation loss: 0.21318465
=====
Epoch 332
training loss: 0.17257361
validation loss: 0.30521223
=====
Epoch 333
training loss: 0.17087962
validation loss: 0.14129084
=====
Epoch 334
training loss: 0.16461869
validation loss: 0.31459171
=====
Epoch 335
training loss: 0.15730017
validation loss: 0.18872675
=====
Epoch 336
training loss: 0.15697657
validation loss: 0.16521946
=====
Epoch 337
training loss: 0.14174321
```

```
validation loss: 0.16365084
=====
Epoch 338
training loss: 0.14520316
validation loss: 0.15052006
=====
Epoch 339
training loss: 0.12123398
validation loss: 0.18987535
=====
Epoch 340
training loss: 0.13819990
validation loss: 0.17497338
=====
Epoch 341
training loss: 0.19219863
validation loss: 0.25472882
=====
Epoch 342
training loss: 0.16988862
validation loss: 0.18282327
=====
Epoch 343
training loss: 0.15239713
validation loss: 0.16788769
=====
Epoch 344
training loss: 0.12956990
validation loss: 0.14837456
=====
Epoch 345
training loss: 0.15394787
validation loss: 0.27845672
=====
Epoch 346
training loss: 0.12657019
validation loss: 0.18290994
=====
Epoch 347
training loss: 0.17714469
validation loss: 0.18848723
=====
Epoch 348
training loss: 0.16552131
validation loss: 0.22408403
=====
Epoch 349
training loss: 0.18039174
```

```
validation loss: 0.29057702
=====
Epoch 350
training loss: 0.15971822
validation loss: 0.21667054
=====
Epoch 351
training loss: 0.16675335
validation loss: 0.24125697
=====
Epoch 352
training loss: 0.17150027
validation loss: 0.18851180
=====
Epoch 353
training loss: 0.19027837
validation loss: 0.20992644
=====
Epoch 354
training loss: 0.22228992
validation loss: 1.46421742
=====
Epoch 355
training loss: 0.16837583
validation loss: 0.16783136
=====
Epoch 356
training loss: 0.14042324
validation loss: 0.17317942
=====
Epoch 357
training loss: 0.16398713
validation loss: 0.48987955
=====
Epoch 358
training loss: 0.17468342
validation loss: 0.29069847
=====
Epoch 359
training loss: 0.13137257
validation loss: 0.18595724
=====
Epoch 360
training loss: 0.12599185
validation loss: 0.18140882
=====
Epoch 361
training loss: 0.18094513
```

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validation loss: 0.56559634
=====
Epoch 362
training loss: 0.14725859
validation loss: 0.16910578
=====
Epoch 363
training loss: 0.13221727
validation loss: 0.14480495
=====
Epoch 364
training loss: 0.13807800
validation loss: 0.19453701
=====
Epoch 365
training loss: 0.13210623
validation loss: 0.16358840
=====
Epoch 366
training loss: 0.14431114
validation loss: 0.20384681
=====
Epoch 367
training loss: 0.18354741
validation loss: 0.42330086
=====
Epoch 368
training loss: 0.16912057
validation loss: 0.19146487
=====
Epoch 369
training loss: 0.13313152
validation loss: 0.19297059
=====
Epoch 370
training loss: 0.13768272
validation loss: 0.21295960
=====
Epoch 371
training loss: 0.15336670
validation loss: 0.37415078
=====
Epoch 372
training loss: 0.17970876
validation loss: 0.16211787
=====
Epoch 373
training loss: 0.19142625

```

```

validation loss: 0.13719209
=====
Epoch 374
training loss: 0.15692635
validation loss: 0.27731359
=====
Epoch 375
training loss: 0.16892637
validation loss: 0.18419845
=====
Epoch 376
training loss: 0.18395074
validation loss: 0.16959880
=====
Epoch 377
training loss: 0.16595638
validation loss: 0.41586566
=====
Epoch 378
training loss: 0.19535862
validation loss: 0.51816601
=====
Epoch 379
training loss: 0.16878963
validation loss: 0.19181946
=====
Epoch 380
training loss: 0.19155976
validation loss: 0.22020018
=====
Epoch 381
training loss: 0.19612381
validation loss: 0.90344399
=====
Epoch 382
training loss: 0.22024758
validation loss: 0.52652627
=====
Epoch 383
training loss: 0.18333082
validation loss: 0.35477883
=====
Epoch 384
training loss: 0.14320022
validation loss: 0.17693591
=====
Epoch 385
training loss: 0.14655383

```

```

validation loss: 0.25989047
=====
Epoch 386
training loss: 0.18917221
validation loss: 0.20712070
=====
Epoch 387
training loss: 0.18078530
validation loss: 0.42164224
=====
Epoch 388
training loss: 0.18089178
validation loss: 0.26119465
=====
Epoch 389
training loss: 0.16318378
validation loss: 0.58890766
=====
Epoch 390
training loss: 0.16669987
validation loss: 0.20993012
=====
Epoch 391
training loss: 0.14772545
validation loss: 0.20489268
=====
Epoch 392
training loss: 0.16055562
validation loss: 0.18947473
=====
Epoch 393
training loss: 0.17168552
validation loss: 0.18386732
=====
Epoch 394
training loss: 0.13946442
validation loss: 0.17769630
=====
Epoch 395
training loss: 0.18171550
validation loss: 0.24229230
=====
Epoch 396
training loss: 0.15734676
validation loss: 0.16348638
=====
Epoch 397
training loss: 0.19747365

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```

validation loss: 1.05852091
=====
Epoch 398
training loss: 0.17213750
validation loss: 0.19012238
=====
Epoch 399
training loss: 0.13699853
validation loss: 0.20782189
=====
Epoch 400
training loss: 0.16561161
validation loss: 0.18479137
=====
Epoch 401
training loss: 0.18101335
validation loss: 0.18214224
=====
Epoch 402
training loss: 0.18235767
validation loss: 0.56140524
=====
Epoch 403
training loss: 0.18648225
validation loss: 0.26383683
=====
Epoch 404
training loss: 0.15230224
validation loss: 0.23058897
=====
Epoch 405
training loss: 0.16203722
validation loss: 0.20235494
=====
Epoch 406
training loss: 0.14878236
validation loss: 0.22421747
=====
Epoch 407
training loss: 0.15266135
validation loss: 0.20655811
=====
Epoch 408
training loss: 0.15521155
validation loss: 0.39069185
=====
Epoch 409
training loss: 0.22667882

```

```

validation loss: 0.60403848
=====
Epoch 410
training loss: 0.16821627
validation loss: 0.20927577
=====
Epoch 411
training loss: 0.15396282
validation loss: 0.23307803
=====
Epoch 412
training loss: 0.17860979
validation loss: 0.17841391
=====
Epoch 413
training loss: 0.15803006
validation loss: 0.19879201
=====
Epoch 414
training loss: 0.16375948
validation loss: 0.20595819
=====
Epoch 415
training loss: 0.15317897
validation loss: 0.19387990
=====
Epoch 416
training loss: 0.14657781
validation loss: 0.22135217
=====
Epoch 417
training loss: 0.16939536
validation loss: 0.18729463
=====
Epoch 418
training loss: 0.14597537
validation loss: 0.21087736
=====
Epoch 419
training loss: 0.12721221
validation loss: 0.19000578
=====
Epoch 420
training loss: 0.17074120
validation loss: 0.19170764
=====
Epoch 421
training loss: 0.13545208

```



```
validation loss: 0.17776985
=====
Epoch 422
training loss: 0.15661147
validation loss: 0.23197347
=====
Epoch 423
training loss: 0.17413309
validation loss: 0.25516599
=====
Epoch 424
training loss: 0.15642068
validation loss: 0.18937729
=====
Epoch 425
training loss: 0.16923319
validation loss: 0.19789593
=====
Epoch 426
training loss: 0.15148968
validation loss: 0.15321706
=====
Epoch 427
training loss: 0.14799251
validation loss: 0.16311504
=====
Epoch 428
training loss: 0.16800794
validation loss: 0.32700264
=====
Epoch 429
training loss: 0.14389627
validation loss: 0.18333907
=====
Epoch 430
training loss: 0.13219751
validation loss: 0.15226014
=====
Epoch 431
training loss: 0.13700831
validation loss: 0.16812646
=====
Epoch 432
training loss: 0.14047030
validation loss: 0.17153336
=====
Epoch 433
training loss: 0.16524598
```

```
validation loss: 0.14898638
=====
Epoch 434
training loss: 0.17153652
validation loss: 0.42162055
=====
Epoch 435
training loss: 0.15069531
validation loss: 0.16287099
=====
Epoch 436
training loss: 0.14915122
validation loss: 0.16644228
=====
Epoch 437
training loss: 0.13596688
validation loss: 0.16902858
=====
Epoch 438
training loss: 0.13882107
validation loss: 0.21715619
=====
Epoch 439
training loss: 0.12365102
validation loss: 0.14232573
=====
Epoch 440
training loss: 0.13742408
validation loss: 0.17977856
=====
Epoch 441
training loss: 0.15451992
validation loss: 0.18327798
=====
Epoch 442
training loss: 0.13603753
validation loss: 0.17796159
=====
Epoch 443
training loss: 0.13692932
validation loss: 0.18414052
=====
Epoch 444
training loss: 0.12062399
validation loss: 0.16377339
=====
Epoch 445
training loss: 0.15569873
```

```
validation loss: 0.19277677
=====
Epoch 446
training loss: 0.15758145
validation loss: 0.17474622
=====
Epoch 447
training loss: 0.15386948
validation loss: 0.17332019
=====
Epoch 448
training loss: 0.13171370
validation loss: 0.19465946
=====
Epoch 449
training loss: 0.13472882
validation loss: 0.18534385
=====
Epoch 450
training loss: 0.18191014
validation loss: 1.08680940
=====
Epoch 451
training loss: 0.19883956
validation loss: 1.34200239
=====
Epoch 452
training loss: 0.53100955
validation loss: 0.47875938
=====
Epoch 453
training loss: 0.40139988
validation loss: 0.43870226
=====
Epoch 454
training loss: 0.36495540
validation loss: 0.37527871
=====
Epoch 455
training loss: 0.32985365
validation loss: 0.42278481
=====
Epoch 456
training loss: 0.34451661
validation loss: 0.35599482
=====
Epoch 457
training loss: 0.31843454
```

```
validation loss: 0.33539233
=====
Epoch 458
training loss: 0.29152787
validation loss: 0.36483967
=====
Epoch 459
training loss: 0.31450826
validation loss: 0.34764752
=====
Epoch 460
training loss: 0.33361015
validation loss: 0.54286665
=====
Epoch 461
training loss: 0.32543290
validation loss: 0.54086947
=====
Epoch 462
training loss: 0.30176049
validation loss: 0.30576068
=====
Epoch 463
training loss: 0.29140347
validation loss: 0.30589259
=====
Epoch 464
training loss: 0.29553494
validation loss: 0.35902441
=====
Epoch 465
training loss: 0.28122768
validation loss: 0.30882728
=====
Epoch 466
training loss: 0.26918069
validation loss: 0.33133084
=====
Epoch 467
training loss: 0.30250567
validation loss: 0.37649053
=====
Epoch 468
training loss: 0.27844021
validation loss: 0.30294847
=====
Epoch 469
training loss: 0.25988251
```

```

validation loss: 0.33514991
=====
Epoch 470
training loss: 0.28553757
validation loss: 0.28047442
=====
Epoch 471
training loss: 0.28124434
validation loss: 0.29011464
=====
Epoch 472
training loss: 0.27486864
validation loss: 0.26718566
=====
Epoch 473
training loss: 0.26692525
validation loss: 0.27390257
=====
Epoch 474
training loss: 0.28016910
validation loss: 0.52582210
=====
Epoch 475
training loss: 0.26217943
validation loss: 0.25430632
=====
Epoch 476
training loss: 0.25811484
validation loss: 0.31332219
=====
Epoch 477
training loss: 0.29245007
validation loss: 0.25832132
=====
Epoch 478
training loss: 0.28593823
validation loss: 0.25678822
=====
Epoch 479
training loss: 0.25888088
validation loss: 0.27203539
=====
Epoch 480
training loss: 0.25346214
validation loss: 0.30697209
=====
Epoch 481
training loss: 0.28083065

```

```
validation loss: 0.25221539
=====
Epoch 482
training loss: 0.25015560
validation loss: 0.25878894
=====
Epoch 483
training loss: 0.25257444
validation loss: 0.25768438
=====
Epoch 484
training loss: 0.23603086
validation loss: 0.24131857
=====
Epoch 485
training loss: 0.25770390
validation loss: 0.26188594
=====
Epoch 486
training loss: 0.26030514
validation loss: 0.24979292
=====
Epoch 487
training loss: 0.24567734
validation loss: 0.28545618
=====
Epoch 488
training loss: 0.25511405
validation loss: 0.24872449
=====
Epoch 489
training loss: 0.28081128
validation loss: 2.37711906
=====
Epoch 490
training loss: 0.28726992
validation loss: 0.28406012
=====
Epoch 491
training loss: 0.30018574
validation loss: 0.25353348
=====
Epoch 492
training loss: 0.30148664
validation loss: 1.03675008
=====
Epoch 493
training loss: 0.27307770
```

```

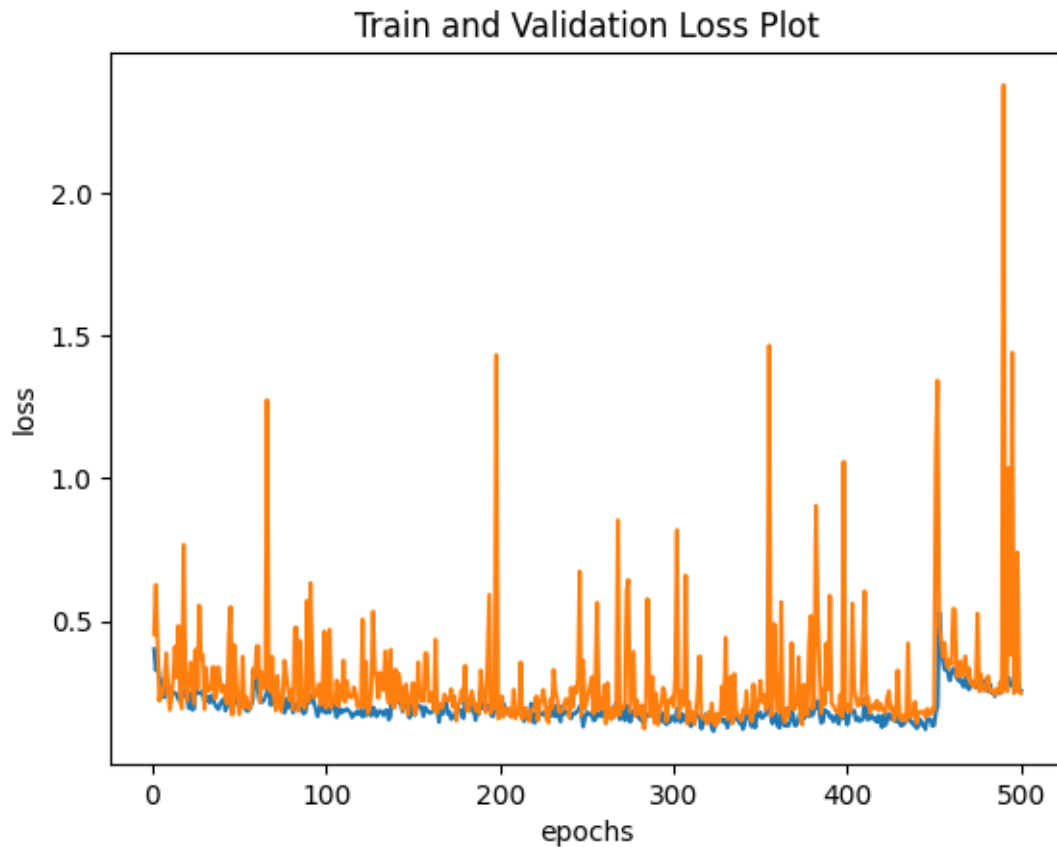
validation loss: 0.38149956
=====
Epoch 494
training loss: 0.27293625
validation loss: 1.44023395
=====
Epoch 495
training loss: 0.28308570
validation loss: 0.24700746
=====
Epoch 496
training loss: 0.25461033
validation loss: 0.25623265
=====
Epoch 497
training loss: 0.29695448
validation loss: 0.74028015
=====
Epoch 498
training loss: 0.26047242
validation loss: 0.25063562
=====
Epoch 499
training loss: 0.25668693
validation loss: 0.24612692

```

```

[ ]: import matplotlib.pyplot as plt
      with torch.no_grad():
          plt.plot(range(1,epochs+1), train_mean_losses)
          plt.plot(range(1,epochs+1), valid_mean_losses)
          plt.xlabel('epochs')
          plt.ylabel('loss')
          plt.title('Train and Validation Loss Plot')
          plt.show()

```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```



```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 0 1 0 1 0 1 0 1 1 0 1 0 1 0 1 0 1 1 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[48  4]
 [ 9 73]]

```

=====

Accuracy: 0.9029850746268657

F1 Score: 0.8994864693324102

=====
Classification Report:

	precision	recall	f1-score	support
0	0.84	0.92	0.88	52
1	0.95	0.89	0.92	82
accuracy			0.90	134
macro avg	0.90	0.91	0.90	134
weighted avg	0.91	0.90	0.90	134

13 Modifikasi Arsitektur 4

- Hidden layer berjumlah 2, dengan jumlah neuron di masing-masing hidden layer sebanyak 15 neuron
- Optimasi yang digunakan adalah SGD dengan learning rate=0.15
- Epoch sebanyak 400

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 15)
        self.bn1 = nn.BatchNorm1d(15)

        self.fc2 = nn.Linear(15, 15)
        self.bn2 = nn.BatchNorm1d(15)

        self.fc3 = nn.Linear(15, 2)
#total ada 2 hidden layer.

#arsitektur, model yg kita rancang
    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X
```

```

[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.15)

[ ]: epochs = 400

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward()
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====
    # validation#setiap epoch lakukan validation
    valid_losses = []
    with torch.set_grad_enabled(False):
        for iteration, batch_data in enumerate(valid_loader):

```

```

        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i

#=====

```

```

=====
Epoch 0
training loss: 0.37423196
validation loss: 0.30794063
=====
Epoch 1
training loss: 0.30698010
validation loss: 0.33224955
=====
Epoch 2
training loss: 0.30239806
validation loss: 0.27699167
=====
Epoch 3
training loss: 0.28709742
validation loss: 0.28314865
=====
Epoch 4
training loss: 0.25526324
validation loss: 0.25985125
=====
Epoch 5
training loss: 0.26790494
validation loss: 0.27901378
=====
Epoch 6
training loss: 0.25476193
validation loss: 0.24843375
=====
Epoch 7

```

```
training loss: 0.26683229
validation loss: 0.22815989
=====
Epoch 8
training loss: 0.24291238
validation loss: 0.22747537
=====
Epoch 9
training loss: 0.21336386
validation loss: 0.24920806
=====
Epoch 10
training loss: 0.22615004
validation loss: 0.34981042
=====
Epoch 11
training loss: 0.24378558
validation loss: 0.37137881
=====
Epoch 12
training loss: 0.23086816
validation loss: 0.23838668
=====
Epoch 13
training loss: 0.23935968
validation loss: 0.29426754
=====
Epoch 14
training loss: 0.23828992
validation loss: 0.25486892
=====
Epoch 15
training loss: 0.20776574
validation loss: 0.20440811
=====
Epoch 16
training loss: 0.21638934
validation loss: 0.22765549
=====
Epoch 17
training loss: 0.18792783
validation loss: 0.18639824
=====
Epoch 18
training loss: 0.20505629
validation loss: 0.22079796
=====
Epoch 19
```

```
training loss: 0.24343896
validation loss: 0.25028950
=====
Epoch 20
training loss: 0.20797595
validation loss: 0.21585071
=====
Epoch 21
training loss: 0.22532231
validation loss: 0.24069203
=====
Epoch 22
training loss: 0.21913739
validation loss: 0.22510360
=====
Epoch 23
training loss: 0.19413979
validation loss: 0.23576421
=====
Epoch 24
training loss: 0.20710538
validation loss: 0.20584258
=====
Epoch 25
training loss: 0.22012861
validation loss: 0.29468676
=====
Epoch 26
training loss: 0.21619748
validation loss: 0.18681644
=====
Epoch 27
training loss: 0.19048832
validation loss: 0.20581004
=====
Epoch 28
training loss: 0.17591316
validation loss: 0.26800913
=====
Epoch 29
training loss: 0.17399849
validation loss: 0.26540112
=====
Epoch 30
training loss: 0.17453624
validation loss: 0.20621853
=====
Epoch 31
```

```
training loss: 0.18481323
validation loss: 0.27253327
=====
Epoch 32
training loss: 0.23235792
validation loss: 0.33643109
=====
Epoch 33
training loss: 0.19935174
validation loss: 0.27371067
=====
Epoch 34
training loss: 0.15295313
validation loss: 0.20141278
=====
Epoch 35
training loss: 0.18334155
validation loss: 0.20157222
=====
Epoch 36
training loss: 0.16559881
validation loss: 0.23077604
=====
Epoch 37
training loss: 0.19772567
validation loss: 0.28591147
=====
Epoch 38
training loss: 0.19253664
validation loss: 0.18390921
=====
Epoch 39
training loss: 0.19084425
validation loss: 0.18194810
=====
Epoch 40
training loss: 0.19310781
validation loss: 0.31074297
=====
Epoch 41
training loss: 0.20724617
validation loss: 0.21578652
=====
Epoch 42
training loss: 0.19015644
validation loss: 0.23662227
=====
Epoch 43
```

```
training loss: 0.20875423
validation loss: 0.19592756
=====
Epoch 44
training loss: 0.17477229
validation loss: 0.21822791
=====
Epoch 45
training loss: 0.20808274
validation loss: 0.20596147
=====
Epoch 46
training loss: 0.17237838
validation loss: 0.18998528
=====
Epoch 47
training loss: 0.20097902
validation loss: 0.17405388
=====
Epoch 48
training loss: 0.18987839
validation loss: 0.30239838
=====
Epoch 49
training loss: 0.20021495
validation loss: 0.21915229
=====
Epoch 50
training loss: 0.19035426
validation loss: 0.20224351
=====
Epoch 51
training loss: 0.16646589
validation loss: 0.27035677
=====
Epoch 52
training loss: 0.20372002
validation loss: 0.17155541
=====
Epoch 53
training loss: 0.18201455
validation loss: 0.22845203
=====
Epoch 54
training loss: 0.19790496
validation loss: 0.22735454
=====
Epoch 55
```



```
training loss: 0.17743315
validation loss: 0.30215949
=====
Epoch 56
training loss: 0.19138396
validation loss: 0.18666553
=====
Epoch 57
training loss: 0.17764401
validation loss: 0.24344616
=====
Epoch 58
training loss: 0.19234447
validation loss: 0.21767303
=====
Epoch 59
training loss: 0.24474590
validation loss: 0.39208403
=====
Epoch 60
training loss: 0.25453943
validation loss: 0.27857476
=====
Epoch 61
training loss: 0.24549946
validation loss: 0.26767924
=====
Epoch 62
training loss: 0.21483564
validation loss: 0.25827333
=====
Epoch 63
training loss: 0.21374999
validation loss: 0.22989561
=====
Epoch 64
training loss: 0.22338854
validation loss: 0.26254201
=====
Epoch 65
training loss: 0.20180759
validation loss: 0.27629936
=====
Epoch 66
training loss: 0.20941702
validation loss: 0.25847816
=====
Epoch 67
```

```
training loss: 0.21623221
validation loss: 0.19364609
=====
Epoch 68
training loss: 0.20231783
validation loss: 0.43406039
=====
Epoch 69
training loss: 0.20562120
validation loss: 0.19500460
=====
Epoch 70
training loss: 0.23048803
validation loss: 0.20412904
=====
Epoch 71
training loss: 0.21315047
validation loss: 0.18876870
=====
Epoch 72
training loss: 0.18817821
validation loss: 0.16743408
=====
Epoch 73
training loss: 0.18381789
validation loss: 0.21160501
=====
Epoch 74
training loss: 0.18011172
validation loss: 0.20736793
=====
Epoch 75
training loss: 0.19993231
validation loss: 0.23610176
=====
Epoch 76
training loss: 0.17550172
validation loss: 0.21623081
=====
Epoch 77
training loss: 0.19338076
validation loss: 0.20621872
=====
Epoch 78
training loss: 0.20799701
validation loss: 0.19542515
=====
Epoch 79
```

```
training loss: 0.17859918
validation loss: 0.28310555
=====
Epoch 80
training loss: 0.19933225
validation loss: 0.22951761
=====
Epoch 81
training loss: 0.21602066
validation loss: 0.17470524
=====
Epoch 82
training loss: 0.16811498
validation loss: 0.18190017
=====
Epoch 83
training loss: 0.17924283
validation loss: 0.16562581
=====
Epoch 84
training loss: 0.17026702
validation loss: 0.19530167
=====
Epoch 85
training loss: 0.20752668
validation loss: 0.22202928
=====
Epoch 86
training loss: 0.18448526
validation loss: 0.18708634
=====
Epoch 87
training loss: 0.17847109
validation loss: 0.15120485
=====
Epoch 88
training loss: 0.17789972
validation loss: 0.20182683
=====
Epoch 89
training loss: 0.16747935
validation loss: 0.17734769
=====
Epoch 90
training loss: 0.19259036
validation loss: 0.17159748
=====
Epoch 91
```

```
training loss: 0.18154590
validation loss: 0.15027890
=====
Epoch 92
training loss: 0.16191994
validation loss: 0.17497292
=====
Epoch 93
training loss: 0.16327192
validation loss: 0.17072803
=====
Epoch 94
training loss: 0.16773053
validation loss: 0.15691034
=====
Epoch 95
training loss: 0.16100886
validation loss: 0.15528718
=====
Epoch 96
training loss: 0.14667550
validation loss: 0.15914509
=====
Epoch 97
training loss: 0.18206576
validation loss: 0.18047342
=====
Epoch 98
training loss: 0.21163815
validation loss: 0.26735574
=====
Epoch 99
training loss: 0.16607054
validation loss: 0.18266086
=====
Epoch 100
training loss: 0.15864648
validation loss: 0.19818158
=====
Epoch 101
training loss: 0.16565898
validation loss: 0.19877054
=====
Epoch 102
training loss: 0.17701040
validation loss: 0.18858773
=====
Epoch 103
```

```

training loss: 0.16690248
validation loss: 0.15030816
=====
Epoch 104
training loss: 0.16270743
validation loss: 0.22200871
=====
Epoch 105
training loss: 0.18008330
validation loss: 0.17218041
=====
Epoch 106
training loss: 0.18033980
validation loss: 0.20026931
=====
Epoch 107
training loss: 0.15330221
validation loss: 0.17907634
=====
Epoch 108
training loss: 0.15495211
validation loss: 0.20604530
=====
Epoch 109
training loss: 0.14558750
validation loss: 0.19491537
=====
Epoch 110
training loss: 0.16757242
validation loss: 0.19642597
=====
Epoch 111
training loss: 0.19178158
validation loss: 0.14113373
=====
Epoch 112
training loss: 0.14643788
validation loss: 0.18039608
=====
Epoch 113
training loss: 0.15502371
validation loss: 0.19396484
=====
Epoch 114
training loss: 0.19472495
validation loss: 0.14413729
=====
Epoch 115

```

```

training loss: 0.15649080
validation loss: 0.15074667
=====
Epoch 116
training loss: 0.16903959
validation loss: 0.18615289
=====
Epoch 117
training loss: 0.17292210
validation loss: 0.13097103
=====
Epoch 118
training loss: 0.13923232
validation loss: 0.15916669
=====
Epoch 119
training loss: 0.18061842
validation loss: 0.21626663
=====
Epoch 120
training loss: 0.18671949
validation loss: 0.20896739
=====
Epoch 121
training loss: 0.19448240
validation loss: 0.23594645
=====
Epoch 122
training loss: 0.18590228
validation loss: 0.17125118
=====
Epoch 123
training loss: 0.14384826
validation loss: 0.18900208
=====
Epoch 124
training loss: 0.16124471
validation loss: 0.16380203
=====
Epoch 125
training loss: 0.17938451
validation loss: 0.19633161
=====
Epoch 126
training loss: 0.17355248
validation loss: 0.14826424
=====
Epoch 127

```

```
training loss: 0.16713792
validation loss: 0.13646539
=====
Epoch 128
training loss: 0.18893000
validation loss: 0.16122970
=====
Epoch 129
training loss: 0.16183077
validation loss: 0.13796714
=====
Epoch 130
training loss: 0.15504929
validation loss: 0.15766494
=====
Epoch 131
training loss: 0.19580096
validation loss: 0.16671549
=====
Epoch 132
training loss: 0.17053428
validation loss: 0.17896432
=====
Epoch 133
training loss: 0.16803211
validation loss: 0.14262518
=====
Epoch 134
training loss: 0.16940942
validation loss: 0.15279913
=====
Epoch 135
training loss: 0.16408616
validation loss: 0.17499024
=====
Epoch 136
training loss: 0.15375759
validation loss: 0.15393159
=====
Epoch 137
training loss: 0.14860824
validation loss: 0.18058822
=====
Epoch 138
training loss: 0.15932997
validation loss: 0.16662195
=====
Epoch 139
```

```

training loss: 0.19021457
validation loss: 0.16876101
=====
Epoch 140
training loss: 0.15979211
validation loss: 0.14603531
=====
Epoch 141
training loss: 0.18178804
validation loss: 0.15462014
=====
Epoch 142
training loss: 0.18880920
validation loss: 0.16490975
=====
Epoch 143
training loss: 0.16552852
validation loss: 0.17494810
=====
Epoch 144
training loss: 0.18029159
validation loss: 0.19952495
=====
Epoch 145
training loss: 0.20272978
validation loss: 0.15290204
=====
Epoch 146
training loss: 0.17451245
validation loss: 0.15504663
=====
Epoch 147
training loss: 0.18225925
validation loss: 0.40038356
=====
Epoch 148
training loss: 0.17745124
validation loss: 0.14947289
=====
Epoch 149
training loss: 0.16249344
validation loss: 0.17418484
=====
Epoch 150
training loss: 0.16848594
validation loss: 0.13502046
=====
Epoch 151

```



```
training loss: 0.17910884
validation loss: 0.16496614
=====
Epoch 152
training loss: 0.18432674
validation loss: 0.15464458
=====
Epoch 153
training loss: 0.16801517
validation loss: 0.12283313
=====
Epoch 154
training loss: 0.16446221
validation loss: 0.13131340
=====
Epoch 155
training loss: 0.19591591
validation loss: 0.23595837
=====
Epoch 156
training loss: 0.16439313
validation loss: 0.12959480
=====
Epoch 157
training loss: 0.15326899
validation loss: 0.14051470
=====
Epoch 158
training loss: 0.17091939
validation loss: 0.14055166
=====
Epoch 159
training loss: 0.15831915
validation loss: 0.16686642
=====
Epoch 160
training loss: 0.13957535
validation loss: 0.16330922
=====
Epoch 161
training loss: 0.16619565
validation loss: 0.16613942
=====
Epoch 162
training loss: 0.14937057
validation loss: 0.18695797
=====
Epoch 163
```

```
training loss: 0.18020968
validation loss: 0.22896799
=====
Epoch 164
training loss: 0.16363661
validation loss: 0.14270046
=====
Epoch 165
training loss: 0.15299833
validation loss: 0.14779972
=====
Epoch 166
training loss: 0.14546704
validation loss: 0.15731123
=====
Epoch 167
training loss: 0.14147350
validation loss: 0.19398057
=====
Epoch 168
training loss: 0.16141120
validation loss: 0.16381253
=====
Epoch 169
training loss: 0.16129768
validation loss: 0.17346293
=====
Epoch 170
training loss: 0.15038201
validation loss: 0.14809687
=====
Epoch 171
training loss: 0.17279375
validation loss: 0.16438380
=====
Epoch 172
training loss: 0.17257807
validation loss: 0.18113324
=====
Epoch 173
training loss: 0.15132800
validation loss: 0.13503459
=====
Epoch 174
training loss: 0.15187584
validation loss: 0.18160167
=====
Epoch 175
```

```
training loss: 0.16453163
validation loss: 0.16665408
=====
Epoch 176
training loss: 0.13987103
validation loss: 0.14536744
=====
Epoch 177
training loss: 0.15430011
validation loss: 0.18653750
=====
Epoch 178
training loss: 0.15304384
validation loss: 0.13722181
=====
Epoch 179
training loss: 0.12915485
validation loss: 0.15784240
=====
Epoch 180
training loss: 0.16724883
validation loss: 0.15625900
=====
Epoch 181
training loss: 0.16734704
validation loss: 0.15695702
=====
Epoch 182
training loss: 0.12793455
validation loss: 0.16711827
=====
Epoch 183
training loss: 0.15033567
validation loss: 0.14379542
=====
Epoch 184
training loss: 0.14429505
validation loss: 0.15232050
=====
Epoch 185
training loss: 0.16000649
validation loss: 0.12874117
=====
Epoch 186
training loss: 0.14973436
validation loss: 0.27028716
=====
Epoch 187
```

```
training loss: 0.13823745
validation loss: 0.16365656
=====
Epoch 188
training loss: 0.17101015
validation loss: 0.17519268
=====
Epoch 189
training loss: 0.16599374
validation loss: 0.17882290
=====
Epoch 190
training loss: 0.15131634
validation loss: 0.15011799
=====
Epoch 191
training loss: 0.15603654
validation loss: 0.14497969
=====
Epoch 192
training loss: 0.13666430
validation loss: 0.20142186
=====
Epoch 193
training loss: 0.15360306
validation loss: 0.23619974
=====
Epoch 194
training loss: 0.13957727
validation loss: 0.15526652
=====
Epoch 195
training loss: 0.13433276
validation loss: 0.13110876
=====
Epoch 196
training loss: 0.17837578
validation loss: 0.24635930
=====
Epoch 197
training loss: 0.14862606
validation loss: 0.13861154
=====
Epoch 198
training loss: 0.16011699
validation loss: 0.14938781
=====
Epoch 199
```

```
training loss: 0.14806019
validation loss: 0.13672258
=====
Epoch 200
training loss: 0.15105981
validation loss: 0.15029371
=====
Epoch 201
training loss: 0.14913347
validation loss: 0.23750362
=====
Epoch 202
training loss: 0.17986755
validation loss: 0.15068963
=====
Epoch 203
training loss: 0.15390500
validation loss: 0.11954630
=====
Epoch 204
training loss: 0.16774836
validation loss: 0.12079722
=====
Epoch 205
training loss: 0.13904709
validation loss: 0.16410626
=====
Epoch 206
training loss: 0.15344672
validation loss: 0.16436845
=====
Epoch 207
training loss: 0.13990760
validation loss: 0.17414546
=====
Epoch 208
training loss: 0.14411110
validation loss: 0.13032880
=====
Epoch 209
training loss: 0.13072632
validation loss: 0.14752576
=====
Epoch 210
training loss: 0.15703812
validation loss: 0.14216110
=====
Epoch 211
```

```
training loss: 0.12861075
validation loss: 0.16616812
=====
Epoch 212
training loss: 0.12592234
validation loss: 0.16746452
=====
Epoch 213
training loss: 0.11844222
validation loss: 0.16579288
=====
Epoch 214
training loss: 0.12837747
validation loss: 0.17368041
=====
Epoch 215
training loss: 0.17345302
validation loss: 0.17279056
=====
Epoch 216
training loss: 0.14449704
validation loss: 0.14732194
=====
Epoch 217
training loss: 0.15598561
validation loss: 0.14451100
=====
Epoch 218
training loss: 0.15176098
validation loss: 0.20193718
=====
Epoch 219
training loss: 0.15728140
validation loss: 0.15410247
=====
Epoch 220
training loss: 0.14846753
validation loss: 0.17520289
=====
Epoch 221
training loss: 0.12632523
validation loss: 0.13513720
=====
Epoch 222
training loss: 0.12207407
validation loss: 0.15558016
=====
Epoch 223
```

```
training loss: 0.12186375
validation loss: 0.16526869
=====
Epoch 224
training loss: 0.13790058
validation loss: 0.17792265
=====
Epoch 225
training loss: 0.16476993
validation loss: 0.14204888
=====
Epoch 226
training loss: 0.17505430
validation loss: 0.18198238
=====
Epoch 227
training loss: 0.11292551
validation loss: 0.14784640
=====
Epoch 228
training loss: 0.15424149
validation loss: 0.14331698
=====
Epoch 229
training loss: 0.13540182
validation loss: 0.13375756
=====
Epoch 230
training loss: 0.12892613
validation loss: 0.17366505
=====
Epoch 231
training loss: 0.16155247
validation loss: 0.12686425
=====
Epoch 232
training loss: 0.13214833
validation loss: 0.17370531
=====
Epoch 233
training loss: 0.16293050
validation loss: 0.14742105
=====
Epoch 234
training loss: 0.17204560
validation loss: 0.14760348
=====
Epoch 235
```

```
training loss: 0.14486791
validation loss: 0.12067992
=====
Epoch 236
training loss: 0.14938211
validation loss: 0.14931995
=====
Epoch 237
training loss: 0.15053904
validation loss: 0.12531382
=====
Epoch 238
training loss: 0.17215709
validation loss: 0.12124696
=====
Epoch 239
training loss: 0.13426967
validation loss: 0.14647627
=====
Epoch 240
training loss: 0.17104919
validation loss: 0.17556843
=====
Epoch 241
training loss: 0.16565354
validation loss: 0.17851767
=====
Epoch 242
training loss: 0.15561485
validation loss: 0.21228907
=====
Epoch 243
training loss: 0.17730382
validation loss: 0.16317728
=====
Epoch 244
training loss: 0.16438320
validation loss: 0.15972282
=====
Epoch 245
training loss: 0.16363756
validation loss: 0.13735196
=====
Epoch 246
training loss: 0.19378076
validation loss: 0.22396353
=====
Epoch 247
```



```
training loss: 0.12107356
validation loss: 0.11965721
=====
Epoch 248
training loss: 0.14884561
validation loss: 0.14316224
=====
Epoch 249
training loss: 0.14411326
validation loss: 0.15724379
=====
Epoch 250
training loss: 0.16097721
validation loss: 0.14883472
=====
Epoch 251
training loss: 0.13186283
validation loss: 0.12979884
=====
Epoch 252
training loss: 0.14239976
validation loss: 0.12006320
=====
Epoch 253
training loss: 0.15862358
validation loss: 0.10128926
=====
Epoch 254
training loss: 0.13216700
validation loss: 0.16130255
=====
Epoch 255
training loss: 0.16887490
validation loss: 0.24667864
=====
Epoch 256
training loss: 0.15856196
validation loss: 0.15458193
=====
Epoch 257
training loss: 0.13292606
validation loss: 0.13961066
=====
Epoch 258
training loss: 0.16171442
validation loss: 0.14734901
=====
Epoch 259
```

```
training loss: 0.19966584
validation loss: 0.20984228
=====
Epoch 260
training loss: 0.17911901
validation loss: 0.14931421
=====
Epoch 261
training loss: 0.14610517
validation loss: 0.20838031
=====
Epoch 262
training loss: 0.18953814
validation loss: 0.41585720
=====
Epoch 263
training loss: 0.16777416
validation loss: 0.17855632
=====
Epoch 264
training loss: 0.16106723
validation loss: 0.14561549
=====
Epoch 265
training loss: 0.16351187
validation loss: 0.14027154
=====
Epoch 266
training loss: 0.19287534
validation loss: 0.12945184
=====
Epoch 267
training loss: 0.19050513
validation loss: 0.13834839
=====
Epoch 268
training loss: 0.20171867
validation loss: 0.15356274
=====
Epoch 269
training loss: 0.16221985
validation loss: 0.15585931
=====
Epoch 270
training loss: 0.16518183
validation loss: 0.13694537
=====
Epoch 271
```

```
training loss: 0.17141667
validation loss: 0.15742978
=====
Epoch 272
training loss: 0.18362109
validation loss: 0.17503883
=====
Epoch 273
training loss: 0.18642913
validation loss: 0.16976866
=====
Epoch 274
training loss: 0.16408941
validation loss: 0.13421088
=====
Epoch 275
training loss: 0.15113002
validation loss: 0.14209902
=====
Epoch 276
training loss: 0.13781737
validation loss: 0.16965976
=====
Epoch 277
training loss: 0.15479636
validation loss: 0.16396719
=====
Epoch 278
training loss: 0.17729487
validation loss: 0.16304059
=====
Epoch 279
training loss: 0.16703108
validation loss: 0.12528630
=====
Epoch 280
training loss: 0.16390401
validation loss: 0.15566248
=====
Epoch 281
training loss: 0.15837041
validation loss: 0.16811307
=====
Epoch 282
training loss: 0.16221817
validation loss: 0.24378264
=====
Epoch 283
```

```

training loss: 0.16227619
validation loss: 0.20693268
=====
Epoch 284
training loss: 0.13884957
validation loss: 0.13637133
=====
Epoch 285
training loss: 0.16285773
validation loss: 0.15813632
=====
Epoch 286
training loss: 0.14559278
validation loss: 0.16045675
=====
Epoch 287
training loss: 0.15351467
validation loss: 0.15987842
=====
Epoch 288
training loss: 0.15376414
validation loss: 0.15073173
=====
Epoch 289
training loss: 0.14076971
validation loss: 0.25831154
=====
Epoch 290
training loss: 0.17880774
validation loss: 0.16612586
=====
Epoch 291
training loss: 0.15315434
validation loss: 0.15206398
=====
Epoch 292
training loss: 0.15569910
validation loss: 0.17633346
=====
Epoch 293
training loss: 0.14782485
validation loss: 0.13933167
=====
Epoch 294
training loss: 0.15762740
validation loss: 0.16252694
=====
Epoch 295

```

```
training loss: 0.16451468
validation loss: 0.16015233
=====
Epoch 296
training loss: 0.13822365
validation loss: 0.13223395
=====
Epoch 297
training loss: 0.12082755
validation loss: 0.15586840
=====
Epoch 298
training loss: 0.17138338
validation loss: 0.17833374
=====
Epoch 299
training loss: 0.14560422
validation loss: 0.17040698
=====
Epoch 300
training loss: 0.14743242
validation loss: 0.18038459
=====
Epoch 301
training loss: 0.14974114
validation loss: 0.13128804
=====
Epoch 302
training loss: 0.14178598
validation loss: 0.12706059
=====
Epoch 303
training loss: 0.14241056
validation loss: 0.12038205
=====
Epoch 304
training loss: 0.13493860
validation loss: 0.11713782
=====
Epoch 305
training loss: 0.13018106
validation loss: 0.14748682
=====
Epoch 306
training loss: 0.16304484
validation loss: 0.15568383
=====
Epoch 307
```

```
training loss: 0.18328321
validation loss: 0.16614303
=====
Epoch 308
training loss: 0.15463202
validation loss: 0.14985904
=====
Epoch 309
training loss: 0.13700129
validation loss: 0.12586215
=====
Epoch 310
training loss: 0.13904580
validation loss: 0.14172406
=====
Epoch 311
training loss: 0.16846605
validation loss: 0.15442611
=====
Epoch 312
training loss: 0.13231923
validation loss: 0.14518440
=====
Epoch 313
training loss: 0.15315552
validation loss: 0.14808616
=====
Epoch 314
training loss: 0.15595163
validation loss: 0.13459964
=====
Epoch 315
training loss: 0.16183135
validation loss: 0.15945604
=====
Epoch 316
training loss: 0.15204114
validation loss: 0.14403449
=====
Epoch 317
training loss: 0.16694291
validation loss: 0.16586623
=====
Epoch 318
training loss: 0.15758193
validation loss: 0.14699821
=====
Epoch 319
```

```
training loss: 0.14056011
validation loss: 0.12251995
=====
Epoch 320
training loss: 0.14721295
validation loss: 0.15260269
=====
Epoch 321
training loss: 0.15209182
validation loss: 0.13980238
=====
Epoch 322
training loss: 0.14023732
validation loss: 0.19122693
=====
Epoch 323
training loss: 0.18231063
validation loss: 0.18410507
=====
Epoch 324
training loss: 0.15549174
validation loss: 0.15878358
=====
Epoch 325
training loss: 0.18242699
validation loss: 0.16931845
=====
Epoch 326
training loss: 0.15981351
validation loss: 0.20401934
=====
Epoch 327
training loss: 0.18245882
validation loss: 0.25955880
=====
Epoch 328
training loss: 0.13187036
validation loss: 0.13797466
=====
Epoch 329
training loss: 0.14651430
validation loss: 0.14117473
=====
Epoch 330
training loss: 0.16981055
validation loss: 0.14103106
=====
Epoch 331
```

```
training loss: 0.17869134
validation loss: 0.22554231
=====
Epoch 332
training loss: 0.19533847
validation loss: 0.16457331
=====
Epoch 333
training loss: 0.14961292
validation loss: 0.15189159
=====
Epoch 334
training loss: 0.14886861
validation loss: 0.13926744
=====
Epoch 335
training loss: 0.16157959
validation loss: 0.15754059
=====
Epoch 336
training loss: 0.17608668
validation loss: 0.17422736
=====
Epoch 337
training loss: 0.13925689
validation loss: 0.16757953
=====
Epoch 338
training loss: 0.14022009
validation loss: 0.14190389
=====
Epoch 339
training loss: 0.14489238
validation loss: 0.19890806
=====
Epoch 340
training loss: 0.16706873
validation loss: 0.13588534
=====
Epoch 341
training loss: 0.14156114
validation loss: 0.12129883
=====
Epoch 342
training loss: 0.13895197
validation loss: 0.14084063
=====
Epoch 343
```



```
training loss: 0.16500874
validation loss: 0.14540228
=====
Epoch 344
training loss: 0.12953338
validation loss: 0.12845916
=====
Epoch 345
training loss: 0.12419660
validation loss: 0.14916870
=====
Epoch 346
training loss: 0.15907609
validation loss: 0.21755749
=====
Epoch 347
training loss: 0.14550121
validation loss: 0.12967627
=====
Epoch 348
training loss: 0.16193764
validation loss: 0.17244306
=====
Epoch 349
training loss: 0.14882717
validation loss: 0.15079132
=====
Epoch 350
training loss: 0.15011480
validation loss: 0.16674472
=====
Epoch 351
training loss: 0.14959696
validation loss: 0.16294512
=====
Epoch 352
training loss: 0.14742121
validation loss: 0.15121153
=====
Epoch 353
training loss: 0.14161959
validation loss: 0.16965136
=====
Epoch 354
training loss: 0.13256989
validation loss: 0.15738443
=====
Epoch 355
```

```
training loss: 0.14182077
validation loss: 0.20629922
=====
Epoch 356
training loss: 0.13725300
validation loss: 0.15413940
=====
Epoch 357
training loss: 0.12711915
validation loss: 0.11822661
=====
Epoch 358
training loss: 0.15691428
validation loss: 0.16837665
=====
Epoch 359
training loss: 0.16947697
validation loss: 0.15631241
=====
Epoch 360
training loss: 0.15635234
validation loss: 0.15155986
=====
Epoch 361
training loss: 0.12585527
validation loss: 0.11916812
=====
Epoch 362
training loss: 0.15537891
validation loss: 0.14099872
=====
Epoch 363
training loss: 0.12300016
validation loss: 0.17174242
=====
Epoch 364
training loss: 0.13774139
validation loss: 0.12709971
=====
Epoch 365
training loss: 0.12452486
validation loss: 0.16138443
=====
Epoch 366
training loss: 0.14024633
validation loss: 0.13243870
=====
Epoch 367
```

```
training loss: 0.13841091
validation loss: 0.15756275
=====
Epoch 368
training loss: 0.14834821
validation loss: 0.15299445
=====
Epoch 369
training loss: 0.14764965
validation loss: 0.15031631
=====
Epoch 370
training loss: 0.13667235
validation loss: 0.11766107
=====
Epoch 371
training loss: 0.14413483
validation loss: 0.13531554
=====
Epoch 372
training loss: 0.13260578
validation loss: 0.13242164
=====
Epoch 373
training loss: 0.09911929
validation loss: 0.16077304
=====
Epoch 374
training loss: 0.14173847
validation loss: 0.14400983
=====
Epoch 375
training loss: 0.15820685
validation loss: 0.11875480
=====
Epoch 376
training loss: 0.15289991
validation loss: 0.23619144
=====
Epoch 377
training loss: 0.15666974
validation loss: 0.13557455
=====
Epoch 378
training loss: 0.13856806
validation loss: 0.16525787
=====
Epoch 379
```

```

training loss: 0.16691513
validation loss: 0.13248453
=====
Epoch 380
training loss: 0.14884132
validation loss: 0.13303649
=====
Epoch 381
training loss: 0.13896872
validation loss: 0.13876332
=====
Epoch 382
training loss: 0.13599879
validation loss: 0.15393406
=====
Epoch 383
training loss: 0.15229556
validation loss: 0.12742709
=====
Epoch 384
training loss: 0.17196912
validation loss: 0.18219067
=====
Epoch 385
training loss: 0.13210261
validation loss: 0.16653988
=====
Epoch 386
training loss: 0.14117977
validation loss: 0.15777349
=====
Epoch 387
training loss: 0.15466528
validation loss: 0.16490278
=====
Epoch 388
training loss: 0.17383681
validation loss: 0.18043536
=====
Epoch 389
training loss: 0.14985618
validation loss: 0.15521193
=====
Epoch 390
training loss: 0.13274948
validation loss: 0.15875533
=====
Epoch 391

```

```

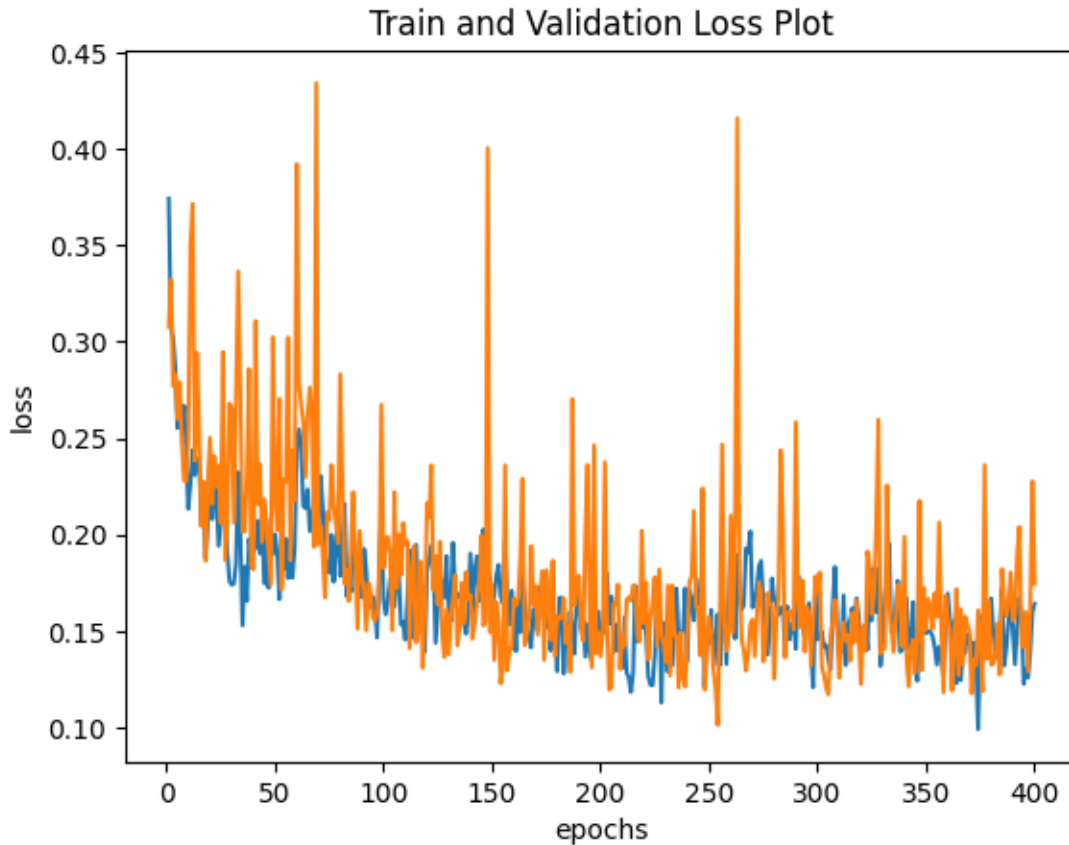
training loss: 0.15303892
validation loss: 0.19063698
=====
Epoch 392
training loss: 0.16734061
validation loss: 0.20402601
=====
Epoch 393
training loss: 0.15861693
validation loss: 0.14221326
=====
Epoch 394
training loss: 0.12261998
validation loss: 0.14179009
=====
Epoch 395
training loss: 0.13033797
validation loss: 0.15985753
=====
Epoch 396
training loss: 0.12592822
validation loss: 0.12906457
=====
Epoch 397
training loss: 0.13882236
validation loss: 0.16051687
=====
Epoch 398
training loss: 0.15968753
validation loss: 0.22763322
=====
Epoch 399
training loss: 0.16417524
validation loss: 0.17445128

```

```

[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()

```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 0 1 0 1 0 1 0 1 1 0 0 0 1 1 1 1 0 0 1 1 1 1 1 1 0 0 0 1 1 1 1 0
 1 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 0 1 0 1 0 1 0 1 1 0 1 0 1 0 1 0 1 0 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[48  4]
 [12 70]]

```

=====

Accuracy: 0.8805970149253731

F1 Score: 0.8772893772893773

=====
Classification Report:

	precision	recall	f1-score	support
0	0.80	0.92	0.86	52
1	0.95	0.85	0.90	82
accuracy			0.88	134
macro avg	0.87	0.89	0.88	134
weighted avg	0.89	0.88	0.88	134

14 Modifikasi Arsitektur 5

- Hidden layer berjumlah 3, dengan jumlah neuron di masing-masing hidden layer sebanyak 15 neuron
- Optimasi yang digunakan adalah SGD dengan learning rate=0.19
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 15)
        self.bn1 = nn.BatchNorm1d(15)

        self.fc2 = nn.Linear(15, 15)
        self.bn2 = nn.BatchNorm1d(15)

        self.fc3 = nn.Linear(15, 15)
        self.bn3 = nn.BatchNorm1d(15)

        self.fc4 = nn.Linear(15, 2)
#total ada 2 hidden layer.

    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)
        X = F.relu(X)
```



```

        X = self.bn3(X)
        X = self.fc4(X)

    return X

```

```

[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.19)

```

```

[ ]: epochs = 300 #jumlah epoch 300 epoch

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward() # perhitungan backpropagation
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

```

```

#=====
valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.37256804
validation loss: 0.38687730
=====
Epoch 1
training loss: 0.32004088
validation loss: 0.25632206
=====
Epoch 2
training loss: 0.28118587
validation loss: 0.27173778
=====
Epoch 3
training loss: 0.27382922
validation loss: 0.22110866
=====
Epoch 4
training loss: 0.25908169
validation loss: 0.19021641
=====
Epoch 5
training loss: 0.24547933
validation loss: 0.22961809
=====
Epoch 6

```

```
training loss: 0.21480691
validation loss: 0.24474949
=====
Epoch 7
training loss: 0.22227636
validation loss: 0.20646983
=====
Epoch 8
training loss: 0.24252160
validation loss: 0.22378765
=====
Epoch 9
training loss: 0.23466691
validation loss: 0.31572807
=====
Epoch 10
training loss: 0.23101024
validation loss: 0.24801528
=====
Epoch 11
training loss: 0.22359836
validation loss: 0.20069104
=====
Epoch 12
training loss: 0.24188456
validation loss: 0.26562104
=====
Epoch 13
training loss: 0.18574044
validation loss: 0.17616317
=====
Epoch 14
training loss: 0.22973637
validation loss: 0.22465648
=====
Epoch 15
training loss: 0.21678613
validation loss: 0.20467794
=====
Epoch 16
training loss: 0.20938298
validation loss: 0.19099835
=====
Epoch 17
training loss: 0.21348771
validation loss: 0.21234876
=====
Epoch 18
```

```
training loss: 0.20770480
validation loss: 0.19897270
=====
Epoch 19
training loss: 0.21011183
validation loss: 0.24281026
=====
Epoch 20
training loss: 0.20715907
validation loss: 0.24047823
=====
Epoch 21
training loss: 0.18972147
validation loss: 0.26658937
=====
Epoch 22
training loss: 0.20209767
validation loss: 0.17760120
=====
Epoch 23
training loss: 0.17954761
validation loss: 0.17189421
=====
Epoch 24
training loss: 0.15167879
validation loss: 0.18084179
=====
Epoch 25
training loss: 0.18391529
validation loss: 0.17189062
=====
Epoch 26
training loss: 0.17226365
validation loss: 0.19712912
=====
Epoch 27
training loss: 0.20298490
validation loss: 0.25771648
=====
Epoch 28
training loss: 0.19302416
validation loss: 0.19639878
=====
Epoch 29
training loss: 0.16654029
validation loss: 0.19845867
=====
Epoch 30
```

```
training loss: 0.21473365
validation loss: 0.20873380
=====
Epoch 31
training loss: 0.17523549
validation loss: 0.19563951
=====
Epoch 32
training loss: 0.20080291
validation loss: 0.19428879
=====
Epoch 33
training loss: 0.15585163
validation loss: 0.19920699
=====
Epoch 34
training loss: 0.16608924
validation loss: 0.19384895
=====
Epoch 35
training loss: 0.17984937
validation loss: 0.30953261
=====
Epoch 36
training loss: 0.19451568
validation loss: 0.17241997
=====
Epoch 37
training loss: 0.15550201
validation loss: 0.18930604
=====
Epoch 38
training loss: 0.14205359
validation loss: 0.28930187
=====
Epoch 39
training loss: 0.17835590
validation loss: 0.15757425
=====
Epoch 40
training loss: 0.17884672
validation loss: 0.17121091
=====
Epoch 41
training loss: 0.19610268
validation loss: 0.14450918
=====
Epoch 42
```

```
training loss: 0.17820632
validation loss: 0.17014547
=====
Epoch 43
training loss: 0.21484566
validation loss: 0.15432547
=====
Epoch 44
training loss: 0.16177550
validation loss: 0.16218406
=====
Epoch 45
training loss: 0.15761429
validation loss: 0.16986135
=====
Epoch 46
training loss: 0.17469381
validation loss: 0.15167746
=====
Epoch 47
training loss: 0.16265936
validation loss: 0.16440490
=====
Epoch 48
training loss: 0.17054857
validation loss: 0.15478741
=====
Epoch 49
training loss: 0.15316902
validation loss: 0.16097283
=====
Epoch 50
training loss: 0.20329753
validation loss: 0.16583008
=====
Epoch 51
training loss: 0.17829144
validation loss: 0.28587374
=====
Epoch 52
training loss: 0.17213130
validation loss: 0.14976025
=====
Epoch 53
training loss: 0.20656011
validation loss: 0.20740059
=====
Epoch 54
```

```
training loss: 0.17261784
validation loss: 0.13322902
=====
Epoch 55
training loss: 0.14526859
validation loss: 0.16503300
=====
Epoch 56
training loss: 0.15908569
validation loss: 0.15587315
=====
Epoch 57
training loss: 0.15128888
validation loss: 0.18393642
=====
Epoch 58
training loss: 0.20468883
validation loss: 0.18686143
=====
Epoch 59
training loss: 0.17451923
validation loss: 0.18343866
=====
Epoch 60
training loss: 0.16060090
validation loss: 0.19322082
=====
Epoch 61
training loss: 0.16173720
validation loss: 0.18358751
=====
Epoch 62
training loss: 0.16842866
validation loss: 0.19728605
=====
Epoch 63
training loss: 0.19263698
validation loss: 0.20526820
=====
Epoch 64
training loss: 0.17042123
validation loss: 0.16706829
=====
Epoch 65
training loss: 0.17626008
validation loss: 0.15698254
=====
Epoch 66
```

```
training loss: 0.18579070
validation loss: 0.16775620
=====
Epoch 67
training loss: 0.21333663
validation loss: 0.15509759
=====
Epoch 68
training loss: 0.15967025
validation loss: 0.26821584
=====
Epoch 69
training loss: 0.19097218
validation loss: 0.21971811
=====
Epoch 70
training loss: 0.19534178
validation loss: 0.17093402
=====
Epoch 71
training loss: 0.18294680
validation loss: 0.15787977
=====
Epoch 72
training loss: 0.14992125
validation loss: 0.19143939
=====
Epoch 73
training loss: 0.16541915
validation loss: 0.15853240
=====
Epoch 74
training loss: 0.18899083
validation loss: 0.22280706
=====
Epoch 75
training loss: 0.13669319
validation loss: 0.17476584
=====
Epoch 76
training loss: 0.21042776
validation loss: 0.31281757
=====
Epoch 77
training loss: 0.22155514
validation loss: 0.23790747
=====
Epoch 78
```



```
training loss: 0.19209170
validation loss: 0.20059459
=====
Epoch 79
training loss: 0.17036720
validation loss: 0.21488595
=====
Epoch 80
training loss: 0.16357183
validation loss: 0.20303737
=====
Epoch 81
training loss: 0.20070916
validation loss: 0.23711480
=====
Epoch 82
training loss: 0.17931093
validation loss: 0.18156105
=====
Epoch 83
training loss: 0.18197286
validation loss: 0.19893384
=====
Epoch 84
training loss: 0.17021485
validation loss: 0.20773230
=====
Epoch 85
training loss: 0.15555063
validation loss: 0.18970503
=====
Epoch 86
training loss: 0.17245686
validation loss: 0.25022697
=====
Epoch 87
training loss: 0.16540121
validation loss: 0.21861680
=====
Epoch 88
training loss: 0.15212600
validation loss: 0.19731556
=====
Epoch 89
training loss: 0.14782783
validation loss: 0.21926251
=====
Epoch 90
```

```
training loss: 0.16994460
validation loss: 0.23729169
=====
Epoch 91
training loss: 0.15761419
validation loss: 0.21749678
=====
Epoch 92
training loss: 0.14995483
validation loss: 0.25668481
=====
Epoch 93
training loss: 0.15117374
validation loss: 0.24192208
=====
Epoch 94
training loss: 0.16521037
validation loss: 0.22898439
=====
Epoch 95
training loss: 0.15155642
validation loss: 0.19813050
=====
Epoch 96
training loss: 0.15423121
validation loss: 0.22217998
=====
Epoch 97
training loss: 0.16835614
validation loss: 0.20312837
=====
Epoch 98
training loss: 0.12330248
validation loss: 0.38137397
=====
Epoch 99
training loss: 0.20622823
validation loss: 0.19426866
=====
Epoch 100
training loss: 0.17353474
validation loss: 0.18251581
=====
Epoch 101
training loss: 0.12107622
validation loss: 0.19856441
=====
Epoch 102
```

```

training loss: 0.15979941
validation loss: 0.22752842
=====
Epoch 103
training loss: 0.17462985
validation loss: 0.20382465
=====
Epoch 104
training loss: 0.17021228
validation loss: 0.18464969
=====
Epoch 105
training loss: 0.16293588
validation loss: 0.22806832
=====
Epoch 106
training loss: 0.16572675
validation loss: 0.19185793
=====
Epoch 107
training loss: 0.15937525
validation loss: 0.24617231
=====
Epoch 108
training loss: 0.19836384
validation loss: 0.15850571
=====
Epoch 109
training loss: 0.16041954
validation loss: 0.17122833
=====
Epoch 110
training loss: 0.14594279
validation loss: 0.19607855
=====
Epoch 111
training loss: 0.12072955
validation loss: 0.18718287
=====
Epoch 112
training loss: 0.13832697
validation loss: 0.23701510
=====
Epoch 113
training loss: 0.20570663
validation loss: 0.20092432
=====
Epoch 114

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```
training loss: 0.18046439
validation loss: 0.18559761
=====
Epoch 115
training loss: 0.16255566
validation loss: 0.18806055
=====
Epoch 116
training loss: 0.16299547
validation loss: 0.18426360
=====
Epoch 117
training loss: 0.17483950
validation loss: 0.18059176
=====
Epoch 118
training loss: 0.14548203
validation loss: 0.17228679
=====
Epoch 119
training loss: 0.19893399
validation loss: 0.36192039
=====
Epoch 120
training loss: 0.15577015
validation loss: 0.16464050
=====
Epoch 121
training loss: 0.15986580
validation loss: 0.15534824
=====
Epoch 122
training loss: 0.13605185
validation loss: 0.19370988
=====
Epoch 123
training loss: 0.14735125
validation loss: 0.17890762
=====
Epoch 124
training loss: 0.12571639
validation loss: 0.18569048
=====
Epoch 125
training loss: 0.11973442
validation loss: 0.23924454
=====
Epoch 126
```

```
training loss: 0.15154837
validation loss: 0.21385115
=====
Epoch 127
training loss: 0.14230755
validation loss: 0.15461034
=====
Epoch 128
training loss: 0.12141291
validation loss: 0.19082959
=====
Epoch 129
training loss: 0.14431024
validation loss: 0.18159111
=====
Epoch 130
training loss: 0.17359674
validation loss: 0.16296497
=====
Epoch 131
training loss: 0.13507681
validation loss: 0.18456003
=====
Epoch 132
training loss: 0.14817667
validation loss: 0.16838719
=====
Epoch 133
training loss: 0.12197498
validation loss: 0.15669164
=====
Epoch 134
training loss: 0.13509271
validation loss: 0.20360582
=====
Epoch 135
training loss: 0.17881216
validation loss: 0.21876509
=====
Epoch 136
training loss: 0.15869768
validation loss: 0.21649620
=====
Epoch 137
training loss: 0.22444981
validation loss: 0.19043435
=====
Epoch 138
```

```
training loss: 0.16547911
validation loss: 0.16834888
=====
Epoch 139
training loss: 0.13790718
validation loss: 0.18474849
=====
Epoch 140
training loss: 0.15350461
validation loss: 0.16890964
=====
Epoch 141
training loss: 0.12345342
validation loss: 0.16472897
=====
Epoch 142
training loss: 0.14028713
validation loss: 0.18036269
=====
Epoch 143
training loss: 0.14541619
validation loss: 0.19457626
=====
Epoch 144
training loss: 0.15167198
validation loss: 0.26148415
=====
Epoch 145
training loss: 0.16127875
validation loss: 0.16971067
=====
Epoch 146
training loss: 0.16533938
validation loss: 0.27483493
=====
Epoch 147
training loss: 0.19204962
validation loss: 0.15600210
=====
Epoch 148
training loss: 0.13655472
validation loss: 0.15662475
=====
Epoch 149
training loss: 0.12371103
validation loss: 0.18520497
=====
Epoch 150
```

```
training loss: 0.16661543
validation loss: 0.17611092
=====
Epoch 151
training loss: 0.15718128
validation loss: 0.21811990
=====
Epoch 152
training loss: 0.14109230
validation loss: 0.16178483
=====
Epoch 153
training loss: 0.13723055
validation loss: 0.19437385
=====
Epoch 154
training loss: 0.11729376
validation loss: 0.15735365
=====
Epoch 155
training loss: 0.14044333
validation loss: 0.14311577
=====
Epoch 156
training loss: 0.12042487
validation loss: 0.15579681
=====
Epoch 157
training loss: 0.11672848
validation loss: 0.19094338
=====
Epoch 158
training loss: 0.13065039
validation loss: 0.17363004
=====
Epoch 159
training loss: 0.16526827
validation loss: 0.17285849
=====
Epoch 160
training loss: 0.14279251
validation loss: 0.16668653
=====
Epoch 161
training loss: 0.11790978
validation loss: 0.18884929
=====
Epoch 162
```

```
training loss: 0.12025947
validation loss: 0.19706771
=====
Epoch 163
training loss: 0.14290512
validation loss: 0.18366379
=====
Epoch 164
training loss: 0.14435776
validation loss: 0.16818216
=====
Epoch 165
training loss: 0.15945646
validation loss: 0.16505013
=====
Epoch 166
training loss: 0.17077367
validation loss: 0.22402647
=====
Epoch 167
training loss: 0.14209482
validation loss: 0.18825684
=====
Epoch 168
training loss: 0.13089457
validation loss: 0.19740656
=====
Epoch 169
training loss: 0.11659293
validation loss: 0.21555865
=====
Epoch 170
training loss: 0.12832861
validation loss: 0.18103775
=====
Epoch 171
training loss: 0.11841025
validation loss: 0.19649756
=====
Epoch 172
training loss: 0.13220881
validation loss: 0.20185907
=====
Epoch 173
training loss: 0.18562771
validation loss: 0.16658740
=====
Epoch 174
```



```
training loss: 0.15407744
validation loss: 0.25169557
=====
Epoch 175
training loss: 0.15519843
validation loss: 0.19514471
=====
Epoch 176
training loss: 0.16490786
validation loss: 0.15404728
=====
Epoch 177
training loss: 0.15022303
validation loss: 0.15431778
=====
Epoch 178
training loss: 0.15079536
validation loss: 0.15210958
=====
Epoch 179
training loss: 0.13948467
validation loss: 0.16962977
=====
Epoch 180
training loss: 0.14182122
validation loss: 0.14986981
=====
Epoch 181
training loss: 0.16711301
validation loss: 0.16758499
=====
Epoch 182
training loss: 0.13570672
validation loss: 0.15910780
=====
Epoch 183
training loss: 0.14948979
validation loss: 0.15472569
=====
Epoch 184
training loss: 0.12260794
validation loss: 0.14945698
=====
Epoch 185
training loss: 0.09570063
validation loss: 0.29126841
=====
Epoch 186
```

```
training loss: 0.16770488
validation loss: 0.16871008
=====
Epoch 187
training loss: 0.14651409
validation loss: 0.14489052
=====
Epoch 188
training loss: 0.16977778
validation loss: 0.16588482
=====
Epoch 189
training loss: 0.15669842
validation loss: 0.16590980
=====
Epoch 190
training loss: 0.11455683
validation loss: 0.15020548
=====
Epoch 191
training loss: 0.13872468
validation loss: 0.15948346
=====
Epoch 192
training loss: 0.15516475
validation loss: 0.16931114
=====
Epoch 193
training loss: 0.13880655
validation loss: 0.16199313
=====
Epoch 194
training loss: 0.13231817
validation loss: 0.23395218
=====
Epoch 195
training loss: 0.13278908
validation loss: 0.18597718
=====
Epoch 196
training loss: 0.16869274
validation loss: 0.24544305
=====
Epoch 197
training loss: 0.21593280
validation loss: 0.21304080
=====
Epoch 198
```

```

training loss: 0.16922085
validation loss: 0.21406427
=====
Epoch 199
training loss: 0.15149371
validation loss: 0.19299820
=====
Epoch 200
training loss: 0.12521182
validation loss: 0.18271850
=====
Epoch 201
training loss: 0.15153961
validation loss: 0.14685549
=====
Epoch 202
training loss: 0.12226044
validation loss: 0.15117334
=====
Epoch 203
training loss: 0.20728014
validation loss: 0.21301484
=====
Epoch 204
training loss: 0.16957754
validation loss: 0.17041983
=====
Epoch 205
training loss: 0.15254077
validation loss: 0.20321949
=====
Epoch 206
training loss: 0.14983216
validation loss: 0.17171486
=====
Epoch 207
training loss: 0.14543992
validation loss: 0.15565966
=====
Epoch 208
training loss: 0.15071730
validation loss: 0.17194588
=====
Epoch 209
training loss: 0.15867837
validation loss: 0.25530040
=====
Epoch 210

```

```
training loss: 0.14238136
validation loss: 0.16648605
=====
Epoch 211
training loss: 0.14486040
validation loss: 0.15904136
=====
Epoch 212
training loss: 0.13928303
validation loss: 0.15391155
=====
Epoch 213
training loss: 0.12277813
validation loss: 0.14044291
=====
Epoch 214
training loss: 0.13582331
validation loss: 0.13530853
=====
Epoch 215
training loss: 0.13948174
validation loss: 0.20798296
=====
Epoch 216
training loss: 0.15702881
validation loss: 0.17077939
=====
Epoch 217
training loss: 0.13114506
validation loss: 0.14900559
=====
Epoch 218
training loss: 0.15514438
validation loss: 0.14736912
=====
Epoch 219
training loss: 0.11787184
validation loss: 0.13535437
=====
Epoch 220
training loss: 0.12087126
validation loss: 0.16453683
=====
Epoch 221
training loss: 0.15614817
validation loss: 0.16524121
=====
Epoch 222
```

```
training loss: 0.13962422
validation loss: 0.17013291
=====
Epoch 223
training loss: 0.16589223
validation loss: 0.14909652
=====
Epoch 224
training loss: 0.14158711
validation loss: 0.16305323
=====
Epoch 225
training loss: 0.13635962
validation loss: 0.15981601
=====
Epoch 226
training loss: 0.11598638
validation loss: 0.15452819
=====
Epoch 227
training loss: 0.12789673
validation loss: 0.16159931
=====
Epoch 228
training loss: 0.11477741
validation loss: 0.17462119
=====
Epoch 229
training loss: 0.12646993
validation loss: 0.19439510
=====
Epoch 230
training loss: 0.11560168
validation loss: 0.19038251
=====
Epoch 231
training loss: 0.13510387
validation loss: 0.17991775
=====
Epoch 232
training loss: 0.14226626
validation loss: 0.17418435
=====
Epoch 233
training loss: 0.13170093
validation loss: 0.17845348
=====
Epoch 234
```

```

training loss: 0.13512711
validation loss: 0.17995781
=====
Epoch 235
training loss: 0.16436464
validation loss: 0.18270515
=====
Epoch 236
training loss: 0.15982892
validation loss: 0.21285561
=====
Epoch 237
training loss: 0.14173274
validation loss: 0.17182094
=====
Epoch 238
training loss: 0.15410033
validation loss: 0.40282041
=====
Epoch 239
training loss: 0.16082770
validation loss: 0.15977678
=====
Epoch 240
training loss: 0.15579322
validation loss: 0.20165525
=====
Epoch 241
training loss: 0.14152741
validation loss: 0.15714814
=====
Epoch 242
training loss: 0.14710283
validation loss: 0.18790326
=====
Epoch 243
training loss: 0.14088684
validation loss: 0.13871664
=====
Epoch 244
training loss: 0.13234057
validation loss: 0.13989490
=====
Epoch 245
training loss: 0.13767785
validation loss: 0.12127482
=====
Epoch 246

```

```

training loss: 0.15047251
validation loss: 0.20039549
=====
Epoch 247
training loss: 0.12581918
validation loss: 0.14166726
=====
Epoch 248
training loss: 0.14598288
validation loss: 0.12222011
=====
Epoch 249
training loss: 0.13754359
validation loss: 0.18639527
=====
Epoch 250
training loss: 0.15100616
validation loss: 0.16607037
=====
Epoch 251
training loss: 0.14288135
validation loss: 0.15635294
=====
Epoch 252
training loss: 0.12913042
validation loss: 0.17359616
=====
Epoch 253
training loss: 0.12447055
validation loss: 0.16938147
=====
Epoch 254
training loss: 0.11044109
validation loss: 0.14211440
=====
Epoch 255
training loss: 0.11227310
validation loss: 0.16332370
=====
Epoch 256
training loss: 0.13730815
validation loss: 0.22022268
=====
Epoch 257
training loss: 0.11693171
validation loss: 0.18218753
=====
Epoch 258

```

```
training loss: 0.13226587
validation loss: 0.18192443
=====
Epoch 259
training loss: 0.15059233
validation loss: 0.15038419
=====
Epoch 260
training loss: 0.13603112
validation loss: 0.16309988
=====
Epoch 261
training loss: 0.15813576
validation loss: 0.18443245
=====
Epoch 262
training loss: 0.11521532
validation loss: 0.16106722
=====
Epoch 263
training loss: 0.11016645
validation loss: 0.16936393
=====
Epoch 264
training loss: 0.13386670
validation loss: 0.16039911
=====
Epoch 265
training loss: 0.12995189
validation loss: 0.14006819
=====
Epoch 266
training loss: 0.12221915
validation loss: 0.22955401
=====
Epoch 267
training loss: 0.15455779
validation loss: 0.22707775
=====
Epoch 268
training loss: 0.18679567
validation loss: 0.16912460
=====
Epoch 269
training loss: 0.13989419
validation loss: 0.18176541
=====
Epoch 270
```



```
training loss: 0.18807034
validation loss: 0.39383513
=====
Epoch 271
training loss: 0.18728898
validation loss: 0.16420589
=====
Epoch 272
training loss: 0.20399058
validation loss: 0.16572168
=====
Epoch 273
training loss: 0.17237769
validation loss: 0.18926382
=====
Epoch 274
training loss: 0.15486555
validation loss: 0.19280140
=====
Epoch 275
training loss: 0.13085496
validation loss: 0.19621497
=====
Epoch 276
training loss: 0.12520413
validation loss: 0.16366050
=====
Epoch 277
training loss: 0.14342131
validation loss: 0.15943599
=====
Epoch 278
training loss: 0.15297283
validation loss: 0.17478397
=====
Epoch 279
training loss: 0.10747852
validation loss: 0.17705019
=====
Epoch 280
training loss: 0.12781791
validation loss: 0.17533457
=====
Epoch 281
training loss: 0.12934184
validation loss: 0.18012872
=====
Epoch 282
```

```
training loss: 0.13654913
validation loss: 0.17590968
=====
Epoch 283
training loss: 0.14282811
validation loss: 0.19848108
=====
Epoch 284
training loss: 0.11850975
validation loss: 0.18289292
=====
Epoch 285
training loss: 0.12296350
validation loss: 0.17219310
=====
Epoch 286
training loss: 0.11026579
validation loss: 0.15140818
=====
Epoch 287
training loss: 0.18069898
validation loss: 0.19645691
=====
Epoch 288
training loss: 0.13083135
validation loss: 0.21066625
=====
Epoch 289
training loss: 0.12189928
validation loss: 0.16579545
=====
Epoch 290
training loss: 0.13809624
validation loss: 0.21032311
=====
Epoch 291
training loss: 0.13398102
validation loss: 0.19144994
=====
Epoch 292
training loss: 0.14378121
validation loss: 0.20979308
=====
Epoch 293
training loss: 0.15539442
validation loss: 0.19876175
=====
Epoch 294
```

```

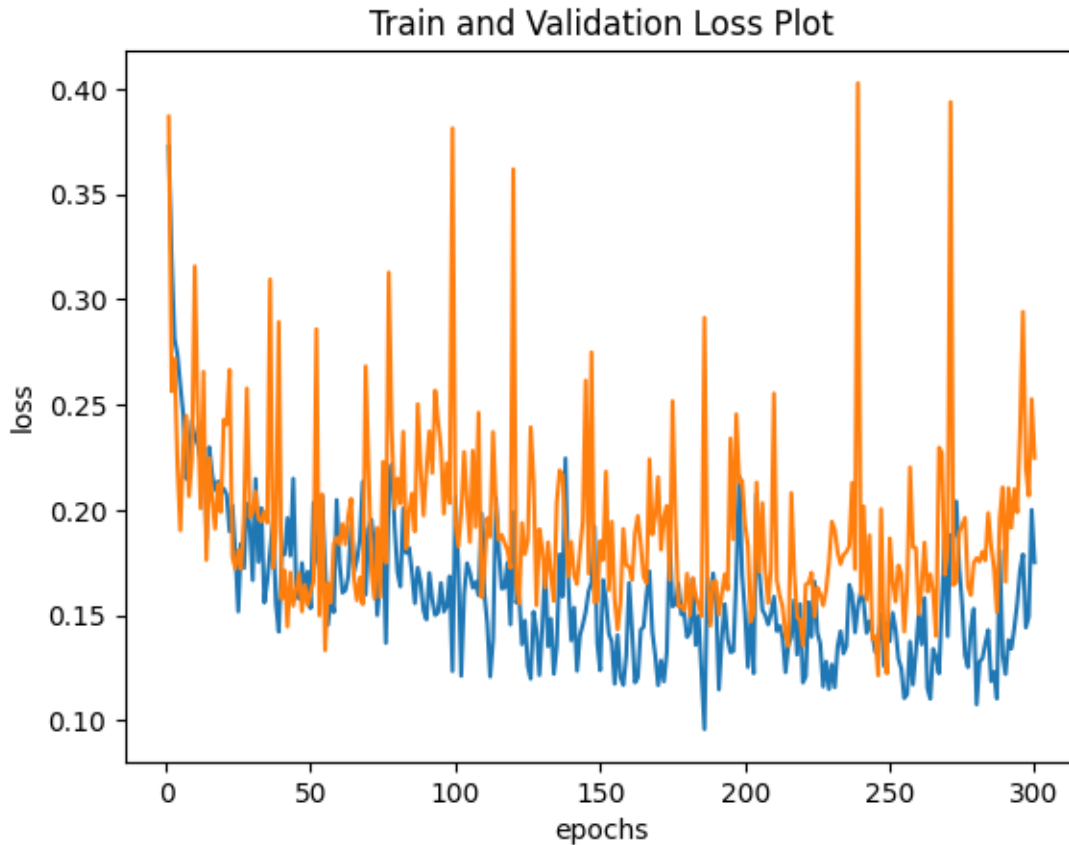
training loss: 0.17112306
validation loss: 0.23802382
=====
Epoch 295
training loss: 0.17883395
validation loss: 0.29413700
=====
Epoch 296
training loss: 0.14405355
validation loss: 0.21975808
=====
Epoch 297
training loss: 0.14919078
validation loss: 0.20667796
=====
Epoch 298
training loss: 0.19998997
validation loss: 0.25257280
=====
Epoch 299
training loss: 0.17503098
validation loss: 0.22468123

```

```

[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()

```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 0 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 1 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 1 1 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[48  4]
 [ 9 73]]

```

=====

Accuracy: 0.9029850746268657

F1 Score: 0.8994864693324102

=====
Classification Report:

	precision	recall	f1-score	support
0	0.84	0.92	0.88	52
1	0.95	0.89	0.92	82
accuracy			0.90	134
macro avg	0.90	0.91	0.90	134
weighted avg	0.91	0.90	0.90	134

15 Modifikasi Arsitektur 6

- Hidden layer berjumlah 4, dengan jumlah neuron di masing-masing hidden layer sebanyak 15 neuron
- Optimasi yang digunakan adalah SGD dengan learning rate=0.1
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 15)
        self.bn1 = nn.BatchNorm1d(15)

        self.fc2 = nn.Linear(15, 15)
        self.bn2 = nn.BatchNorm1d(15)

        self.fc3 = nn.Linear(15, 15)
        self.bn3 = nn.BatchNorm1d(15)

        self.fc4 = nn.Linear(15, 15)
        self.bn4 = nn.BatchNorm1d(15)

        self.fc5 = nn.Linear(15, 2)
#total ada 2 hidden layer.

    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
```

```

X = self.bn2(X)
X = self.fc3(X)
X = F.relu(X)
X = self.bn3(X)
X = self.fc4(X)
X = F.relu(X)
X = self.bn4(X)
X = self.fc5(X)

return X

```

```

[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.1)

```

```

[ ]: epochs = 300

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward() # perhitungan backpropagation
        optimizer.step()

        train_losses.append(loss) #memperbaharui setiao weight atau bbotot

```

```

train_mean_loss = torch.mean(torch.stack(train_losses))
print('training loss: {:.10.8f}'.format(train_mean_loss))

train_mean_losses.append(train_mean_loss)

#=====
# validation#setiap epoch lakukan validation
valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.41000202
validation loss: 0.41421187
=====
Epoch 1
training loss: 0.32861048
validation loss: 0.34127921
=====
Epoch 2
training loss: 0.29459330
validation loss: 0.32178760
=====
Epoch 3
training loss: 0.30003858
validation loss: 0.25492510
=====
Epoch 4
training loss: 0.29258028

```



```
validation loss: 0.30173314
=====
Epoch 5
training loss: 0.26084867
validation loss: 0.27672815
=====
Epoch 6
training loss: 0.27489704
validation loss: 0.30149141
=====
Epoch 7
training loss: 0.26879305
validation loss: 0.24167413
=====
Epoch 8
training loss: 0.26282719
validation loss: 0.30967695
=====
Epoch 9
training loss: 0.24591576
validation loss: 0.26956719
=====
Epoch 10
training loss: 0.23728745
validation loss: 0.23829244
=====
Epoch 11
training loss: 0.23063949
validation loss: 0.21752004
=====
Epoch 12
training loss: 0.22564307
validation loss: 0.21308210
=====
Epoch 13
training loss: 0.22513333
validation loss: 0.58353817
=====
Epoch 14
training loss: 0.30088076
validation loss: 0.25780571
=====
Epoch 15
training loss: 0.26247835
validation loss: 0.23177774
=====
Epoch 16
training loss: 0.22333030
```

```
validation loss: 0.21669094
=====
Epoch 17
training loss: 0.25266728
validation loss: 0.25282338
=====
Epoch 18
training loss: 0.22700098
validation loss: 0.20343018
=====
Epoch 19
training loss: 0.19623989
validation loss: 0.19405952
=====
Epoch 20
training loss: 0.22203737
validation loss: 0.17849770
=====
Epoch 21
training loss: 0.20309135
validation loss: 0.16996090
=====
Epoch 22
training loss: 0.21751894
validation loss: 0.24415919
=====
Epoch 23
training loss: 0.21934366
validation loss: 0.25914785
=====
Epoch 24
training loss: 0.19332480
validation loss: 0.76085204
=====
Epoch 25
training loss: 0.21107285
validation loss: 0.22967185
=====
Epoch 26
training loss: 0.20674899
validation loss: 0.18528977
=====
Epoch 27
training loss: 0.20772375
validation loss: 0.16700794
=====
Epoch 28
training loss: 0.21681464
```

```

validation loss: 0.55947167
=====
Epoch 29
training loss: 0.26468834
validation loss: 0.31626350
=====
Epoch 30
training loss: 0.21029668
validation loss: 0.19492358
=====
Epoch 31
training loss: 0.20649245
validation loss: 0.18271787
=====
Epoch 32
training loss: 0.21660212
validation loss: 0.21495387
=====
Epoch 33
training loss: 0.19807710
validation loss: 0.17938395
=====
Epoch 34
training loss: 0.18494605
validation loss: 0.18661481
=====
Epoch 35
training loss: 0.22055438
validation loss: 0.22801723
=====
Epoch 36
training loss: 0.20588847
validation loss: 0.31042558
=====
Epoch 37
training loss: 0.21143176
validation loss: 0.24872959
=====
Epoch 38
training loss: 0.18384923
validation loss: 0.21066479
=====
Epoch 39
training loss: 0.19514389
validation loss: 0.16188249
=====
Epoch 40
training loss: 0.18774374

```

```
validation loss: 0.17340791
=====
Epoch 41
training loss: 0.16887926
validation loss: 0.18803757
=====
Epoch 42
training loss: 0.17092769
validation loss: 0.20322736
=====
Epoch 43
training loss: 0.23706976
validation loss: 0.20245826
=====
Epoch 44
training loss: 0.16598523
validation loss: 0.16701669
=====
Epoch 45
training loss: 0.21183237
validation loss: 0.19538309
=====
Epoch 46
training loss: 0.16586912
validation loss: 0.18346328
=====
Epoch 47
training loss: 0.18387723
validation loss: 0.21105027
=====
Epoch 48
training loss: 0.17038646
validation loss: 0.18339200
=====
Epoch 49
training loss: 0.15555130
validation loss: 0.19656797
=====
Epoch 50
training loss: 0.19022064
validation loss: 0.17896628
=====
Epoch 51
training loss: 0.18955933
validation loss: 0.20685339
=====
Epoch 52
training loss: 0.18028463
```

```
validation loss: 0.16469194
=====
Epoch 53
training loss: 0.17480575
validation loss: 0.19122103
=====
Epoch 54
training loss: 0.16397974
validation loss: 0.16153263
=====
Epoch 55
training loss: 0.17093875
validation loss: 0.16269629
=====
Epoch 56
training loss: 0.17628936
validation loss: 0.17207375
=====
Epoch 57
training loss: 0.16429558
validation loss: 0.15798765
=====
Epoch 58
training loss: 0.17829663
validation loss: 0.14025864
=====
Epoch 59
training loss: 0.15644005
validation loss: 0.17552604
=====
Epoch 60
training loss: 0.15156083
validation loss: 0.15648489
=====
Epoch 61
training loss: 0.17428456
validation loss: 0.17406937
=====
Epoch 62
training loss: 0.16272195
validation loss: 0.15406141
=====
Epoch 63
training loss: 0.15296303
validation loss: 0.16752331
=====
Epoch 64
training loss: 0.19054273
```

```

validation loss: 0.15655977
=====
Epoch 65
training loss: 0.16375342
validation loss: 0.20643018
=====
Epoch 66
training loss: 0.19913553
validation loss: 0.20640957
=====
Epoch 67
training loss: 0.14765695
validation loss: 0.24906877
=====
Epoch 68
training loss: 0.15243693
validation loss: 0.16894738
=====
Epoch 69
training loss: 0.17343827
validation loss: 0.16522169
=====
Epoch 70
training loss: 0.17896371
validation loss: 0.21901378
=====
Epoch 71
training loss: 0.16936496
validation loss: 0.21892288
=====
Epoch 72
training loss: 0.14641681
validation loss: 0.18209340
=====
Epoch 73
training loss: 0.16371913
validation loss: 0.51868886
=====
Epoch 74
training loss: 0.20746458
validation loss: 0.15972866
=====
Epoch 75
training loss: 0.14079040
validation loss: 0.15641551
=====
Epoch 76
training loss: 0.15889432

```

```
validation loss: 0.14741108
=====
Epoch 77
training loss: 0.17699347
validation loss: 0.21143061
=====
Epoch 78
training loss: 0.17874239
validation loss: 0.18901776
=====
Epoch 79
training loss: 0.14614277
validation loss: 0.14401123
=====
Epoch 80
training loss: 0.14292821
validation loss: 0.14415914
=====
Epoch 81
training loss: 0.13134749
validation loss: 0.14628384
=====
Epoch 82
training loss: 0.17531335
validation loss: 0.27364767
=====
Epoch 83
training loss: 0.18485129
validation loss: 0.17551818
=====
Epoch 84
training loss: 0.17439149
validation loss: 0.15123093
=====
Epoch 85
training loss: 0.17978416
validation loss: 0.14571443
=====
Epoch 86
training loss: 0.18404855
validation loss: 0.19898829
=====
Epoch 87
training loss: 0.16441098
validation loss: 0.20439589
=====
Epoch 88
training loss: 0.17354721
```

```
validation loss: 0.19295895
=====
Epoch 89
training loss: 0.14047058
validation loss: 0.16136996
=====
Epoch 90
training loss: 0.15905255
validation loss: 0.24836364
=====
Epoch 91
training loss: 0.20985526
validation loss: 0.48430753
=====
Epoch 92
training loss: 0.27026030
validation loss: 0.19280462
=====
Epoch 93
training loss: 0.20293821
validation loss: 0.16615711
=====
Epoch 94
training loss: 0.21276020
validation loss: 0.22539589
=====
Epoch 95
training loss: 0.17404228
validation loss: 0.17873596
=====
Epoch 96
training loss: 0.16176900
validation loss: 0.17511074
=====
Epoch 97
training loss: 0.16508967
validation loss: 0.19085200
=====
Epoch 98
training loss: 0.16314153
validation loss: 0.21128309
=====
Epoch 99
training loss: 0.17492399
validation loss: 0.19854291
=====
Epoch 100
training loss: 0.17822416
```



```
validation loss: 0.16957489
=====
Epoch 101
training loss: 0.15357053
validation loss: 0.17452767
=====
Epoch 102
training loss: 0.18907329
validation loss: 0.17462799
=====
Epoch 103
training loss: 0.17117760
validation loss: 0.26337010
=====
Epoch 104
training loss: 0.20542777
validation loss: 0.18922177
=====
Epoch 105
training loss: 0.17089057
validation loss: 0.22712168
=====
Epoch 106
training loss: 0.18772310
validation loss: 0.25402904
=====
Epoch 107
training loss: 0.19045317
validation loss: 0.20771931
=====
Epoch 108
training loss: 0.18617605
validation loss: 0.17038560
=====
Epoch 109
training loss: 0.15972945
validation loss: 0.15957935
=====
Epoch 110
training loss: 0.17051560
validation loss: 0.18180674
=====
Epoch 111
training loss: 0.17918274
validation loss: 0.17043395
=====
Epoch 112
training loss: 0.16445056
```

```
validation loss: 0.17961082
=====
Epoch 113
training loss: 0.16309409
validation loss: 0.18117614
=====
Epoch 114
training loss: 0.15382472
validation loss: 0.17972343
=====
Epoch 115
training loss: 0.12135263
validation loss: 0.17787051
=====
Epoch 116
training loss: 0.14965408
validation loss: 0.18299696
=====
Epoch 117
training loss: 0.16217375
validation loss: 0.15884842
=====
Epoch 118
training loss: 0.13862716
validation loss: 0.20094036
=====
Epoch 119
training loss: 0.16310817
validation loss: 0.22554657
=====
Epoch 120
training loss: 0.14501330
validation loss: 0.24223253
=====
Epoch 121
training loss: 0.14478438
validation loss: 0.18527436
=====
Epoch 122
training loss: 0.13810548
validation loss: 0.19781730
=====
Epoch 123
training loss: 0.17766143
validation loss: 0.23523341
=====
Epoch 124
training loss: 0.16685368
```

```
validation loss: 0.17800342
=====
Epoch 125
training loss: 0.14065512
validation loss: 0.17659982
=====
Epoch 126
training loss: 0.17025989
validation loss: 0.19127928
=====
Epoch 127
training loss: 0.14525183
validation loss: 0.17096463
=====
Epoch 128
training loss: 0.13615465
validation loss: 0.22510882
=====
Epoch 129
training loss: 0.16982020
validation loss: 0.16233824
=====
Epoch 130
training loss: 0.15936024
validation loss: 0.17021058
=====
Epoch 131
training loss: 0.15436402
validation loss: 0.22156011
=====
Epoch 132
training loss: 0.13042283
validation loss: 0.20949398
=====
Epoch 133
training loss: 0.17215617
validation loss: 0.19941597
=====
Epoch 134
training loss: 0.11865059
validation loss: 0.20371835
=====
Epoch 135
training loss: 0.12841757
validation loss: 0.16352433
=====
Epoch 136
training loss: 0.13685185
```

```
validation loss: 0.17868276
=====
Epoch 137
training loss: 0.11646269
validation loss: 0.19403169
=====
Epoch 138
training loss: 0.12338934
validation loss: 0.18410373
=====
Epoch 139
training loss: 0.16200820
validation loss: 0.21287316
=====
Epoch 140
training loss: 0.16198041
validation loss: 0.14792122
=====
Epoch 141
training loss: 0.15323098
validation loss: 0.19389409
=====
Epoch 142
training loss: 0.14061482
validation loss: 0.12637483
=====
Epoch 143
training loss: 0.13508172
validation loss: 0.16513360
=====
Epoch 144
training loss: 0.12958059
validation loss: 0.13323262
=====
Epoch 145
training loss: 0.15749976
validation loss: 0.19150615
=====
Epoch 146
training loss: 0.14795624
validation loss: 0.14317232
=====
Epoch 147
training loss: 0.15447707
validation loss: 0.20108704
=====
Epoch 148
training loss: 0.14015019
```

```

validation loss: 0.12671942
=====
Epoch 149
training loss: 0.14293455
validation loss: 0.16713655
=====
Epoch 150
training loss: 0.14566545
validation loss: 0.16720966
=====
Epoch 151
training loss: 0.13277699
validation loss: 0.16848113
=====
Epoch 152
training loss: 0.14502244
validation loss: 0.17753729
=====
Epoch 153
training loss: 0.10148047
validation loss: 0.14156894
=====
Epoch 154
training loss: 0.12030212
validation loss: 0.16914074
=====
Epoch 155
training loss: 0.12678541
validation loss: 0.14888746
=====
Epoch 156
training loss: 0.14193162
validation loss: 0.14542273
=====
Epoch 157
training loss: 0.13619858
validation loss: 0.22651252
=====
Epoch 158
training loss: 0.12415622
validation loss: 0.21085896
=====
Epoch 159
training loss: 0.12207827
validation loss: 0.14501239
=====
Epoch 160
training loss: 0.12398105

```

```
validation loss: 0.18365631
=====
Epoch 161
training loss: 0.11006802
validation loss: 0.18084399
=====
Epoch 162
training loss: 0.13643698
validation loss: 0.21494974
=====
Epoch 163
training loss: 0.11707725
validation loss: 0.16958281
=====
Epoch 164
training loss: 0.13828242
validation loss: 0.13337770
=====
Epoch 165
training loss: 0.13522257
validation loss: 0.15491436
=====
Epoch 166
training loss: 0.12426902
validation loss: 0.14005998
=====
Epoch 167
training loss: 0.14078604
validation loss: 0.22931540
=====
Epoch 168
training loss: 0.13016860
validation loss: 0.17927897
=====
Epoch 169
training loss: 0.11692742
validation loss: 0.15705839
=====
Epoch 170
training loss: 0.11075168
validation loss: 0.14259493
=====
Epoch 171
training loss: 0.12049636
validation loss: 0.20383823
=====
Epoch 172
training loss: 0.13268521
```

```
validation loss: 0.25513494
=====
Epoch 173
training loss: 0.13055731
validation loss: 0.16527975
=====
Epoch 174
training loss: 0.13388580
validation loss: 0.21505046
=====
Epoch 175
training loss: 0.12471603
validation loss: 0.17569613
=====
Epoch 176
training loss: 0.12207261
validation loss: 0.16993736
=====
Epoch 177
training loss: 0.10667221
validation loss: 0.16303714
=====
Epoch 178
training loss: 0.12316804
validation loss: 0.14711419
=====
Epoch 179
training loss: 0.14528205
validation loss: 0.21275999
=====
Epoch 180
training loss: 0.13513786
validation loss: 0.26208097
=====
Epoch 181
training loss: 0.12384536
validation loss: 0.18844543
=====
Epoch 182
training loss: 0.11697917
validation loss: 0.20961311
=====
Epoch 183
training loss: 0.10555395
validation loss: 0.18696336
=====
Epoch 184
training loss: 0.11233584
```

```
validation loss: 0.18083891
=====
Epoch 185
training loss: 0.15132587
validation loss: 0.18223280
=====
Epoch 186
training loss: 0.11509456
validation loss: 0.18565106
=====
Epoch 187
training loss: 0.12636913
validation loss: 0.20785263
=====
Epoch 188
training loss: 0.13384897
validation loss: 0.18050298
=====
Epoch 189
training loss: 0.11006390
validation loss: 0.14626487
=====
Epoch 190
training loss: 0.11522519
validation loss: 0.16297156
=====
Epoch 191
training loss: 0.13094936
validation loss: 0.13604783
=====
Epoch 192
training loss: 0.12051089
validation loss: 0.21642470
=====
Epoch 193
training loss: 0.15156496
validation loss: 0.20966367
=====
Epoch 194
training loss: 0.11701128
validation loss: 0.18117841
=====
Epoch 195
training loss: 0.11321583
validation loss: 0.26749969
=====
Epoch 196
training loss: 0.13509077
```



```

validation loss: 0.35993671
=====
Epoch 197
training loss: 0.14544410
validation loss: 0.21776776
=====
Epoch 198
training loss: 0.16277720
validation loss: 0.21601066
=====
Epoch 199
training loss: 0.15845849
validation loss: 0.23728985
=====
Epoch 200
training loss: 0.10981136
validation loss: 0.19339629
=====
Epoch 201
training loss: 0.12760435
validation loss: 0.18513626
=====
Epoch 202
training loss: 0.13435420
validation loss: 0.19973136
=====
Epoch 203
training loss: 0.13494806
validation loss: 0.21664122
=====
Epoch 204
training loss: 0.11840659
validation loss: 0.16283217
=====
Epoch 205
training loss: 0.12292138
validation loss: 0.23314200
=====
Epoch 206
training loss: 0.12263785
validation loss: 0.20766589
=====
Epoch 207
training loss: 0.15393418
validation loss: 0.20993717
=====
Epoch 208
training loss: 0.11971360

```

```
validation loss: 0.17351562
=====
Epoch 209
training loss: 0.12142563
validation loss: 0.18231279
=====
Epoch 210
training loss: 0.15463111
validation loss: 0.22686914
=====
Epoch 211
training loss: 0.16022655
validation loss: 0.27915767
=====
Epoch 212
training loss: 0.17440699
validation loss: 0.20476767
=====
Epoch 213
training loss: 0.14412165
validation loss: 0.35422391
=====
Epoch 214
training loss: 0.21942888
validation loss: 0.18561797
=====
Epoch 215
training loss: 0.13858721
validation loss: 0.21062963
=====
Epoch 216
training loss: 0.16909322
validation loss: 0.17236297
=====
Epoch 217
training loss: 0.15065427
validation loss: 0.17880842
=====
Epoch 218
training loss: 0.13103572
validation loss: 0.20014150
=====
Epoch 219
training loss: 0.15166222
validation loss: 0.18405625
=====
Epoch 220
training loss: 0.14687252
```

```
validation loss: 0.24410556
=====
Epoch 221
training loss: 0.13355151
validation loss: 0.17272542
=====
Epoch 222
training loss: 0.15536937
validation loss: 0.17318356
=====
Epoch 223
training loss: 0.11508012
validation loss: 0.21074748
=====
Epoch 224
training loss: 0.10809647
validation loss: 0.21640426
=====
Epoch 225
training loss: 0.11444301
validation loss: 0.17256165
=====
Epoch 226
training loss: 0.10468033
validation loss: 0.17837796
=====
Epoch 227
training loss: 0.14139643
validation loss: 0.21324681
=====
Epoch 228
training loss: 0.10921617
validation loss: 0.18138114
=====
Epoch 229
training loss: 0.13774924
validation loss: 0.22223499
=====
Epoch 230
training loss: 0.11882019
validation loss: 0.18186644
=====
Epoch 231
training loss: 0.11239123
validation loss: 0.16257153
=====
Epoch 232
training loss: 0.11783815
```

```

validation loss: 0.16969462
=====
Epoch 233
training loss: 0.13818188
validation loss: 0.17925587
=====
Epoch 234
training loss: 0.14857614
validation loss: 0.18546085
=====
Epoch 235
training loss: 0.15317096
validation loss: 0.22127923
=====
Epoch 236
training loss: 0.14858770
validation loss: 0.25504619
=====
Epoch 237
training loss: 0.11547987
validation loss: 0.17591065
=====
Epoch 238
training loss: 0.13115524
validation loss: 0.20162959
=====
Epoch 239
training loss: 0.15025562
validation loss: 0.19561581
=====
Epoch 240
training loss: 0.11536916
validation loss: 0.17238297
=====
Epoch 241
training loss: 0.10577185
validation loss: 0.15848467
=====
Epoch 242
training loss: 0.12728472
validation loss: 0.17462429
=====
Epoch 243
training loss: 0.13699950
validation loss: 0.21585651
=====
Epoch 244
training loss: 0.11470521

```

```
validation loss: 0.18618034
=====
Epoch 245
training loss: 0.13855329
validation loss: 0.50668997
=====
Epoch 246
training loss: 0.16115816
validation loss: 0.20167296
=====
Epoch 247
training loss: 0.14819469
validation loss: 0.22602871
=====
Epoch 248
training loss: 0.14685887
validation loss: 0.20122264
=====
Epoch 249
training loss: 0.15048455
validation loss: 0.18488924
=====
Epoch 250
training loss: 0.16433904
validation loss: 0.15578008
=====
Epoch 251
training loss: 0.12650728
validation loss: 0.15648139
=====
Epoch 252
training loss: 0.12965553
validation loss: 0.15053579
=====
Epoch 253
training loss: 0.11881296
validation loss: 0.14738700
=====
Epoch 254
training loss: 0.13801050
validation loss: 0.13676432
=====
Epoch 255
training loss: 0.13080701
validation loss: 0.33768553
=====
Epoch 256
training loss: 0.17255510
```

```
validation loss: 0.15695514
=====
Epoch 257
training loss: 0.12875992
validation loss: 0.15826418
=====
Epoch 258
training loss: 0.13129103
validation loss: 0.15782700
=====
Epoch 259
training loss: 0.16099432
validation loss: 0.19722444
=====
Epoch 260
training loss: 0.15755084
validation loss: 0.17888539
=====
Epoch 261
training loss: 0.12031454
validation loss: 0.15983948
=====
Epoch 262
training loss: 0.13122746
validation loss: 0.23417929
=====
Epoch 263
training loss: 0.11215143
validation loss: 0.19544651
=====
Epoch 264
training loss: 0.11307392
validation loss: 0.20506085
=====
Epoch 265
training loss: 0.11370435
validation loss: 0.15382618
=====
Epoch 266
training loss: 0.11897957
validation loss: 0.21902189
=====
Epoch 267
training loss: 0.14281645
validation loss: 0.30702087
=====
Epoch 268
training loss: 0.17739972
```

```

validation loss: 0.20793127
=====
Epoch 269
training loss: 0.18469927
validation loss: 0.17506610
=====
Epoch 270
training loss: 0.13628265
validation loss: 0.21022317
=====
Epoch 271
training loss: 0.15415251
validation loss: 0.15964872
=====
Epoch 272
training loss: 0.17231865
validation loss: 0.19616474
=====
Epoch 273
training loss: 0.16115534
validation loss: 0.17589840
=====
Epoch 274
training loss: 0.14212398
validation loss: 0.16865456
=====
Epoch 275
training loss: 0.11749005
validation loss: 0.21728651
=====
Epoch 276
training loss: 0.18071947
validation loss: 0.18455464
=====
Epoch 277
training loss: 0.14122400
validation loss: 0.20029554
=====
Epoch 278
training loss: 0.15887134
validation loss: 0.19447961
=====
Epoch 279
training loss: 0.14857537
validation loss: 0.18776080
=====
Epoch 280
training loss: 0.15248859

```

```
validation loss: 0.17816061
=====
Epoch 281
training loss: 0.13754056
validation loss: 0.23611854
=====
Epoch 282
training loss: 0.13734923
validation loss: 0.14853348
=====
Epoch 283
training loss: 0.14022735
validation loss: 0.21809532
=====
Epoch 284
training loss: 0.14718948
validation loss: 0.18399069
=====
Epoch 285
training loss: 0.12651053
validation loss: 0.19714423
=====
Epoch 286
training loss: 0.15999912
validation loss: 0.27688676
=====
Epoch 287
training loss: 0.13630095
validation loss: 0.22217856
=====
Epoch 288
training loss: 0.14967968
validation loss: 0.21907794
=====
Epoch 289
training loss: 0.16379824
validation loss: 0.20449933
=====
Epoch 290
training loss: 0.12376219
validation loss: 0.18643375
=====
Epoch 291
training loss: 0.12498320
validation loss: 0.20131294
=====
Epoch 292
training loss: 0.13637492
```



```

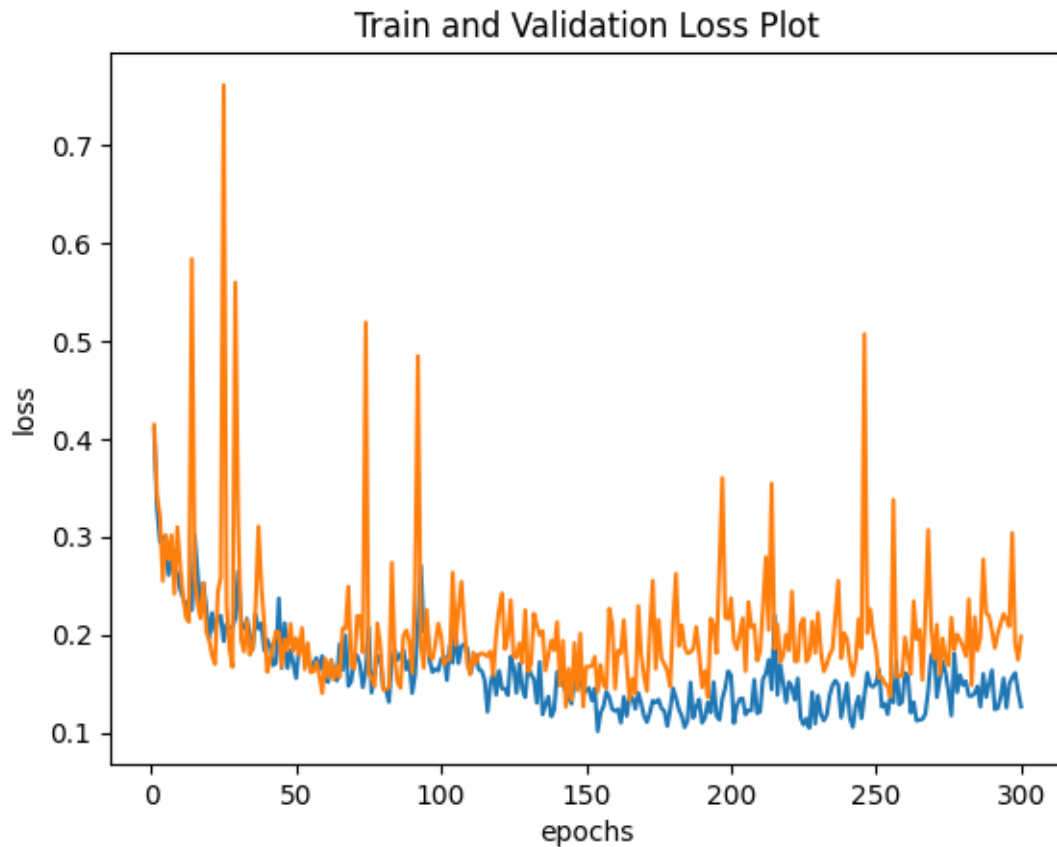
validation loss: 0.21095349
=====
Epoch 293
training loss: 0.15557086
validation loss: 0.22111768
=====
Epoch 294
training loss: 0.12562972
validation loss: 0.21592420
=====
Epoch 295
training loss: 0.14985199
validation loss: 0.20844933
=====
Epoch 296
training loss: 0.15652807
validation loss: 0.30377406
=====
Epoch 297
training loss: 0.16094340
validation loss: 0.19116457
=====
Epoch 298
training loss: 0.14248401
validation loss: 0.17446092
=====
Epoch 299
training loss: 0.12655011
validation loss: 0.19814020

```

```

[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()

```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                    axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 0 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 1 1 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[49  3]
 [ 7 75]]

```

=====

Accuracy: 0.9253731343283582

F1 Score: 0.9224537037037037

=====
Classification Report:

	precision	recall	f1-score	support
0	0.88	0.94	0.91	52
1	0.96	0.91	0.94	82
accuracy			0.93	134
macro avg	0.92	0.93	0.92	134
weighted avg	0.93	0.93	0.93	134

16 Modifikasi Arsitektur 7

- Hidden layer berjumlah 1, dengan jumlah neuron 30
- Optimasi yang digunakan adalah Adam dengan learning rate=0.09
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 30)
        self.bn1 = nn.BatchNorm1d(30)

        self.fc2= nn.Linear(30, 2)
#total ada 2 hidden layer.

    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)

        return X
```

```
[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.Adam(net.parameters(), lr=0.09)
```

```

[ ]: epochs = 300

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward()
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====

    valid_losses = []
    with torch.set_grad_enabled(False):
        for iteration, batch_data in enumerate(valid_loader):
            X_batch, y_batch = batch_data

            out = net(X_batch)
            loss = criterion(out, y_batch.squeeze())
            valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

```

```

        valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i

#=====

```

```

=====
Epoch 0
training loss: 0.46405444
validation loss: 0.26669800
=====
Epoch 1
training loss: 0.33381635
validation loss: 0.32636827
=====
Epoch 2
training loss: 0.34517238
validation loss: 0.39976457
=====
Epoch 3
training loss: 0.35501701
validation loss: 0.35991490
=====
Epoch 4
training loss: 0.32806626
validation loss: 0.33645666
=====
Epoch 5
training loss: 0.37738141
validation loss: 0.39230630
=====
Epoch 6
training loss: 0.38633084
validation loss: 0.30273533
=====
Epoch 7
training loss: 0.32223630
validation loss: 0.30017030
=====
Epoch 8
training loss: 0.39256513
validation loss: 0.26582858
=====
Epoch 9
training loss: 0.34419391

```

```
validation loss: 0.41484013
=====
Epoch 10
training loss: 0.32867810
validation loss: 0.29081145
=====
Epoch 11
training loss: 0.30407995
validation loss: 0.27355367
=====
Epoch 12
training loss: 0.30928802
validation loss: 0.26326886
=====
Epoch 13
training loss: 0.28858083
validation loss: 0.31837407
=====
Epoch 14
training loss: 0.31093499
validation loss: 0.28376210
=====
Epoch 15
training loss: 0.35326481
validation loss: 0.44320911
=====
Epoch 16
training loss: 0.32981491
validation loss: 0.53830761
=====
Epoch 17
training loss: 0.33576280
validation loss: 0.32428396
=====
Epoch 18
training loss: 0.31328914
validation loss: 0.23437081
=====
Epoch 19
training loss: 0.28930300
validation loss: 0.21537806
=====
Epoch 20
training loss: 0.32312280
validation loss: 0.28998005
=====
Epoch 21
training loss: 0.29376170
```

```
validation loss: 0.21453133
=====
Epoch 22
training loss: 0.35414752
validation loss: 0.27170479
=====
Epoch 23
training loss: 0.33155492
validation loss: 0.61697161
=====
Epoch 24
training loss: 0.26811811
validation loss: 0.28571352
=====
Epoch 25
training loss: 0.25567868
validation loss: 0.26262161
=====
Epoch 26
training loss: 0.34905586
validation loss: 0.20631622
=====
Epoch 27
training loss: 0.29897693
validation loss: 0.24440935
=====
Epoch 28
training loss: 0.27953446
validation loss: 0.35897666
=====
Epoch 29
training loss: 0.30763939
validation loss: 0.26299489
=====
Epoch 30
training loss: 0.33063972
validation loss: 0.33966449
=====
Epoch 31
training loss: 0.36319995
validation loss: 0.31551695
=====
Epoch 32
training loss: 0.31231439
validation loss: 0.21409488
=====
Epoch 33
training loss: 0.27966544
```



```
validation loss: 0.26493153
=====
Epoch 34
training loss: 0.26649636
validation loss: 0.24042086
=====
Epoch 35
training loss: 0.30200335
validation loss: 0.21506576
=====
Epoch 36
training loss: 0.30255052
validation loss: 0.25228325
=====
Epoch 37
training loss: 0.34902567
validation loss: 0.24828753
=====
Epoch 38
training loss: 0.36175251
validation loss: 0.22278197
=====
Epoch 39
training loss: 0.32256672
validation loss: 0.23492168
=====
Epoch 40
training loss: 0.28607219
validation loss: 0.24138555
=====
Epoch 41
training loss: 0.31843910
validation loss: 0.25796157
=====
Epoch 42
training loss: 0.34531209
validation loss: 0.31286001
=====
Epoch 43
training loss: 0.40032789
validation loss: 0.48910308
=====
Epoch 44
training loss: 0.36731827
validation loss: 0.80271804
=====
Epoch 45
training loss: 0.33443332
```

```

validation loss: 0.50765377
=====
Epoch 46
training loss: 0.29712570
validation loss: 0.31170261
=====
Epoch 47
training loss: 0.30931297
validation loss: 0.24064280
=====
Epoch 48
training loss: 0.27023712
validation loss: 0.28110799
=====
Epoch 49
training loss: 0.31792298
validation loss: 0.28301850
=====
Epoch 50
training loss: 0.30480197
validation loss: 0.19224992
=====
Epoch 51
training loss: 0.34959227
validation loss: 0.42393589
=====
Epoch 52
training loss: 0.35813653
validation loss: 0.26679781
=====
Epoch 53
training loss: 0.37896168
validation loss: 0.33727652
=====
Epoch 54
training loss: 0.43340001
validation loss: 0.26793784
=====
Epoch 55
training loss: 0.29372299
validation loss: 0.22248974
=====
Epoch 56
training loss: 0.27445561
validation loss: 0.28627476
=====
Epoch 57
training loss: 0.31995967

```

```
validation loss: 0.25883639
=====
Epoch 58
training loss: 0.31085086
validation loss: 0.25326294
=====
Epoch 59
training loss: 0.24559970
validation loss: 0.18427950
=====
Epoch 60
training loss: 0.26048014
validation loss: 0.24724454
=====
Epoch 61
training loss: 0.27348086
validation loss: 0.18877751
=====
Epoch 62
training loss: 0.27065778
validation loss: 0.20659395
=====
Epoch 63
training loss: 0.27798796
validation loss: 0.25520205
=====
Epoch 64
training loss: 0.26327962
validation loss: 0.29908115
=====
Epoch 65
training loss: 0.29562810
validation loss: 0.30583891
=====
Epoch 66
training loss: 0.27048621
validation loss: 0.22792296
=====
Epoch 67
training loss: 0.27477112
validation loss: 0.43570137
=====
Epoch 68
training loss: 0.32185155
validation loss: 0.24591330
=====
Epoch 69
training loss: 0.29092717
```

```

validation loss: 0.22273177
=====
Epoch 70
training loss: 0.26661569
validation loss: 0.22798491
=====
Epoch 71
training loss: 0.26098797
validation loss: 0.35772175
=====
Epoch 72
training loss: 0.31845391
validation loss: 0.22690488
=====
Epoch 73
training loss: 0.39069453
validation loss: 0.38449210
=====
Epoch 74
training loss: 0.30786258
validation loss: 0.20557725
=====
Epoch 75
training loss: 0.31647798
validation loss: 0.32071239
=====
Epoch 76
training loss: 0.30948260
validation loss: 0.24529092
=====
Epoch 77
training loss: 0.29420936
validation loss: 0.26967058
=====
Epoch 78
training loss: 0.27159995
validation loss: 0.25580534
=====
Epoch 79
training loss: 0.30402666
validation loss: 0.23116876
=====
Epoch 80
training loss: 0.29843035
validation loss: 0.25348961
=====
Epoch 81
training loss: 0.31854793

```

```
validation loss: 0.36585054
=====
Epoch 82
training loss: 0.34951863
validation loss: 0.28414077
=====
Epoch 83
training loss: 0.32312846
validation loss: 0.35886776
=====
Epoch 84
training loss: 0.33908564
validation loss: 0.41206250
=====
Epoch 85
training loss: 0.30340147
validation loss: 0.28001112
=====
Epoch 86
training loss: 0.29686686
validation loss: 0.26591983
=====
Epoch 87
training loss: 0.25446504
validation loss: 0.26999304
=====
Epoch 88
training loss: 0.26190633
validation loss: 0.29002520
=====
Epoch 89
training loss: 0.27115008
validation loss: 0.24616450
=====
Epoch 90
training loss: 0.28159845
validation loss: 0.31379563
=====
Epoch 91
training loss: 0.27934760
validation loss: 0.30689883
=====
Epoch 92
training loss: 0.31551528
validation loss: 0.27101630
=====
Epoch 93
training loss: 0.31204444
```

```
validation loss: 0.20382842
=====
Epoch 94
training loss: 0.26137123
validation loss: 0.20886055
=====
Epoch 95
training loss: 0.24911435
validation loss: 0.23073818
=====
Epoch 96
training loss: 0.27188879
validation loss: 0.43689913
=====
Epoch 97
training loss: 0.35033879
validation loss: 0.20369172
=====
Epoch 98
training loss: 0.32870582
validation loss: 0.21198072
=====
Epoch 99
training loss: 0.27417481
validation loss: 0.24004722
=====
Epoch 100
training loss: 0.24306215
validation loss: 0.29523909
=====
Epoch 101
training loss: 0.27014360
validation loss: 0.21348780
=====
Epoch 102
training loss: 0.29180881
validation loss: 0.20740877
=====
Epoch 103
training loss: 0.28223109
validation loss: 0.22179803
=====
Epoch 104
training loss: 0.33680698
validation loss: 0.22833990
=====
Epoch 105
training loss: 0.30627453
```

```

validation loss: 0.26519334
=====
Epoch 106
training loss: 0.26136941
validation loss: 0.22831339
=====
Epoch 107
training loss: 0.30140215
validation loss: 0.28194356
=====
Epoch 108
training loss: 0.29025730
validation loss: 0.29047519
=====
Epoch 109
training loss: 0.33173433
validation loss: 0.20702830
=====
Epoch 110
training loss: 0.29903364
validation loss: 0.31155872
=====
Epoch 111
training loss: 0.34192166
validation loss: 0.28599599
=====
Epoch 112
training loss: 0.29663271
validation loss: 0.26226452
=====
Epoch 113
training loss: 0.27897322
validation loss: 0.22442995
=====
Epoch 114
training loss: 0.26171803
validation loss: 0.23402816
=====
Epoch 115
training loss: 0.32848421
validation loss: 0.26052704
=====
Epoch 116
training loss: 0.28710735
validation loss: 0.26166850
=====
Epoch 117
training loss: 0.27296633

```

```
validation loss: 0.21159196
=====
Epoch 118
training loss: 0.31182367
validation loss: 0.28310665
=====
Epoch 119
training loss: 0.30436012
validation loss: 0.31752807
=====
Epoch 120
training loss: 0.33205879
validation loss: 0.22029576
=====
Epoch 121
training loss: 0.26607284
validation loss: 0.19680479
=====
Epoch 122
training loss: 0.28718403
validation loss: 0.24226043
=====
Epoch 123
training loss: 0.26461804
validation loss: 0.28277662
=====
Epoch 124
training loss: 0.23240289
validation loss: 0.41153792
=====
Epoch 125
training loss: 0.30393538
validation loss: 0.18059151
=====
Epoch 126
training loss: 0.26822922
validation loss: 0.27544233
=====
Epoch 127
training loss: 0.28149873
validation loss: 0.22517693
=====
Epoch 128
training loss: 0.32257000
validation loss: 0.23035812
=====
Epoch 129
training loss: 0.31014636
```



```
validation loss: 0.23404574
=====
Epoch 130
training loss: 0.27926457
validation loss: 0.38396922
=====
Epoch 131
training loss: 0.30732363
validation loss: 0.32883871
=====
Epoch 132
training loss: 0.30033889
validation loss: 0.24045846
=====
Epoch 133
training loss: 0.30469394
validation loss: 0.20183885
=====
Epoch 134
training loss: 0.36115786
validation loss: 0.31902575
=====
Epoch 135
training loss: 0.30996415
validation loss: 0.29090154
=====
Epoch 136
training loss: 0.29510570
validation loss: 0.21434878
=====
Epoch 137
training loss: 0.27002931
validation loss: 0.28019878
=====
Epoch 138
training loss: 0.27154285
validation loss: 0.22275430
=====
Epoch 139
training loss: 0.27865720
validation loss: 0.28258485
=====
Epoch 140
training loss: 0.29491076
validation loss: 0.33016092
=====
Epoch 141
training loss: 0.32283679
```

```
validation loss: 0.28926411
=====
Epoch 142
training loss: 0.28319788
validation loss: 0.46769863
=====
Epoch 143
training loss: 0.31779429
validation loss: 0.22218332
=====
Epoch 144
training loss: 0.25984049
validation loss: 0.39492616
=====
Epoch 145
training loss: 0.27760544
validation loss: 0.21031350
=====
Epoch 146
training loss: 0.25013331
validation loss: 0.26095742
=====
Epoch 147
training loss: 0.24607491
validation loss: 0.21600652
=====
Epoch 148
training loss: 0.25734034
validation loss: 0.31579453
=====
Epoch 149
training loss: 0.33648229
validation loss: 0.28497940
=====
Epoch 150
training loss: 0.28427500
validation loss: 0.25922206
=====
Epoch 151
training loss: 0.39709368
validation loss: 0.51191241
=====
Epoch 152
training loss: 0.34694687
validation loss: 0.18654586
=====
Epoch 153
training loss: 0.26281622
```

```
validation loss: 0.25686336
=====
Epoch 154
training loss: 0.25443441
validation loss: 0.19770755
=====
Epoch 155
training loss: 0.24849567
validation loss: 0.26275378
=====
Epoch 156
training loss: 0.27165776
validation loss: 0.19923989
=====
Epoch 157
training loss: 0.29919451
validation loss: 0.25624204
=====
Epoch 158
training loss: 0.26233405
validation loss: 0.19223899
=====
Epoch 159
training loss: 0.27975941
validation loss: 0.22150201
=====
Epoch 160
training loss: 0.29825661
validation loss: 0.20533982
=====
Epoch 161
training loss: 0.29131821
validation loss: 0.20717819
=====
Epoch 162
training loss: 0.30020911
validation loss: 0.23233844
=====
Epoch 163
training loss: 0.28908023
validation loss: 0.38069636
=====
Epoch 164
training loss: 0.27716929
validation loss: 0.26945108
=====
Epoch 165
training loss: 0.30584991
```

```
validation loss: 0.23512498
=====
Epoch 166
training loss: 0.28665680
validation loss: 0.23736963
=====
Epoch 167
training loss: 0.30772939
validation loss: 0.24856120
=====
Epoch 168
training loss: 0.27990487
validation loss: 0.19964156
=====
Epoch 169
training loss: 0.24891382
validation loss: 0.20001893
=====
Epoch 170
training loss: 0.29478797
validation loss: 0.24812017
=====
Epoch 171
training loss: 0.34767282
validation loss: 0.27082419
=====
Epoch 172
training loss: 0.40410656
validation loss: 0.23918456
=====
Epoch 173
training loss: 0.26665473
validation loss: 0.23057099
=====
Epoch 174
training loss: 0.27168179
validation loss: 0.23178834
=====
Epoch 175
training loss: 0.26135615
validation loss: 0.23110552
=====
Epoch 176
training loss: 0.27874985
validation loss: 0.42843783
=====
Epoch 177
training loss: 0.31940997
```

```
validation loss: 0.27055532
=====
Epoch 178
training loss: 0.27621680
validation loss: 0.49315828
=====
Epoch 179
training loss: 0.29674873
validation loss: 0.28577262
=====
Epoch 180
training loss: 0.28483328
validation loss: 0.22750054
=====
Epoch 181
training loss: 0.29282552
validation loss: 0.23112690
=====
Epoch 182
training loss: 0.28726417
validation loss: 0.30018398
=====
Epoch 183
training loss: 0.30057347
validation loss: 0.30895892
=====
Epoch 184
training loss: 0.28067732
validation loss: 0.31216839
=====
Epoch 185
training loss: 0.27708814
validation loss: 0.26304469
=====
Epoch 186
training loss: 0.29064161
validation loss: 0.31756768
=====
Epoch 187
training loss: 0.34480160
validation loss: 0.39970541
=====
Epoch 188
training loss: 0.28068236
validation loss: 0.23596928
=====
Epoch 189
training loss: 0.27200800
```

```
validation loss: 0.31076866
=====
Epoch 190
training loss: 0.28612018
validation loss: 0.35244569
=====
Epoch 191
training loss: 0.31757623
validation loss: 0.29172349
=====
Epoch 192
training loss: 0.29096693
validation loss: 0.26411852
=====
Epoch 193
training loss: 0.30666578
validation loss: 0.26977333
=====
Epoch 194
training loss: 0.27486974
validation loss: 0.34227830
=====
Epoch 195
training loss: 0.26557314
validation loss: 0.28765735
=====
Epoch 196
training loss: 0.25318184
validation loss: 0.37183487
=====
Epoch 197
training loss: 0.32329273
validation loss: 0.18596075
=====
Epoch 198
training loss: 0.29656410
validation loss: 0.37851286
=====
Epoch 199
training loss: 0.29404882
validation loss: 0.22529465
=====
Epoch 200
training loss: 0.29195932
validation loss: 0.30481884
=====
Epoch 201
training loss: 0.25247803
```

```
validation loss: 0.23481256
=====
Epoch 202
training loss: 0.28203282
validation loss: 0.24006024
=====
Epoch 203
training loss: 0.41212356
validation loss: 0.44818223
=====
Epoch 204
training loss: 0.34821585
validation loss: 0.22876526
=====
Epoch 205
training loss: 0.37195107
validation loss: 0.28130817
=====
Epoch 206
training loss: 0.29446191
validation loss: 0.29153842
=====
Epoch 207
training loss: 0.27014592
validation loss: 0.28915653
=====
Epoch 208
training loss: 0.26997885
validation loss: 0.20734048
=====
Epoch 209
training loss: 0.26124933
validation loss: 0.26273790
=====
Epoch 210
training loss: 0.27527153
validation loss: 0.23387004
=====
Epoch 211
training loss: 0.28806037
validation loss: 0.24265045
=====
Epoch 212
training loss: 0.30998132
validation loss: 0.21069312
=====
Epoch 213
training loss: 0.26399860
```

```

validation loss: 0.21017410
=====
Epoch 214
training loss: 0.29518095
validation loss: 0.26881143
=====
Epoch 215
training loss: 0.27346674
validation loss: 0.30303338
=====
Epoch 216
training loss: 0.30094838
validation loss: 0.27180332
=====
Epoch 217
training loss: 0.33083746
validation loss: 0.23351569
=====
Epoch 218
training loss: 0.27272066
validation loss: 0.23490429
=====
Epoch 219
training loss: 0.26814684
validation loss: 0.23205991
=====
Epoch 220
training loss: 0.23243311
validation loss: 0.18576600
=====
Epoch 221
training loss: 0.24891272
validation loss: 0.22373222
=====
Epoch 222
training loss: 0.30617377
validation loss: 0.31210670
=====
Epoch 223
training loss: 0.26538897
validation loss: 0.33610955
=====
Epoch 224
training loss: 0.24034025
validation loss: 0.20093541
=====
Epoch 225
training loss: 0.23740575

```



```
validation loss: 0.21288474
=====
Epoch 226
training loss: 0.25650480
validation loss: 0.22262041
=====
Epoch 227
training loss: 0.31626573
validation loss: 0.18978123
=====
Epoch 228
training loss: 0.27874932
validation loss: 0.22649372
=====
Epoch 229
training loss: 0.30284831
validation loss: 0.31483865
=====
Epoch 230
training loss: 0.35583401
validation loss: 0.23008445
=====
Epoch 231
training loss: 0.31125227
validation loss: 0.29398552
=====
Epoch 232
training loss: 0.31279817
validation loss: 0.32852036
=====
Epoch 233
training loss: 0.28055871
validation loss: 0.27575591
=====
Epoch 234
training loss: 0.29772639
validation loss: 0.32695043
=====
Epoch 235
training loss: 0.33141416
validation loss: 0.38006541
=====
Epoch 236
training loss: 0.28699955
validation loss: 0.23482172
=====
Epoch 237
training loss: 0.26425210
```

```
validation loss: 0.18853405
=====
Epoch 238
training loss: 0.28562659
validation loss: 0.25159580
=====
Epoch 239
training loss: 0.30678242
validation loss: 0.19808447
=====
Epoch 240
training loss: 0.27693844
validation loss: 0.20010009
=====
Epoch 241
training loss: 0.28827703
validation loss: 0.25535280
=====
Epoch 242
training loss: 0.28928864
validation loss: 0.51747203
=====
Epoch 243
training loss: 0.33818901
validation loss: 0.22010484
=====
Epoch 244
training loss: 0.33739623
validation loss: 0.28308538
=====
Epoch 245
training loss: 0.31731245
validation loss: 0.21446203
=====
Epoch 246
training loss: 0.23435239
validation loss: 0.17586507
=====
Epoch 247
training loss: 0.25224692
validation loss: 0.22936121
=====
Epoch 248
training loss: 0.24245529
validation loss: 0.22330672
=====
Epoch 249
training loss: 0.38559517
```

```
validation loss: 0.30951971
=====
Epoch 250
training loss: 0.33348727
validation loss: 0.20094056
=====
Epoch 251
training loss: 0.29000166
validation loss: 0.35687137
=====
Epoch 252
training loss: 0.26306725
validation loss: 0.23176414
=====
Epoch 253
training loss: 0.29411054
validation loss: 0.18786809
=====
Epoch 254
training loss: 0.29880300
validation loss: 0.31009939
=====
Epoch 255
training loss: 0.35930246
validation loss: 0.20346764
=====
Epoch 256
training loss: 0.27753597
validation loss: 0.29674658
=====
Epoch 257
training loss: 0.32516298
validation loss: 0.25567237
=====
Epoch 258
training loss: 0.25485110
validation loss: 0.19776976
=====
Epoch 259
training loss: 0.25916967
validation loss: 0.32294247
=====
Epoch 260
training loss: 0.28481987
validation loss: 0.35754329
=====
Epoch 261
training loss: 0.28602111
```

```

validation loss: 0.24040575
=====
Epoch 262
training loss: 0.25029528
validation loss: 0.24461710
=====
Epoch 263
training loss: 0.23543237
validation loss: 0.31756404
=====
Epoch 264
training loss: 0.28965384
validation loss: 0.28122553
=====
Epoch 265
training loss: 0.28006312
validation loss: 0.28722098
=====
Epoch 266
training loss: 0.26288483
validation loss: 0.24056599
=====
Epoch 267
training loss: 0.25425166
validation loss: 0.23904243
=====
Epoch 268
training loss: 0.31716314
validation loss: 0.31795391
=====
Epoch 269
training loss: 0.41404179
validation loss: 0.53607690
=====
Epoch 270
training loss: 0.32719433
validation loss: 0.20183748
=====
Epoch 271
training loss: 0.22056033
validation loss: 0.38298637
=====
Epoch 272
training loss: 0.28997403
validation loss: 0.21954761
=====
Epoch 273
training loss: 0.32323277

```

```
validation loss: 0.21454668
=====
Epoch 274
training loss: 0.31171390
validation loss: 0.23733124
=====
Epoch 275
training loss: 0.26879010
validation loss: 0.19103548
=====
Epoch 276
training loss: 0.27125335
validation loss: 0.21888782
=====
Epoch 277
training loss: 0.25483426
validation loss: 0.21343917
=====
Epoch 278
training loss: 0.25927874
validation loss: 0.35607046
=====
Epoch 279
training loss: 0.29671955
validation loss: 0.28223515
=====
Epoch 280
training loss: 0.25204650
validation loss: 0.42961052
=====
Epoch 281
training loss: 0.26859441
validation loss: 0.27862412
=====
Epoch 282
training loss: 0.33718157
validation loss: 0.25359845
=====
Epoch 283
training loss: 0.35722190
validation loss: 0.25005960
=====
Epoch 284
training loss: 0.30513361
validation loss: 0.23746119
=====
Epoch 285
training loss: 0.21823937
```

```
validation loss: 0.17329870
=====
Epoch 286
training loss: 0.27488172
validation loss: 0.30744052
=====
Epoch 287
training loss: 0.29095721
validation loss: 0.23495603
=====
Epoch 288
training loss: 0.28794688
validation loss: 0.28213301
=====
Epoch 289
training loss: 0.26476967
validation loss: 0.28199306
=====
Epoch 290
training loss: 0.25213870
validation loss: 0.22129717
=====
Epoch 291
training loss: 0.25266892
validation loss: 0.24465373
=====
Epoch 292
training loss: 0.24098483
validation loss: 0.19439730
=====
Epoch 293
training loss: 0.25997666
validation loss: 0.22237362
=====
Epoch 294
training loss: 0.33157349
validation loss: 0.19880925
=====
Epoch 295
training loss: 0.23498823
validation loss: 0.24534370
=====
Epoch 296
training loss: 0.26062760
validation loss: 0.19753014
=====
Epoch 297
training loss: 0.25693151
```

validation loss: 0.23825823

=====

Epoch 298

training loss: 0.26384908

validation loss: 0.16877052

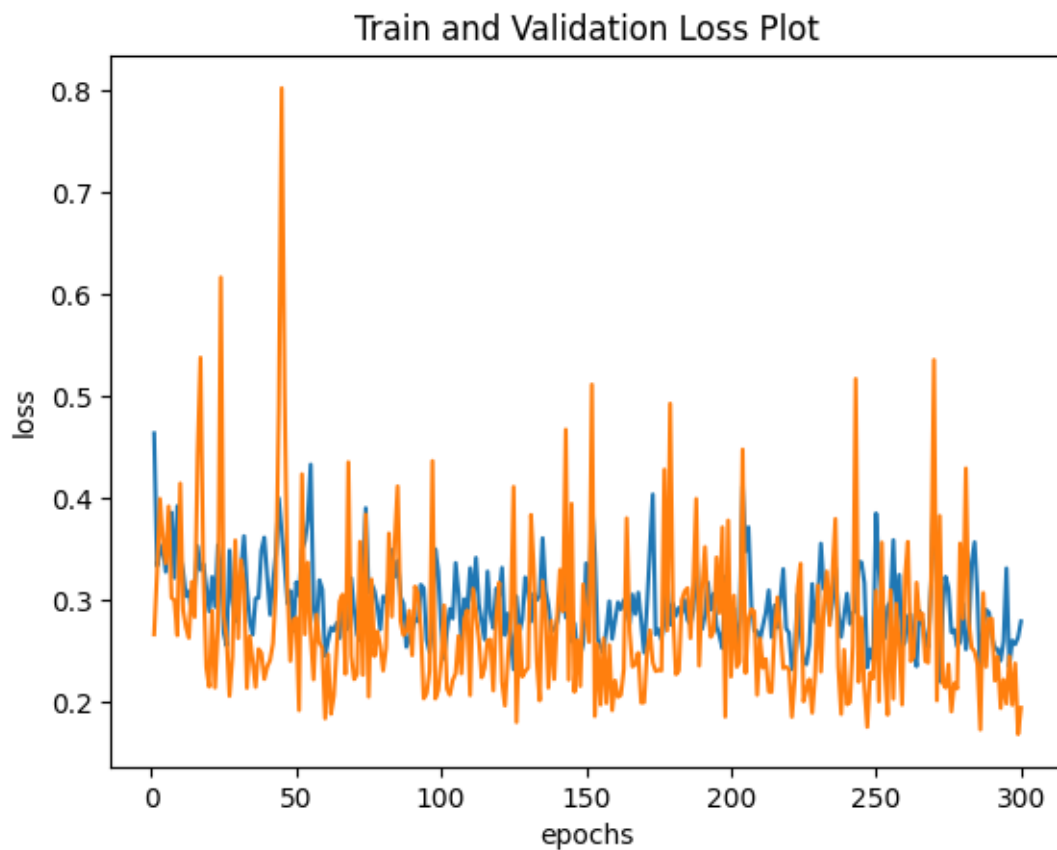
=====

Epoch 299

training loss: 0.27955905

validation loss: 0.19471090

```
[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.show()
```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))
```

=====

Predicted Class:

```
[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 0 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 0 1 0 1 1 1 0 0 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 0
 1 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 0
```



```
0 0 1 0 1 0 0 0 1 0 0 1 0 1 0 1 0 1 0 0 1]
```

Ground Truth:

```
[1 1 1 0 0 1 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 1 0 0 1]
```

Confusion Matrix:

```
[[49  3]
 [14 68]]
```

Accuracy: 0.8731343283582089

F1 Score: 0.8705314009661835

Classification Report:

	precision	recall	f1-score	support
0	0.78	0.94	0.85	52
1	0.96	0.83	0.89	82
accuracy			0.87	134
macro avg	0.87	0.89	0.87	134
weighted avg	0.89	0.87	0.87	134

17 Modifikasi Arsitektur 8

- Hidden layer berjumlah 2, dengan jumlah neuron di masing-masing hidden layer sebanyak 20 dan 16 neuron
- Optimasi yang digunakan adalah Adam dengan learning rate=0.15
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 20)
        self.bn1 = nn.BatchNorm1d(20)
```

```

        self.fc2 = nn.Linear(20, 16)
        self.bn2 = nn.BatchNorm1d(16)

        self.fc3 = nn.Linear(16, 2)
#total ada 2 hidden layer.

    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X

```

```

[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.Adam(net.parameters(), lr=0.15)

```

```

[ ]: epochs = 300

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

```

```

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward()
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

#=====

valid_losses = []
with torch.set_grad_enabled(False):
    for iteration, batch_data in enumerate(valid_loader):
        X_batch, y_batch = batch_data

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i

#=====

```

```
=====
Epoch 0
```

```
training loss: 0.45805734
```

```
validation loss: 0.32344127
```

```
=====
Epoch 1
```

```
training loss: 0.37683550
```

```
validation loss: 0.28839469
```

```
=====
Epoch 2
```

```
training loss: 0.32267123
```

```
validation loss: 0.31197897
```

```
=====
Epoch 3
training loss: 0.29647771
validation loss: 0.28869748
=====
Epoch 4
training loss: 0.30295277
validation loss: 0.23287442
=====
Epoch 5
training loss: 0.31383115
validation loss: 0.27797902
=====
Epoch 6
training loss: 0.32247001
validation loss: 0.29425615
=====
Epoch 7
training loss: 0.32779646
validation loss: 0.20789030
=====
Epoch 8
training loss: 0.30837941
validation loss: 0.32970512
=====
Epoch 9
training loss: 0.34555259
validation loss: 0.32365668
=====
Epoch 10
training loss: 0.39088556
validation loss: 0.24934275
=====
Epoch 11
training loss: 0.29266396
validation loss: 0.20178697
=====
Epoch 12
training loss: 0.33653444
validation loss: 0.52950883
=====
Epoch 13
training loss: 0.36761197
validation loss: 0.38612810
=====
Epoch 14
training loss: 0.26379216
validation loss: 0.27895159
```

```

=====
Epoch 15
training loss: 0.29311702
validation loss: 0.22597244
=====
Epoch 16
training loss: 0.26744908
validation loss: 0.19453362
=====
Epoch 17
training loss: 0.22815916
validation loss: 0.20303082
=====
Epoch 18
training loss: 0.26840574
validation loss: 0.22826605
=====
Epoch 19
training loss: 0.31224504
validation loss: 0.18688166
=====
Epoch 20
training loss: 0.34722602
validation loss: 0.29491085
=====
Epoch 21
training loss: 0.29933712
validation loss: 0.19201510
=====
Epoch 22
training loss: 0.26369616
validation loss: 0.20755488
=====
Epoch 23
training loss: 0.29756439
validation loss: 0.18485363
=====
Epoch 24
training loss: 0.22733806
validation loss: 0.18412337
=====
Epoch 25
training loss: 0.33656895
validation loss: 0.18752304
=====
Epoch 26
training loss: 0.26254281
validation loss: 0.19437599
=====

```

```

=====
Epoch 27
training loss: 0.21150763
validation loss: 0.62638986
=====
Epoch 28
training loss: 0.26849037
validation loss: 0.29438651
=====
Epoch 29
training loss: 0.29674029
validation loss: 0.25143746
=====
Epoch 30
training loss: 0.29314148
validation loss: 0.19040212
=====
Epoch 31
training loss: 0.25204277
validation loss: 0.27383286
=====
Epoch 32
training loss: 0.24169022
validation loss: 0.24684457
=====
Epoch 33
training loss: 0.25845790
validation loss: 0.18365207
=====
Epoch 34
training loss: 0.24305375
validation loss: 0.22250563
=====
Epoch 35
training loss: 0.24085839
validation loss: 0.17517133
=====
Epoch 36
training loss: 0.26164180
validation loss: 0.23523462
=====
Epoch 37
training loss: 0.28804088
validation loss: 0.35943818
=====
Epoch 38
training loss: 0.25174066
validation loss: 0.19798547

```

```

=====
Epoch 39
training loss: 0.22432473
validation loss: 0.26015663
=====
Epoch 40
training loss: 0.24969120
validation loss: 0.18048121
=====
Epoch 41
training loss: 0.23909241
validation loss: 0.18541907
=====
Epoch 42
training loss: 0.29516721
validation loss: 0.18951601
=====
Epoch 43
training loss: 0.27973047
validation loss: 0.26575226
=====
Epoch 44
training loss: 0.24650678
validation loss: 0.24052820
=====
Epoch 45
training loss: 0.29637429
validation loss: 0.23978944
=====
Epoch 46
training loss: 0.24836832
validation loss: 0.17418161
=====
Epoch 47
training loss: 0.23630764
validation loss: 0.16969071
=====
Epoch 48
training loss: 0.25973308
validation loss: 0.30855992
=====
Epoch 49
training loss: 0.27986407
validation loss: 0.27562428
=====
Epoch 50
training loss: 0.40145624
validation loss: 0.41602695

```

```

=====
Epoch 51
training loss: 0.32316947
validation loss: 0.19766241
=====
Epoch 52
training loss: 0.24700697
validation loss: 0.28709280
=====
Epoch 53
training loss: 0.22547337
validation loss: 0.20077430
=====
Epoch 54
training loss: 0.25574973
validation loss: 0.19693649
=====
Epoch 55
training loss: 0.35340098
validation loss: 0.22247365
=====
Epoch 56
training loss: 0.33692333
validation loss: 0.20472074
=====
Epoch 57
training loss: 0.26105708
validation loss: 0.22449388
=====
Epoch 58
training loss: 0.28528982
validation loss: 0.29793134
=====
Epoch 59
training loss: 0.20098159
validation loss: 0.23972660
=====
Epoch 60
training loss: 0.23964736
validation loss: 0.25431708
=====
Epoch 61
training loss: 0.22098096
validation loss: 0.21951249
=====
Epoch 62
training loss: 0.25621387
validation loss: 0.32078582
=====

```



```

=====
Epoch 63
training loss: 0.22886679
validation loss: 0.19105819
=====
Epoch 64
training loss: 0.27009565
validation loss: 0.25078109
=====
Epoch 65
training loss: 0.23266739
validation loss: 0.22994196
=====
Epoch 66
training loss: 0.30941701
validation loss: 0.22508268
=====
Epoch 67
training loss: 0.25080553
validation loss: 0.39201021
=====
Epoch 68
training loss: 0.34475577
validation loss: 0.18954663
=====
Epoch 69
training loss: 0.22725007
validation loss: 0.24168682
=====
Epoch 70
training loss: 0.21489346
validation loss: 0.17537177
=====
Epoch 71
training loss: 0.20918019
validation loss: 0.24324322
=====
Epoch 72
training loss: 0.19851345
validation loss: 0.21667886
=====
Epoch 73
training loss: 0.22202066
validation loss: 0.35838073
=====
Epoch 74
training loss: 0.29207572
validation loss: 0.27645946
=====

```

```

=====
Epoch 75
training loss: 0.24473162
validation loss: 0.21989933
=====
Epoch 76
training loss: 0.24736032
validation loss: 0.68744594
=====
Epoch 77
training loss: 0.27769297
validation loss: 0.21084608
=====
Epoch 78
training loss: 0.28619525
validation loss: 0.19398095
=====
Epoch 79
training loss: 0.27555293
validation loss: 0.21353555
=====
Epoch 80
training loss: 0.22633711
validation loss: 0.22754236
=====
Epoch 81
training loss: 0.24555190
validation loss: 0.19474438
=====
Epoch 82
training loss: 0.20953739
validation loss: 0.25395665
=====
Epoch 83
training loss: 0.20717633
validation loss: 0.34227014
=====
Epoch 84
training loss: 0.44474679
validation loss: 0.44610772
=====
Epoch 85
training loss: 0.30122977
validation loss: 0.17936927
=====
Epoch 86
training loss: 0.21312958
validation loss: 0.18211475
=====

```

```

=====
Epoch 87
training loss: 0.20182443
validation loss: 0.21483447
=====
Epoch 88
training loss: 0.24303047
validation loss: 0.22990984
=====
Epoch 89
training loss: 0.20920287
validation loss: 0.19499153
=====
Epoch 90
training loss: 0.18912660
validation loss: 0.22836988
=====
Epoch 91
training loss: 0.24730435
validation loss: 0.26249996
=====
Epoch 92
training loss: 0.21223007
validation loss: 0.19470054
=====
Epoch 93
training loss: 0.18292256
validation loss: 0.18674140
=====
Epoch 94
training loss: 0.19710532
validation loss: 0.16718042
=====
Epoch 95
training loss: 0.23335047
validation loss: 0.18047608
=====
Epoch 96
training loss: 0.24361274
validation loss: 0.23498787
=====
Epoch 97
training loss: 0.22728327
validation loss: 0.19049050
=====
Epoch 98
training loss: 0.21497251
validation loss: 0.23546840
=====

```

```

=====
Epoch 99
training loss: 0.25813961
validation loss: 0.26896602
=====
Epoch 100
training loss: 0.22784005
validation loss: 0.35400027
=====
Epoch 101
training loss: 0.26672065
validation loss: 0.16361074
=====
Epoch 102
training loss: 0.21108133
validation loss: 0.27342746
=====
Epoch 103
training loss: 0.23616754
validation loss: 0.22497636
=====
Epoch 104
training loss: 0.22258835
validation loss: 0.18199004
=====
Epoch 105
training loss: 0.22100882
validation loss: 0.23066634
=====
Epoch 106
training loss: 0.20861685
validation loss: 0.20570461
=====
Epoch 107
training loss: 0.17772599
validation loss: 0.26239106
=====
Epoch 108
training loss: 0.20451407
validation loss: 0.18295692
=====
Epoch 109
training loss: 0.19792460
validation loss: 0.19252127
=====
Epoch 110
training loss: 0.20474717
validation loss: 0.18541391

```

```

=====
Epoch 111
training loss: 0.17518108
validation loss: 0.24131845
=====
Epoch 112
training loss: 0.21782432
validation loss: 0.25665987
=====
Epoch 113
training loss: 0.21057539
validation loss: 0.18521191
=====
Epoch 114
training loss: 0.20871146
validation loss: 0.21523690
=====
Epoch 115
training loss: 0.21246983
validation loss: 0.21326540
=====
Epoch 116
training loss: 0.22088228
validation loss: 0.17698036
=====
Epoch 117
training loss: 0.26605493
validation loss: 0.32546470
=====
Epoch 118
training loss: 0.28068438
validation loss: 0.17766620
=====
Epoch 119
training loss: 0.19137150
validation loss: 0.25133255
=====
Epoch 120
training loss: 0.23800018
validation loss: 0.29743287
=====
Epoch 121
training loss: 0.24239065
validation loss: 0.38457516
=====
Epoch 122
training loss: 0.23045127
validation loss: 0.19319355
=====

```

```

=====
Epoch 123
training loss: 0.24918149
validation loss: 0.21630444
=====
Epoch 124
training loss: 0.20109741
validation loss: 0.17576145
=====
Epoch 125
training loss: 0.19955100
validation loss: 0.27444449
=====
Epoch 126
training loss: 0.20145611
validation loss: 0.17537525
=====
Epoch 127
training loss: 0.20395981
validation loss: 0.31677520
=====
Epoch 128
training loss: 0.21814683
validation loss: 0.34898767
=====
Epoch 129
training loss: 0.25334239
validation loss: 0.22873931
=====
Epoch 130
training loss: 0.29882050
validation loss: 0.17012200
=====
Epoch 131
training loss: 0.20149632
validation loss: 0.26029748
=====
Epoch 132
training loss: 0.20925444
validation loss: 0.20386396
=====
Epoch 133
training loss: 0.25516427
validation loss: 0.17860055
=====
Epoch 134
training loss: 0.17554758
validation loss: 0.18657440
=====

```

```

=====
Epoch 135
training loss: 0.19766024
validation loss: 0.18774867
=====
Epoch 136
training loss: 0.18538845
validation loss: 0.19122075
=====
Epoch 137
training loss: 0.21795857
validation loss: 0.19409597
=====
Epoch 138
training loss: 0.19489694
validation loss: 0.18621300
=====
Epoch 139
training loss: 0.19231029
validation loss: 0.17975044
=====
Epoch 140
training loss: 0.18081875
validation loss: 0.20004836
=====
Epoch 141
training loss: 0.23565698
validation loss: 0.19295570
=====
Epoch 142
training loss: 0.20351946
validation loss: 0.21051735
=====
Epoch 143
training loss: 0.22931384
validation loss: 0.23873097
=====
Epoch 144
training loss: 0.24496928
validation loss: 0.41704589
=====
Epoch 145
training loss: 0.22430187
validation loss: 0.19929665
=====
Epoch 146
training loss: 0.23405623
validation loss: 0.23260355
=====

```

```

=====
Epoch 147
training loss: 0.20176230
validation loss: 0.28202635
=====
Epoch 148
training loss: 0.19885510
validation loss: 0.27491915
=====
Epoch 149
training loss: 0.19761178
validation loss: 0.20869525
=====
Epoch 150
training loss: 0.21656263
validation loss: 0.40707850
=====
Epoch 151
training loss: 0.30809048
validation loss: 0.24483636
=====
Epoch 152
training loss: 0.22042742
validation loss: 0.23382141
=====
Epoch 153
training loss: 0.21908772
validation loss: 0.24478754
=====
Epoch 154
training loss: 0.19419058
validation loss: 0.27108663
=====
Epoch 155
training loss: 0.22901072
validation loss: 0.21060869
=====
Epoch 156
training loss: 0.17011781
validation loss: 0.17610781
=====
Epoch 157
training loss: 0.21797088
validation loss: 0.28633952
=====
Epoch 158
training loss: 0.25216997
validation loss: 0.23555785
=====

```



```

=====
Epoch 159
training loss: 0.20535579
validation loss: 0.22658275
=====
Epoch 160
training loss: 0.16721049
validation loss: 0.22302231
=====
Epoch 161
training loss: 0.31011206
validation loss: 0.84259236
=====
Epoch 162
training loss: 0.41995940
validation loss: 0.23965105
=====
Epoch 163
training loss: 0.21750405
validation loss: 0.27879035
=====
Epoch 164
training loss: 0.18421534
validation loss: 0.29826128
=====
Epoch 165
training loss: 0.21789020
validation loss: 0.52259541
=====
Epoch 166
training loss: 0.31206393
validation loss: 0.44472754
=====
Epoch 167
training loss: 0.25562605
validation loss: 0.24193260
=====
Epoch 168
training loss: 0.21979094
validation loss: 0.22071669
=====
Epoch 169
training loss: 0.19900289
validation loss: 0.22956529
=====
Epoch 170
training loss: 0.20621589
validation loss: 0.34335691
=====

```

```

=====
Epoch 171
training loss: 0.19292736
validation loss: 0.22258703
=====
Epoch 172
training loss: 0.17576469
validation loss: 0.23603368
=====
Epoch 173
training loss: 0.18688060
validation loss: 0.21036327
=====
Epoch 174
training loss: 0.17195623
validation loss: 0.18669648
=====
Epoch 175
training loss: 0.15541406
validation loss: 0.20768391
=====
Epoch 176
training loss: 0.29665539
validation loss: 0.33756226
=====
Epoch 177
training loss: 0.19391587
validation loss: 0.22189617
=====
Epoch 178
training loss: 0.21040307
validation loss: 0.31834340
=====
Epoch 179
training loss: 0.24600662
validation loss: 0.19078682
=====
Epoch 180
training loss: 0.23732390
validation loss: 0.45300668
=====
Epoch 181
training loss: 0.28075573
validation loss: 0.22259040
=====
Epoch 182
training loss: 0.18487591
validation loss: 0.24072447
=====

```

```

=====
Epoch 183
training loss: 0.21850343
validation loss: 0.26083139
=====
Epoch 184
training loss: 0.23018537
validation loss: 0.22050858
=====
Epoch 185
training loss: 0.18809904
validation loss: 0.20831954
=====
Epoch 186
training loss: 0.18583480
validation loss: 0.17206228
=====
Epoch 187
training loss: 0.18223390
validation loss: 0.24121454
=====
Epoch 188
training loss: 0.19931769
validation loss: 0.21373333
=====
Epoch 189
training loss: 0.17351077
validation loss: 0.19826630
=====
Epoch 190
training loss: 0.25952956
validation loss: 0.34777105
=====
Epoch 191
training loss: 0.31321016
validation loss: 0.26597825
=====
Epoch 192
training loss: 0.28353757
validation loss: 0.25658521
=====
Epoch 193
training loss: 0.23872951
validation loss: 0.28502315
=====
Epoch 194
training loss: 0.21478218
validation loss: 0.27110484

```

```

=====
Epoch 195
training loss: 0.24128723
validation loss: 0.38796490
=====
Epoch 196
training loss: 0.27070028
validation loss: 0.30237532
=====
Epoch 197
training loss: 0.24029557
validation loss: 0.20098059
=====
Epoch 198
training loss: 0.19506755
validation loss: 0.22959441
=====
Epoch 199
training loss: 0.19149211
validation loss: 0.27856392
=====
Epoch 200
training loss: 0.20196143
validation loss: 0.20715766
=====
Epoch 201
training loss: 0.24127957
validation loss: 0.24600591
=====
Epoch 202
training loss: 0.24978630
validation loss: 0.21495897
=====
Epoch 203
training loss: 0.17954466
validation loss: 0.17839609
=====
Epoch 204
training loss: 0.15982760
validation loss: 0.18268450
=====
Epoch 205
training loss: 0.16100292
validation loss: 0.20657568
=====
Epoch 206
training loss: 0.14678173
validation loss: 0.18258859
=====

```

```

=====
Epoch 207
training loss: 0.16942218
validation loss: 0.19176877
=====
Epoch 208
training loss: 0.18673190
validation loss: 0.19591939
=====
Epoch 209
training loss: 0.17242151
validation loss: 0.27342921
=====
Epoch 210
training loss: 0.17679963
validation loss: 0.26580614
=====
Epoch 211
training loss: 0.18077134
validation loss: 0.18652080
=====
Epoch 212
training loss: 0.19395433
validation loss: 0.21800058
=====
Epoch 213
training loss: 0.21135370
validation loss: 0.25763369
=====
Epoch 214
training loss: 0.18830316
validation loss: 0.44111946
=====
Epoch 215
training loss: 0.25572613
validation loss: 0.28221646
=====
Epoch 216
training loss: 0.17944396
validation loss: 0.25645262
=====
Epoch 217
training loss: 0.22081469
validation loss: 0.25282934
=====
Epoch 218
training loss: 0.20435610
validation loss: 0.22102618

```

```

=====
Epoch 219
training loss: 0.15194125
validation loss: 0.27312014
=====
Epoch 220
training loss: 0.20002267
validation loss: 0.20251557
=====
Epoch 221
training loss: 0.18017125
validation loss: 0.21017776
=====
Epoch 222
training loss: 0.21221672
validation loss: 0.72968692
=====
Epoch 223
training loss: 0.27987906
validation loss: 0.24338016
=====
Epoch 224
training loss: 0.18874367
validation loss: 0.18916561
=====
Epoch 225
training loss: 0.16034150
validation loss: 0.21470284
=====
Epoch 226
training loss: 0.24795821
validation loss: 0.24996483
=====
Epoch 227
training loss: 0.20208305
validation loss: 0.30185151
=====
Epoch 228
training loss: 0.26959574
validation loss: 0.25059721
=====
Epoch 229
training loss: 0.20241283
validation loss: 0.23282294
=====
Epoch 230
training loss: 0.17154005
validation loss: 0.22040433

```

```

=====
Epoch 231
training loss: 0.19571522
validation loss: 0.20011653
=====
Epoch 232
training loss: 0.17723244
validation loss: 0.26448455
=====
Epoch 233
training loss: 0.18260863
validation loss: 0.23059440
=====
Epoch 234
training loss: 0.17957461
validation loss: 0.19318208
=====
Epoch 235
training loss: 0.19297932
validation loss: 0.21649221
=====
Epoch 236
training loss: 0.21200764
validation loss: 0.21594425
=====
Epoch 237
training loss: 0.17643102
validation loss: 0.33284360
=====
Epoch 238
training loss: 0.22391063
validation loss: 0.33216369
=====
Epoch 239
training loss: 0.22455581
validation loss: 0.50565892
=====
Epoch 240
training loss: 0.25303096
validation loss: 0.45478624
=====
Epoch 241
training loss: 0.21459572
validation loss: 0.24185516
=====
Epoch 242
training loss: 0.16964905
validation loss: 0.22925994

```

```

=====
Epoch 243
training loss: 0.17970419
validation loss: 0.23764849
=====
Epoch 244
training loss: 0.19847009
validation loss: 0.22004430
=====
Epoch 245
training loss: 0.17491016
validation loss: 0.30752605
=====
Epoch 246
training loss: 0.21108221
validation loss: 0.31146276
=====
Epoch 247
training loss: 0.20597489
validation loss: 0.26370853
=====
Epoch 248
training loss: 0.21903253
validation loss: 0.21758877
=====
Epoch 249
training loss: 0.27122810
validation loss: 0.19558951
=====
Epoch 250
training loss: 0.16637483
validation loss: 0.17487004
=====
Epoch 251
training loss: 0.18939777
validation loss: 0.22595429
=====
Epoch 252
training loss: 0.36107427
validation loss: 0.26063067
=====
Epoch 253
training loss: 0.18711087
validation loss: 0.21168514
=====
Epoch 254
training loss: 0.14906852
validation loss: 0.20729646
=====

```



```

=====
Epoch 255
training loss: 0.19136059
validation loss: 0.17915896
=====
Epoch 256
training loss: 0.19217932
validation loss: 0.27365458
=====
Epoch 257
training loss: 0.23856267
validation loss: 0.18258403
=====
Epoch 258
training loss: 0.16343784
validation loss: 0.18385479
=====
Epoch 259
training loss: 0.17033701
validation loss: 0.20779696
=====
Epoch 260
training loss: 0.15297158
validation loss: 0.17553282
=====
Epoch 261
training loss: 0.17297220
validation loss: 0.22144228
=====
Epoch 262
training loss: 0.20779586
validation loss: 0.24302635
=====
Epoch 263
training loss: 0.15542923
validation loss: 0.19597065
=====
Epoch 264
training loss: 0.16637440
validation loss: 0.16258730
=====
Epoch 265
training loss: 0.21759476
validation loss: 0.19038263
=====
Epoch 266
training loss: 0.21685106
validation loss: 0.21195865
=====

```

```

=====
Epoch 267
training loss: 0.20976956
validation loss: 0.19983242
=====
Epoch 268
training loss: 0.21209507
validation loss: 0.18511198
=====
Epoch 269
training loss: 0.20096242
validation loss: 0.34733185
=====
Epoch 270
training loss: 0.19189523
validation loss: 0.23235033
=====
Epoch 271
training loss: 0.14688975
validation loss: 0.23053947
=====
Epoch 272
training loss: 0.16506349
validation loss: 0.19260989
=====
Epoch 273
training loss: 0.20563173
validation loss: 0.21944448
=====
Epoch 274
training loss: 0.22770919
validation loss: 0.32266879
=====
Epoch 275
training loss: 0.23230107
validation loss: 0.20996325
=====
Epoch 276
training loss: 0.21176179
validation loss: 0.27140132
=====
Epoch 277
training loss: 0.25044450
validation loss: 0.19691208
=====
Epoch 278
training loss: 0.18799257
validation loss: 0.29221264
=====

```

```

=====
Epoch 279
training loss: 0.16237900
validation loss: 0.22967163
=====
Epoch 280
training loss: 0.22887827
validation loss: 0.22857419
=====
Epoch 281
training loss: 0.30233377
validation loss: 0.24148397
=====
Epoch 282
training loss: 0.15302150
validation loss: 0.27338299
=====
Epoch 283
training loss: 0.15723242
validation loss: 0.20410448
=====
Epoch 284
training loss: 0.20242696
validation loss: 0.18520275
=====
Epoch 285
training loss: 0.19834043
validation loss: 0.26494038
=====
Epoch 286
training loss: 0.19022731
validation loss: 0.90229678
=====
Epoch 287
training loss: 0.27011690
validation loss: 0.19905849
=====
Epoch 288
training loss: 0.19795336
validation loss: 0.19398856
=====
Epoch 289
training loss: 0.25034562
validation loss: 0.32594451
=====
Epoch 290
training loss: 0.19592117
validation loss: 0.19844624

```

```
=====  
Epoch 291  
training loss: 0.15802583  
validation loss: 0.20849781  
=====
```

```
Epoch 292  
training loss: 0.15633373  
validation loss: 0.22559454  
=====
```

```
Epoch 293  
training loss: 0.15706173  
validation loss: 0.19580817  
=====
```

```
Epoch 294  
training loss: 0.15718497  
validation loss: 0.29446766  
=====
```

```
Epoch 295  
training loss: 0.20489450  
validation loss: 0.25115132  
=====
```

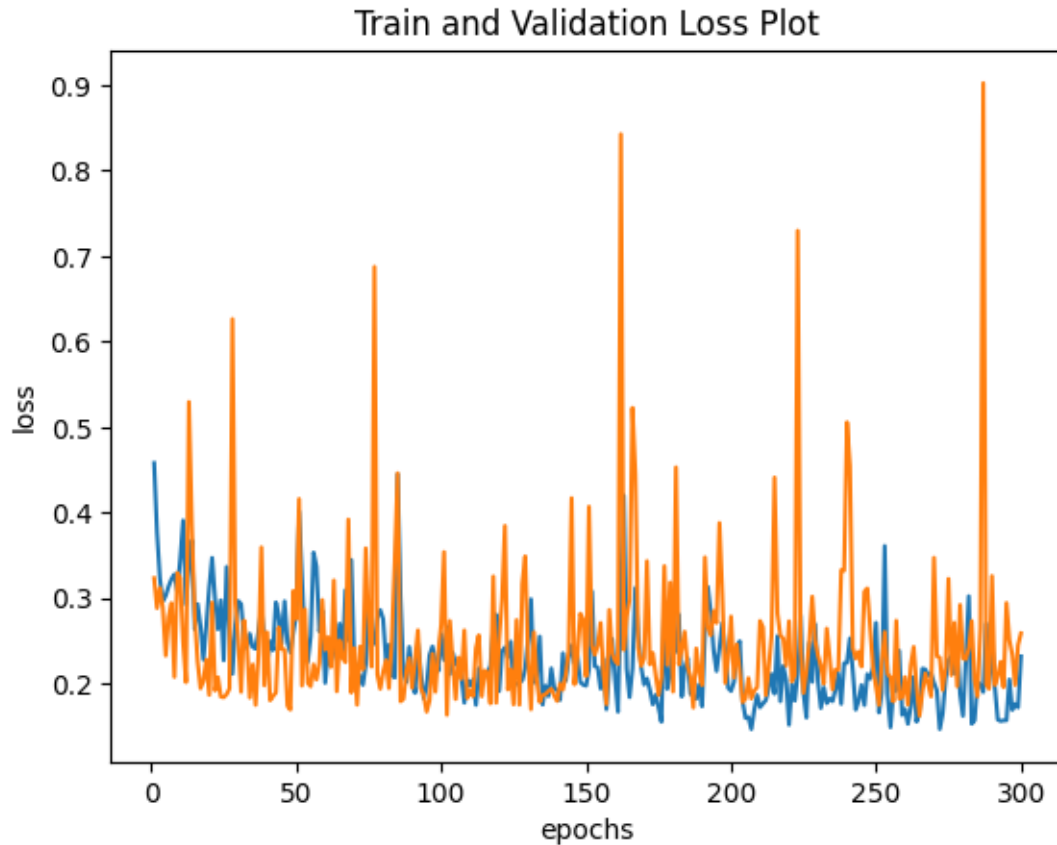
```
Epoch 296  
training loss: 0.16924095  
validation loss: 0.23439014  
=====
```

```
Epoch 297  
training loss: 0.17644364  
validation loss: 0.19848505  
=====
```

```
Epoch 298  
training loss: 0.17224275  
validation loss: 0.24522336  
=====
```

```
Epoch 299  
training loss: 0.23197466  
validation loss: 0.25888473
```

```
[ ]: import matplotlib.pyplot as plt  
with torch.no_grad():  
    plt.plot(range(1,epochs+1), train_mean_losses)  
    plt.plot(range(1,epochs+1), valid_mean_losses)  
    plt.xlabel('epochs')  
    plt.ylabel('loss')  
    plt.title('Train and Validation Loss Plot')  
    plt.show()
```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                     axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 0 1 1 0 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 1 1 0 1 0 0 0 1 1 0 1 0 1 0 0 0 1 0 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[48  4]
 [11 71]]

```

=====

Accuracy: 0.8880597014925373

F1 Score: 0.8846617317954898

=====
Classification Report:

	precision	recall	f1-score	support
0	0.81	0.92	0.86	52
1	0.95	0.87	0.90	82
accuracy			0.89	134
macro avg	0.88	0.89	0.88	134
weighted avg	0.90	0.89	0.89	134

18 Modifikasi Arsitektur 9

- Hidden layer berjumlah 2, dengan jumlah neuron di masing-masing hidden layer sebanyak 16 dan 10 neuron
- Optimasi yang digunakan adalah SGD dengan learning rate=0.15
- Epoch sebanyak 300

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 12)
        self.bn1 = nn.BatchNorm1d(12)

        self.fc2 = nn.Linear(12, 10)
        self.bn2 = nn.BatchNorm1d(10)

        self.fc3 = nn.Linear(10, 2)

    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X
```

```
[ ]: # Instantiating the model
net = Net()
```

```

# Choosing the loss function
criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.SGD(net.parameters(), lr=0.15)

```

```

[ ]: epochs = 300 #jumlah epoch 300 epoch

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward() # perhitungan backpropagation
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====

    valid_losses = []
    with torch.set_grad_enabled(False):
        for iteration, batch_data in enumerate(valid_loader):
            X_batch, y_batch = batch_data

```



```

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())
        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.35541326
validation loss: 0.33083951
=====
Epoch 1
training loss: 0.31579432
validation loss: 0.31301063
=====
Epoch 2
training loss: 0.29306239
validation loss: 0.33509660
=====
Epoch 3
training loss: 0.27158797
validation loss: 0.29586449
=====
Epoch 4
training loss: 0.26403874
validation loss: 0.34605762
=====
Epoch 5
training loss: 0.24469684
validation loss: 0.22305478
=====
Epoch 6
training loss: 0.22456741
validation loss: 0.33889365
=====
Epoch 7
training loss: 0.25552180
validation loss: 0.29682738

```

```

=====
Epoch 8
training loss: 0.23764479
validation loss: 0.28202114
=====
Epoch 9
training loss: 0.24117757
validation loss: 0.25868076
=====
Epoch 10
training loss: 0.25174838
validation loss: 0.25983050
=====
Epoch 11
training loss: 0.20994118
validation loss: 0.24539414
=====
Epoch 12
training loss: 0.21261437
validation loss: 0.32874644
=====
Epoch 13
training loss: 0.23239817
validation loss: 0.42980272
=====
Epoch 14
training loss: 0.24325289
validation loss: 0.22933100
=====
Epoch 15
training loss: 0.19857654
validation loss: 0.21779528
=====
Epoch 16
training loss: 0.21385120
validation loss: 0.24529105
=====
Epoch 17
training loss: 0.20117611
validation loss: 0.24310550
=====
Epoch 18
training loss: 0.21791916
validation loss: 0.29671007
=====
Epoch 19
training loss: 0.20861562
validation loss: 0.22356008
=====

```

```

=====
Epoch 20
training loss: 0.21480756
validation loss: 0.29731268
=====
Epoch 21
training loss: 0.20386790
validation loss: 0.22338331
=====
Epoch 22
training loss: 0.20268773
validation loss: 0.21270105
=====
Epoch 23
training loss: 0.22795652
validation loss: 0.24186531
=====
Epoch 24
training loss: 0.18764447
validation loss: 0.22806171
=====
Epoch 25
training loss: 0.18857870
validation loss: 0.20117085
=====
Epoch 26
training loss: 0.19484097
validation loss: 0.28593063
=====
Epoch 27
training loss: 0.19624698
validation loss: 0.22051427
=====
Epoch 28
training loss: 0.18287510
validation loss: 0.22646207
=====
Epoch 29
training loss: 0.19590919
validation loss: 0.19459288
=====
Epoch 30
training loss: 0.21058455
validation loss: 0.25296453
=====
Epoch 31
training loss: 0.18673068
validation loss: 0.22276612

```

```

=====
Epoch 32
training loss: 0.19295603
validation loss: 0.25511408
=====
Epoch 33
training loss: 0.17774208
validation loss: 0.20072241
=====
Epoch 34
training loss: 0.19949713
validation loss: 0.20339252
=====
Epoch 35
training loss: 0.16145499
validation loss: 0.21739089
=====
Epoch 36
training loss: 0.16992500
validation loss: 0.20270896
=====
Epoch 37
training loss: 0.22447294
validation loss: 0.21534035
=====
Epoch 38
training loss: 0.19230878
validation loss: 0.18468100
=====
Epoch 39
training loss: 0.20746888
validation loss: 0.22359583
=====
Epoch 40
training loss: 0.20767337
validation loss: 0.20755796
=====
Epoch 41
training loss: 0.17040931
validation loss: 0.18099193
=====
Epoch 42
training loss: 0.16259348
validation loss: 0.18862329
=====
Epoch 43
training loss: 0.15830828
validation loss: 0.16940385
=====

```

```

=====
Epoch 44
training loss: 0.17841761
validation loss: 0.19934432
=====
Epoch 45
training loss: 0.14682770
validation loss: 0.19310930
=====
Epoch 46
training loss: 0.15716556
validation loss: 0.18277881
=====
Epoch 47
training loss: 0.18150441
validation loss: 0.22242169
=====
Epoch 48
training loss: 0.16820924
validation loss: 0.18923107
=====
Epoch 49
training loss: 0.16206707
validation loss: 0.18075143
=====
Epoch 50
training loss: 0.18737517
validation loss: 0.23699787
=====
Epoch 51
training loss: 0.18039678
validation loss: 0.18684691
=====
Epoch 52
training loss: 0.19467749
validation loss: 0.26534760
=====
Epoch 53
training loss: 0.17446056
validation loss: 0.25121993
=====
Epoch 54
training loss: 0.16641644
validation loss: 0.16632962
=====
Epoch 55
training loss: 0.16205299
validation loss: 0.18123917

```

```

=====
Epoch 56
training loss: 0.17420481
validation loss: 0.24160869
=====
Epoch 57
training loss: 0.16588494
validation loss: 0.24117723
=====
Epoch 58
training loss: 0.16273454
validation loss: 0.20603833
=====
Epoch 59
training loss: 0.19374123
validation loss: 0.22832425
=====
Epoch 60
training loss: 0.17311107
validation loss: 0.23718247
=====
Epoch 61
training loss: 0.22527501
validation loss: 0.20535637
=====
Epoch 62
training loss: 0.18123922
validation loss: 0.24581611
=====
Epoch 63
training loss: 0.19025470
validation loss: 0.19086015
=====
Epoch 64
training loss: 0.18088888
validation loss: 0.21425647
=====
Epoch 65
training loss: 0.21800065
validation loss: 0.18380699
=====
Epoch 66
training loss: 0.17643170
validation loss: 0.21658243
=====
Epoch 67
training loss: 0.23018168
validation loss: 0.25950363

```

```

=====
Epoch 68
training loss: 0.19008590
validation loss: 0.16585025
=====
Epoch 69
training loss: 0.19431207
validation loss: 0.18352184
=====
Epoch 70
training loss: 0.21348535
validation loss: 0.21229774
=====
Epoch 71
training loss: 0.20371227
validation loss: 0.21027023
=====
Epoch 72
training loss: 0.22264534
validation loss: 0.24096441
=====
Epoch 73
training loss: 0.19126984
validation loss: 0.20013714
=====
Epoch 74
training loss: 0.18740167
validation loss: 0.21640402
=====
Epoch 75
training loss: 0.23506124
validation loss: 0.33661306
=====
Epoch 76
training loss: 0.21806797
validation loss: 0.19369781
=====
Epoch 77
training loss: 0.19983368
validation loss: 0.23416042
=====
Epoch 78
training loss: 0.20024867
validation loss: 0.19842505
=====
Epoch 79
training loss: 0.17995140
validation loss: 0.19541956
=====

```

```

=====
Epoch 80
training loss: 0.19364190
validation loss: 0.23166275
=====
Epoch 81
training loss: 0.18500195
validation loss: 0.24827412
=====
Epoch 82
training loss: 0.19961159
validation loss: 0.30694520
=====
Epoch 83
training loss: 0.18846659
validation loss: 0.18645835
=====
Epoch 84
training loss: 0.20331560
validation loss: 0.23922884
=====
Epoch 85
training loss: 0.18335854
validation loss: 0.22968464
=====
Epoch 86
training loss: 0.20652620
validation loss: 0.25669432
=====
Epoch 87
training loss: 0.23183069
validation loss: 0.22069831
=====
Epoch 88
training loss: 0.19973673
validation loss: 0.21296087
=====
Epoch 89
training loss: 0.20125806
validation loss: 0.20949477
=====
Epoch 90
training loss: 0.22303264
validation loss: 0.22141472
=====
Epoch 91
training loss: 0.18067855
validation loss: 0.19073115

```



```

=====
Epoch 92
training loss: 0.21177632
validation loss: 0.20460533
=====
Epoch 93
training loss: 0.19563155
validation loss: 0.20948441
=====
Epoch 94
training loss: 0.17797810
validation loss: 0.21127315
=====
Epoch 95
training loss: 0.18640280
validation loss: 0.20069002
=====
Epoch 96
training loss: 0.20817019
validation loss: 0.20889454
=====
Epoch 97
training loss: 0.18428497
validation loss: 0.19007766
=====
Epoch 98
training loss: 0.19770999
validation loss: 0.17816688
=====
Epoch 99
training loss: 0.18366298
validation loss: 0.18058726
=====
Epoch 100
training loss: 0.18876493
validation loss: 0.19134247
=====
Epoch 101
training loss: 0.17427354
validation loss: 0.16918527
=====
Epoch 102
training loss: 0.16495240
validation loss: 0.17478159
=====
Epoch 103
training loss: 0.17226569
validation loss: 0.17584065
=====

```

```

=====
Epoch 104
training loss: 0.18716878
validation loss: 0.17400944
=====
Epoch 105
training loss: 0.15206513
validation loss: 0.16275072
=====
Epoch 106
training loss: 0.20153177
validation loss: 0.25007740
=====
Epoch 107
training loss: 0.23697954
validation loss: 0.19242725
=====
Epoch 108
training loss: 0.17438491
validation loss: 0.18683238
=====
Epoch 109
training loss: 0.20671086
validation loss: 0.17644575
=====
Epoch 110
training loss: 0.18235235
validation loss: 0.20180826
=====
Epoch 111
training loss: 0.19143549
validation loss: 0.19310878
=====
Epoch 112
training loss: 0.19018939
validation loss: 0.18851659
=====
Epoch 113
training loss: 0.17609307
validation loss: 0.20302695
=====
Epoch 114
training loss: 0.16689195
validation loss: 0.19395867
=====
Epoch 115
training loss: 0.19575642
validation loss: 0.19308504

```

```

=====
Epoch 116
training loss: 0.20486248
validation loss: 0.19844669
=====
Epoch 117
training loss: 0.17771944
validation loss: 0.22265542
=====
Epoch 118
training loss: 0.15731214
validation loss: 0.22661260
=====
Epoch 119
training loss: 0.16033259
validation loss: 0.17499697
=====
Epoch 120
training loss: 0.16260789
validation loss: 0.17929022
=====
Epoch 121
training loss: 0.19671965
validation loss: 0.19852500
=====
Epoch 122
training loss: 0.17824398
validation loss: 0.18795730
=====
Epoch 123
training loss: 0.19075361
validation loss: 0.19350360
=====
Epoch 124
training loss: 0.17317574
validation loss: 0.20855981
=====
Epoch 125
training loss: 0.17613207
validation loss: 0.19076543
=====
Epoch 126
training loss: 0.17044951
validation loss: 0.20613565
=====
Epoch 127
training loss: 0.17907527
validation loss: 0.15947597

```

```

=====
Epoch 128
training loss: 0.19282770
validation loss: 0.18219051
=====
Epoch 129
training loss: 0.18215072
validation loss: 0.16767105
=====
Epoch 130
training loss: 0.17293823
validation loss: 0.17444615
=====
Epoch 131
training loss: 0.17932348
validation loss: 0.27980989
=====
Epoch 132
training loss: 0.19070190
validation loss: 0.21485861
=====
Epoch 133
training loss: 0.18874134
validation loss: 0.21190837
=====
Epoch 134
training loss: 0.18414204
validation loss: 0.18045600
=====
Epoch 135
training loss: 0.20344362
validation loss: 0.18847199
=====
Epoch 136
training loss: 0.17443523
validation loss: 0.17642720
=====
Epoch 137
training loss: 0.17885153
validation loss: 0.20464489
=====
Epoch 138
training loss: 0.18515809
validation loss: 0.24268104
=====
Epoch 139
training loss: 0.19874837
validation loss: 0.19679032
=====

```

```

=====
Epoch 140
training loss: 0.18952395
validation loss: 0.19496694
=====
Epoch 141
training loss: 0.16983874
validation loss: 0.19898546
=====
Epoch 142
training loss: 0.15205532
validation loss: 0.18494812
=====
Epoch 143
training loss: 0.18447296
validation loss: 0.21021353
=====
Epoch 144
training loss: 0.19008552
validation loss: 0.23460498
=====
Epoch 145
training loss: 0.17453966
validation loss: 0.20450009
=====
Epoch 146
training loss: 0.17805952
validation loss: 0.19156973
=====
Epoch 147
training loss: 0.19797349
validation loss: 0.18316643
=====
Epoch 148
training loss: 0.17220303
validation loss: 0.16728455
=====
Epoch 149
training loss: 0.19091515
validation loss: 0.22990561
=====
Epoch 150
training loss: 0.16797033
validation loss: 0.16430825
=====
Epoch 151
training loss: 0.17010935
validation loss: 0.17610151

```

```

=====
Epoch 152
training loss: 0.17918485
validation loss: 0.32911021
=====
Epoch 153
training loss: 0.20963129
validation loss: 0.17825525
=====
Epoch 154
training loss: 0.18092495
validation loss: 0.18550174
=====
Epoch 155
training loss: 0.18857083
validation loss: 0.19016975
=====
Epoch 156
training loss: 0.16956899
validation loss: 0.15050419
=====
Epoch 157
training loss: 0.15284880
validation loss: 0.15795213
=====
Epoch 158
training loss: 0.17752293
validation loss: 0.17235370
=====
Epoch 159
training loss: 0.21968456
validation loss: 0.18190247
=====
Epoch 160
training loss: 0.18884653
validation loss: 0.17550251
=====
Epoch 161
training loss: 0.19483124
validation loss: 0.17350885
=====
Epoch 162
training loss: 0.19507153
validation loss: 0.18583694
=====
Epoch 163
training loss: 0.18683767
validation loss: 0.18165460
=====

```

```

=====
Epoch 164
training loss: 0.18541059
validation loss: 0.27719158
=====
Epoch 165
training loss: 0.17913306
validation loss: 0.18642247
=====
Epoch 166
training loss: 0.16205466
validation loss: 0.16634122
=====
Epoch 167
training loss: 0.16893938
validation loss: 0.19057564
=====
Epoch 168
training loss: 0.16481268
validation loss: 0.17703438
=====
Epoch 169
training loss: 0.18099660
validation loss: 0.16961889
=====
Epoch 170
training loss: 0.18641128
validation loss: 0.16765587
=====
Epoch 171
training loss: 0.16180681
validation loss: 0.15623736
=====
Epoch 172
training loss: 0.17079437
validation loss: 0.22237945
=====
Epoch 173
training loss: 0.16366918
validation loss: 0.18122809
=====
Epoch 174
training loss: 0.15832254
validation loss: 0.18811649
=====
Epoch 175
training loss: 0.17230541
validation loss: 0.14986689
=====

```

```

=====
Epoch 176
training loss: 0.15670100
validation loss: 0.14326900
=====
Epoch 177
training loss: 0.14410934
validation loss: 0.16159242
=====
Epoch 178
training loss: 0.16689292
validation loss: 0.22048086
=====
Epoch 179
training loss: 0.15912306
validation loss: 0.15025629
=====
Epoch 180
training loss: 0.15256497
validation loss: 0.14797767
=====
Epoch 181
training loss: 0.17249557
validation loss: 0.15666591
=====
Epoch 182
training loss: 0.18507834
validation loss: 0.16270427
=====
Epoch 183
training loss: 0.16935237
validation loss: 0.14467125
=====
Epoch 184
training loss: 0.17523943
validation loss: 0.16057202
=====
Epoch 185
training loss: 0.17632443
validation loss: 0.15296566
=====
Epoch 186
training loss: 0.19571924
validation loss: 0.15554072
=====
Epoch 187
training loss: 0.19752511
validation loss: 0.19329855
=====

```



```

=====
Epoch 188
training loss: 0.16887486
validation loss: 0.17380655
=====
Epoch 189
training loss: 0.15611871
validation loss: 0.13231315
=====
Epoch 190
training loss: 0.15509807
validation loss: 0.15479732
=====
Epoch 191
training loss: 0.15561055
validation loss: 0.16351669
=====
Epoch 192
training loss: 0.19674647
validation loss: 0.17006263
=====
Epoch 193
training loss: 0.17556742
validation loss: 0.14413536
=====
Epoch 194
training loss: 0.14430012
validation loss: 0.17330611
=====
Epoch 195
training loss: 0.15903388
validation loss: 0.17279418
=====
Epoch 196
training loss: 0.16172509
validation loss: 0.14516005
=====
Epoch 197
training loss: 0.16026787
validation loss: 0.15130496
=====
Epoch 198
training loss: 0.15386038
validation loss: 0.25217840
=====
Epoch 199
training loss: 0.16549197
validation loss: 0.15055309
=====

```

```

=====
Epoch 200
training loss: 0.16390249
validation loss: 0.18621223
=====
Epoch 201
training loss: 0.16739108
validation loss: 0.14085697
=====
Epoch 202
training loss: 0.17788948
validation loss: 0.14332460
=====
Epoch 203
training loss: 0.15345739
validation loss: 0.19462806
=====
Epoch 204
training loss: 0.17962964
validation loss: 0.22827867
=====
Epoch 205
training loss: 0.14788195
validation loss: 0.14568812
=====
Epoch 206
training loss: 0.13227306
validation loss: 0.13527043
=====
Epoch 207
training loss: 0.18513818
validation loss: 0.16099860
=====
Epoch 208
training loss: 0.18307026
validation loss: 0.22320759
=====
Epoch 209
training loss: 0.18859781
validation loss: 0.22911224
=====
Epoch 210
training loss: 0.19261077
validation loss: 0.16603409
=====
Epoch 211
training loss: 0.18492815
validation loss: 0.21471876

```

```

=====
Epoch 212
training loss: 0.17571618
validation loss: 0.18827333
=====
Epoch 213
training loss: 0.17436349
validation loss: 0.18565720
=====
Epoch 214
training loss: 0.16693898
validation loss: 0.17627825
=====
Epoch 215
training loss: 0.17514470
validation loss: 0.26511776
=====
Epoch 216
training loss: 0.18925574
validation loss: 0.19284125
=====
Epoch 217
training loss: 0.16218048
validation loss: 0.15150209
=====
Epoch 218
training loss: 0.18105800
validation loss: 0.16748729
=====
Epoch 219
training loss: 0.14749551
validation loss: 0.13916753
=====
Epoch 220
training loss: 0.18982270
validation loss: 0.24660696
=====
Epoch 221
training loss: 0.18038416
validation loss: 0.16283569
=====
Epoch 222
training loss: 0.15372083
validation loss: 0.14917272
=====
Epoch 223
training loss: 0.15797675
validation loss: 0.17305833

```

```

=====
Epoch 224
training loss: 0.15467119
validation loss: 0.14416140
=====
Epoch 225
training loss: 0.14245112
validation loss: 0.18494055
=====
Epoch 226
training loss: 0.14876051
validation loss: 0.24830821
=====
Epoch 227
training loss: 0.17943153
validation loss: 0.16510722
=====
Epoch 228
training loss: 0.14902560
validation loss: 0.20602109
=====
Epoch 229
training loss: 0.17057203
validation loss: 0.30157360
=====
Epoch 230
training loss: 0.17860097
validation loss: 0.20366034
=====
Epoch 231
training loss: 0.14667650
validation loss: 0.16314353
=====
Epoch 232
training loss: 0.15834323
validation loss: 0.16086039
=====
Epoch 233
training loss: 0.14419429
validation loss: 0.17302194
=====
Epoch 234
training loss: 0.17463857
validation loss: 0.18653682
=====
Epoch 235
training loss: 0.18249537
validation loss: 0.16357701

```

```

=====
Epoch 236
training loss: 0.15596245
validation loss: 0.19107395
=====
Epoch 237
training loss: 0.19184680
validation loss: 0.33920863
=====
Epoch 238
training loss: 0.16224408
validation loss: 0.15151882
=====
Epoch 239
training loss: 0.17349710
validation loss: 0.16693076
=====
Epoch 240
training loss: 0.15265052
validation loss: 0.15298524
=====
Epoch 241
training loss: 0.15209444
validation loss: 0.18855640
=====
Epoch 242
training loss: 0.16801588
validation loss: 0.16914855
=====
Epoch 243
training loss: 0.17825915
validation loss: 0.18795717
=====
Epoch 244
training loss: 0.16698065
validation loss: 0.17260954
=====
Epoch 245
training loss: 0.16510276
validation loss: 0.18615463
=====
Epoch 246
training loss: 0.15520099
validation loss: 0.15037154
=====
Epoch 247
training loss: 0.18080215
validation loss: 0.16462521

```

```

=====
Epoch 248
training loss: 0.16560242
validation loss: 0.18938413
=====
Epoch 249
training loss: 0.14831781
validation loss: 0.16499300
=====
Epoch 250
training loss: 0.17191398
validation loss: 0.27832568
=====
Epoch 251
training loss: 0.19833097
validation loss: 0.19936337
=====
Epoch 252
training loss: 0.16878571
validation loss: 0.26103434
=====
Epoch 253
training loss: 0.17513102
validation loss: 0.17351428
=====
Epoch 254
training loss: 0.18802562
validation loss: 0.24038641
=====
Epoch 255
training loss: 0.18413875
validation loss: 0.17364860
=====
Epoch 256
training loss: 0.19618951
validation loss: 0.23600021
=====
Epoch 257
training loss: 0.16423173
validation loss: 0.27118930
=====
Epoch 258
training loss: 0.17233206
validation loss: 0.24073184
=====
Epoch 259
training loss: 0.16375765
validation loss: 0.16341917
=====

```

```

=====
Epoch 260
training loss: 0.16861904
validation loss: 0.17194386
=====
Epoch 261
training loss: 0.17629163
validation loss: 0.18466432
=====
Epoch 262
training loss: 0.14721730
validation loss: 0.16683401
=====
Epoch 263
training loss: 0.14800075
validation loss: 0.17584245
=====
Epoch 264
training loss: 0.15081424
validation loss: 0.16491210
=====
Epoch 265
training loss: 0.16060802
validation loss: 0.14773464
=====
Epoch 266
training loss: 0.15314531
validation loss: 0.15074974
=====
Epoch 267
training loss: 0.14834405
validation loss: 0.16853552
=====
Epoch 268
training loss: 0.14336078
validation loss: 0.24210720
=====
Epoch 269
training loss: 0.16492140
validation loss: 0.23590964
=====
Epoch 270
training loss: 0.15001632
validation loss: 0.22181144
=====
Epoch 271
training loss: 0.18466730
validation loss: 0.19160405

```

```

=====
Epoch 272
training loss: 0.18696558
validation loss: 0.18757991
=====
Epoch 273
training loss: 0.16390394
validation loss: 0.18517746
=====
Epoch 274
training loss: 0.13593702
validation loss: 0.18358642
=====
Epoch 275
training loss: 0.15959637
validation loss: 0.17344135
=====
Epoch 276
training loss: 0.15151361
validation loss: 0.14539039
=====
Epoch 277
training loss: 0.19387861
validation loss: 0.19133386
=====
Epoch 278
training loss: 0.13870859
validation loss: 0.15652171
=====
Epoch 279
training loss: 0.11806402
validation loss: 0.15767321
=====
Epoch 280
training loss: 0.15161562
validation loss: 0.17107207
=====
Epoch 281
training loss: 0.18903866
validation loss: 0.30992845
=====
Epoch 282
training loss: 0.18708900
validation loss: 0.16690286
=====
Epoch 283
training loss: 0.13570371
validation loss: 0.17567852

```



```

=====
Epoch 284
training loss: 0.13629127
validation loss: 0.16175817
=====
Epoch 285
training loss: 0.18248396
validation loss: 0.18010436
=====
Epoch 286
training loss: 0.15406439
validation loss: 0.16048510
=====
Epoch 287
training loss: 0.16506912
validation loss: 0.19900273
=====
Epoch 288
training loss: 0.15861943
validation loss: 0.17158122
=====
Epoch 289
training loss: 0.14326747
validation loss: 0.16020523
=====
Epoch 290
training loss: 0.14710978
validation loss: 0.19104260
=====
Epoch 291
training loss: 0.14320929
validation loss: 0.17433846
=====
Epoch 292
training loss: 0.12343695
validation loss: 0.21318448
=====
Epoch 293
training loss: 0.16354614
validation loss: 0.15685950
=====
Epoch 294
training loss: 0.14361177
validation loss: 0.14994709
=====
Epoch 295
training loss: 0.18007477
validation loss: 0.15606052

```

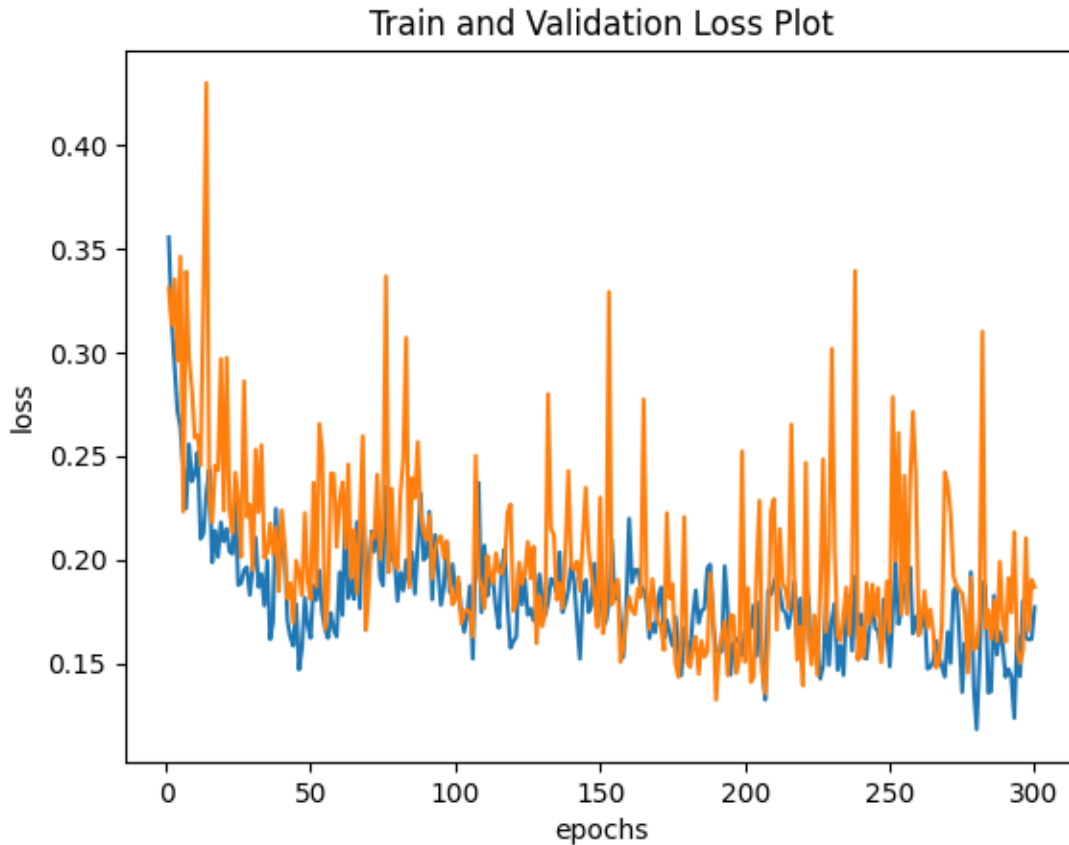
```
=====  
Epoch 296  
training loss: 0.16237037  
validation loss: 0.21028964  
=====
```

```
Epoch 297  
training loss: 0.16125979  
validation loss: 0.16570807  
=====
```

```
Epoch 298  
training loss: 0.16160133  
validation loss: 0.19019386  
=====
```

```
Epoch 299  
training loss: 0.17695686  
validation loss: 0.18669757
```

```
[ ]: import matplotlib.pyplot as plt  
with torch.no_grad():  
    plt.plot(range(1,epochs+1), train_mean_losses)  
    plt.plot(range(1,epochs+1), valid_mean_losses)  
    plt.xlabel('epochs')  
    plt.ylabel('loss')  
    plt.title('Train and Validation Loss Plot')  
    plt.show()
```



```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                    axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 0 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 1 1 0 1 1 1 0 1 1 0 0 0 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 0 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 1 1 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[48  4]
 [ 8 74]]

```

=====

Accuracy: 0.9104477611940298

F1 Score: 0.9069444444444444

=====
Classification Report:

	precision	recall	f1-score	support
0	0.86	0.92	0.89	52
1	0.95	0.90	0.92	82
accuracy			0.91	134
macro avg	0.90	0.91	0.91	134
weighted avg	0.91	0.91	0.91	134

19 Modifikasi Arsitektur 10

```
[ ]: #bikin object model
class Net(nn.Module):
    # define nn
    def __init__(self):
        super(Net, self).__init__()
        self.fc1 = nn.Linear(6, 16)
        self.bn1 = nn.BatchNorm1d(16)

        self.fc2 = nn.Linear(16, 15)
        self.bn2 = nn.BatchNorm1d(15)

        self.fc3 = nn.Linear(15, 2)
#total ada 2 hidden layer.

#arsitektur, model yg kita rancang
    def forward(self, X):
        X = self.fc1(X)
        X = F.relu(X)
        X = self.bn1(X)
        X = self.fc2(X)
        X = F.relu(X)
        X = self.bn2(X)
        X = self.fc3(X)

        return X
```

```
[ ]: # Instantiating the model
net = Net()

# Choosing the loss function
```

```

criterion = nn.CrossEntropyLoss()

# Choosing the optimizer
optimizer = torch.optim.Adam(net.parameters(), lr=0.1)

```

```

[ ]: epochs = 300 #jumlah epoch 300 epoch

train_mean_losses = []
valid_mean_losses = []

valid_best_loss = np.inf

for i in range(epochs):
    #=====
    # training
    train_losses = []

    print("=====")
    print("Epoch {}".format(i))

    for iteration, batch_data in enumerate(train_loader):
        X_batch, y_batch = batch_data

        optimizer.zero_grad()

        out = net(X_batch)
        loss = criterion(out, y_batch.squeeze())

        loss.backward() # perhitungan backpropagation
        optimizer.step()

        train_losses.append(loss)

    train_mean_loss = torch.mean(torch.stack(train_losses))
    print('training loss: {:.10.8f}'.format(train_mean_loss))

    train_mean_losses.append(train_mean_loss)

    #=====
    # validation
    valid_losses = []
    with torch.set_grad_enabled(False):
        for iteration, batch_data in enumerate(valid_loader):
            X_batch, y_batch = batch_data

            out = net(X_batch)
            loss = criterion(out, y_batch.squeeze())

```

```

        valid_losses.append(loss)

    valid_mean_loss = torch.mean(torch.stack(valid_losses))
    print('validation loss: {:.10.8f}'.format(valid_mean_loss))

    valid_mean_losses.append(valid_mean_loss)

    if valid_mean_loss.cpu().numpy()[()] < valid_best_loss:
        valid_best_loss = valid_mean_loss
        torch.save(net.state_dict(), "best_model.pth")
        best_epoch = i
#=====

```

```

=====
Epoch 0
training loss: 0.40754279
validation loss: 0.30149242
=====
Epoch 1
training loss: 0.36215058
validation loss: 0.31497428
=====
Epoch 2
training loss: 0.31999651
validation loss: 0.24184313
=====
Epoch 3
training loss: 0.33650741
validation loss: 0.26413611
=====
Epoch 4
training loss: 0.30679432
validation loss: 0.25332329
=====
Epoch 5
training loss: 0.34443983
validation loss: 0.34133613
=====
Epoch 6
training loss: 0.31563655
validation loss: 0.24156950
=====
Epoch 7
training loss: 0.32066548
validation loss: 0.25516838
=====
Epoch 8

```

```
training loss: 0.28746343
validation loss: 0.26820970
=====
Epoch 9
training loss: 0.25764126
validation loss: 0.22920804
=====
Epoch 10
training loss: 0.25867307
validation loss: 0.24999332
=====
Epoch 11
training loss: 0.26011854
validation loss: 0.25434983
=====
Epoch 12
training loss: 0.26719576
validation loss: 0.23914656
=====
Epoch 13
training loss: 0.29991394
validation loss: 0.25889042
=====
Epoch 14
training loss: 0.26652509
validation loss: 0.27643853
=====
Epoch 15
training loss: 0.24620023
validation loss: 0.22007044
=====
Epoch 16
training loss: 0.25169137
validation loss: 0.25725824
=====
Epoch 17
training loss: 0.22603616
validation loss: 0.33615372
=====
Epoch 18
training loss: 0.27020010
validation loss: 0.29678619
=====
Epoch 19
training loss: 0.24410389
validation loss: 0.25581709
=====
Epoch 20
```



```
training loss: 0.25594041
validation loss: 0.26743755
=====
Epoch 21
training loss: 0.27951583
validation loss: 0.28531027
=====
Epoch 22
training loss: 0.28359655
validation loss: 0.22097141
=====
Epoch 23
training loss: 0.29757583
validation loss: 0.22507520
=====
Epoch 24
training loss: 0.24082918
validation loss: 0.24564460
=====
Epoch 25
training loss: 0.23287205
validation loss: 0.22257982
=====
Epoch 26
training loss: 0.25206432
validation loss: 0.43736190
=====
Epoch 27
training loss: 0.31855029
validation loss: 0.25905502
=====
Epoch 28
training loss: 0.35947806
validation loss: 0.27027085
=====
Epoch 29
training loss: 0.37867138
validation loss: 0.35807127
=====
Epoch 30
training loss: 0.31990570
validation loss: 0.24853367
=====
Epoch 31
training loss: 0.26125285
validation loss: 0.21498887
=====
Epoch 32
```

```
training loss: 0.28297797
validation loss: 0.24971163
=====
Epoch 33
training loss: 0.29004204
validation loss: 0.24002011
=====
Epoch 34
training loss: 0.26932886
validation loss: 0.22042096
=====
Epoch 35
training loss: 0.27673066
validation loss: 0.30814302
=====
Epoch 36
training loss: 0.25898889
validation loss: 0.21018468
=====
Epoch 37
training loss: 0.24208727
validation loss: 0.25419179
=====
Epoch 38
training loss: 0.22841905
validation loss: 0.21647044
=====
Epoch 39
training loss: 0.23853603
validation loss: 0.22428310
=====
Epoch 40
training loss: 0.23303393
validation loss: 0.24496689
=====
Epoch 41
training loss: 0.22779709
validation loss: 0.25084481
=====
Epoch 42
training loss: 0.22278421
validation loss: 0.28877586
=====
Epoch 43
training loss: 0.23277880
validation loss: 0.25057197
=====
Epoch 44
```

```
training loss: 0.26189354
validation loss: 0.23705089
=====
Epoch 45
training loss: 0.23383847
validation loss: 0.21403313
=====
Epoch 46
training loss: 0.26284006
validation loss: 0.19980463
=====
Epoch 47
training loss: 0.22540262
validation loss: 0.25560474
=====
Epoch 48
training loss: 0.26238254
validation loss: 0.70327342
=====
Epoch 49
training loss: 0.27534404
validation loss: 0.25812662
=====
Epoch 50
training loss: 0.22729683
validation loss: 0.22140053
=====
Epoch 51
training loss: 0.21604300
validation loss: 0.22949779
=====
Epoch 52
training loss: 0.19874901
validation loss: 0.21510342
=====
Epoch 53
training loss: 0.24028543
validation loss: 0.18328986
=====
Epoch 54
training loss: 0.20190248
validation loss: 0.19016045
=====
Epoch 55
training loss: 0.20927349
validation loss: 0.24452665
=====
Epoch 56
```

```
training loss: 0.24902278
validation loss: 0.22993258
=====
Epoch 57
training loss: 0.19096436
validation loss: 0.26265836
=====
Epoch 58
training loss: 0.21169361
validation loss: 0.25765008
=====
Epoch 59
training loss: 0.24466449
validation loss: 0.21912855
=====
Epoch 60
training loss: 0.23409787
validation loss: 0.23506954
=====
Epoch 61
training loss: 0.23236418
validation loss: 0.21087940
=====
Epoch 62
training loss: 0.25919878
validation loss: 0.19139443
=====
Epoch 63
training loss: 0.20549384
validation loss: 0.29314134
=====
Epoch 64
training loss: 0.23491274
validation loss: 0.27470246
=====
Epoch 65
training loss: 0.23408101
validation loss: 0.21582019
=====
Epoch 66
training loss: 0.24360065
validation loss: 0.24293762
=====
Epoch 67
training loss: 0.23224096
validation loss: 0.20906875
=====
Epoch 68
```

```
training loss: 0.22604419
validation loss: 0.22452819
=====
Epoch 69
training loss: 0.22547029
validation loss: 0.23995055
=====
Epoch 70
training loss: 0.22459246
validation loss: 0.22269510
=====
Epoch 71
training loss: 0.23808199
validation loss: 0.21817365
=====
Epoch 72
training loss: 0.23377439
validation loss: 0.22762109
=====
Epoch 73
training loss: 0.21318591
validation loss: 0.21539688
=====
Epoch 74
training loss: 0.25138724
validation loss: 0.22494313
=====
Epoch 75
training loss: 0.24442494
validation loss: 0.20028819
=====
Epoch 76
training loss: 0.20149714
validation loss: 0.21857551
=====
Epoch 77
training loss: 0.23834744
validation loss: 0.20504943
=====
Epoch 78
training loss: 0.25880736
validation loss: 0.28123766
=====
Epoch 79
training loss: 0.26475665
validation loss: 0.20655070
=====
Epoch 80
```

```
training loss: 0.24668685
validation loss: 0.23944293
=====
Epoch 81
training loss: 0.22600546
validation loss: 0.22310428
=====
Epoch 82
training loss: 0.20866950
validation loss: 0.18110631
=====
Epoch 83
training loss: 0.20067917
validation loss: 0.21013412
=====
Epoch 84
training loss: 0.19792439
validation loss: 0.20242870
=====
Epoch 85
training loss: 0.23995757
validation loss: 0.18423191
=====
Epoch 86
training loss: 0.23959920
validation loss: 0.22840878
=====
Epoch 87
training loss: 0.23733546
validation loss: 0.19617146
=====
Epoch 88
training loss: 0.20676740
validation loss: 0.21914196
=====
Epoch 89
training loss: 0.21948718
validation loss: 0.20286028
=====
Epoch 90
training loss: 0.21474217
validation loss: 0.19265869
=====
Epoch 91
training loss: 0.20883374
validation loss: 0.21880589
=====
Epoch 92
```

```
training loss: 0.20244415
validation loss: 0.21336657
=====
Epoch 93
training loss: 0.18379077
validation loss: 0.31953433
=====
Epoch 94
training loss: 0.23317614
validation loss: 0.35222054
=====
Epoch 95
training loss: 0.21712071
validation loss: 0.19088599
=====
Epoch 96
training loss: 0.19789855
validation loss: 0.20895404
=====
Epoch 97
training loss: 0.23751839
validation loss: 0.16317461
=====
Epoch 98
training loss: 0.22360344
validation loss: 0.22880580
=====
Epoch 99
training loss: 0.22780472
validation loss: 0.18831043
=====
Epoch 100
training loss: 0.22951998
validation loss: 0.21287416
=====
Epoch 101
training loss: 0.26072258
validation loss: 0.22122444
=====
Epoch 102
training loss: 0.23605825
validation loss: 0.16601321
=====
Epoch 103
training loss: 0.22113450
validation loss: 0.17596346
=====
Epoch 104
```

```
training loss: 0.22708605
validation loss: 0.24930455
=====
Epoch 105
training loss: 0.21524280
validation loss: 0.18005881
=====
Epoch 106
training loss: 0.24728483
validation loss: 0.17819470
=====
Epoch 107
training loss: 0.20788734
validation loss: 0.20681193
=====
Epoch 108
training loss: 0.21258558
validation loss: 0.17572492
=====
Epoch 109
training loss: 0.24030544
validation loss: 0.19917788
=====
Epoch 110
training loss: 0.23413374
validation loss: 0.19061095
=====
Epoch 111
training loss: 0.30483413
validation loss: 0.21292208
=====
Epoch 112
training loss: 0.20565565
validation loss: 0.19990453
=====
Epoch 113
training loss: 0.22359020
validation loss: 0.19016984
=====
Epoch 114
training loss: 0.21050631
validation loss: 0.19596124
=====
Epoch 115
training loss: 0.18985994
validation loss: 0.18423499
=====
Epoch 116
```



```
training loss: 0.18941991
validation loss: 0.18258642
=====
Epoch 117
training loss: 0.20426098
validation loss: 0.16037914
=====
Epoch 118
training loss: 0.23920427
validation loss: 0.18806005
=====
Epoch 119
training loss: 0.25180152
validation loss: 0.20473762
=====
Epoch 120
training loss: 0.19904818
validation loss: 0.17139190
=====
Epoch 121
training loss: 0.19436122
validation loss: 0.17996214
=====
Epoch 122
training loss: 0.23305483
validation loss: 0.22623019
=====
Epoch 123
training loss: 0.21807370
validation loss: 0.18082878
=====
Epoch 124
training loss: 0.20179132
validation loss: 0.16854118
=====
Epoch 125
training loss: 0.20706068
validation loss: 0.20253985
=====
Epoch 126
training loss: 0.26965919
validation loss: 0.24541125
=====
Epoch 127
training loss: 0.22185844
validation loss: 0.18569678
=====
Epoch 128
```

```
training loss: 0.21570924
validation loss: 0.24408329
=====
Epoch 129
training loss: 0.27990294
validation loss: 0.19871508
=====
Epoch 130
training loss: 0.20849714
validation loss: 0.23591441
=====
Epoch 131
training loss: 0.18615137
validation loss: 0.21476367
=====
Epoch 132
training loss: 0.20171498
validation loss: 0.22346568
=====
Epoch 133
training loss: 0.19533871
validation loss: 0.17249604
=====
Epoch 134
training loss: 0.18340719
validation loss: 0.22030465
=====
Epoch 135
training loss: 0.18156342
validation loss: 0.18167710
=====
Epoch 136
training loss: 0.24046710
validation loss: 0.25632483
=====
Epoch 137
training loss: 0.22531822
validation loss: 0.20221131
=====
Epoch 138
training loss: 0.17960297
validation loss: 0.19475402
=====
Epoch 139
training loss: 0.25782055
validation loss: 0.33690181
=====
Epoch 140
```

```
training loss: 0.20083849
validation loss: 0.18279836
=====
Epoch 141
training loss: 0.19135827
validation loss: 0.19172879
=====
Epoch 142
training loss: 0.19167788
validation loss: 0.16673298
=====
Epoch 143
training loss: 0.17395088
validation loss: 0.18956567
=====
Epoch 144
training loss: 0.21478319
validation loss: 0.19150639
=====
Epoch 145
training loss: 0.22101419
validation loss: 0.32493988
=====
Epoch 146
training loss: 0.22189425
validation loss: 0.23918985
=====
Epoch 147
training loss: 0.19708526
validation loss: 0.22620966
=====
Epoch 148
training loss: 0.17431997
validation loss: 0.18309613
=====
Epoch 149
training loss: 0.17988415
validation loss: 0.19055250
=====
Epoch 150
training loss: 0.17577858
validation loss: 0.18355922
=====
Epoch 151
training loss: 0.17540048
validation loss: 0.17384559
=====
Epoch 152
```

```
training loss: 0.18072049
validation loss: 0.19547087
=====
Epoch 153
training loss: 0.18002795
validation loss: 0.18134217
=====
Epoch 154
training loss: 0.20961978
validation loss: 0.18489230
=====
Epoch 155
training loss: 0.23368670
validation loss: 0.29229003
=====
Epoch 156
training loss: 0.23016532
validation loss: 0.16931763
=====
Epoch 157
training loss: 0.24076495
validation loss: 0.18858270
=====
Epoch 158
training loss: 0.21718426
validation loss: 0.16773084
=====
Epoch 159
training loss: 0.20835581
validation loss: 0.24989022
=====
Epoch 160
training loss: 0.22004862
validation loss: 0.18481573
=====
Epoch 161
training loss: 0.20868379
validation loss: 0.17547271
=====
Epoch 162
training loss: 0.19697016
validation loss: 0.25510338
=====
Epoch 163
training loss: 0.21504821
validation loss: 0.31727502
=====
Epoch 164
```

```
training loss: 0.19008903
validation loss: 0.21363342
=====
Epoch 165
training loss: 0.24921662
validation loss: 0.21608396
=====
Epoch 166
training loss: 0.23188594
validation loss: 0.18306848
=====
Epoch 167
training loss: 0.17094734
validation loss: 0.22224480
=====
Epoch 168
training loss: 0.19014826
validation loss: 0.18616016
=====
Epoch 169
training loss: 0.17935042
validation loss: 0.18480048
=====
Epoch 170
training loss: 0.22491767
validation loss: 0.18721895
=====
Epoch 171
training loss: 0.18469389
validation loss: 0.17388141
=====
Epoch 172
training loss: 0.18889441
validation loss: 0.22034228
=====
Epoch 173
training loss: 0.17724814
validation loss: 0.22381656
=====
Epoch 174
training loss: 0.21906933
validation loss: 0.20856485
=====
Epoch 175
training loss: 0.24662362
validation loss: 0.20286651
=====
Epoch 176
```

```
training loss: 0.22372904
validation loss: 0.16162018
=====
Epoch 177
training loss: 0.18854640
validation loss: 0.19239761
=====
Epoch 178
training loss: 0.19332543
validation loss: 0.21334985
=====
Epoch 179
training loss: 0.19738932
validation loss: 0.19106753
=====
Epoch 180
training loss: 0.19427599
validation loss: 0.20601791
=====
Epoch 181
training loss: 0.20809278
validation loss: 0.21764129
=====
Epoch 182
training loss: 0.19727999
validation loss: 0.19214934
=====
Epoch 183
training loss: 0.19303165
validation loss: 0.18407559
=====
Epoch 184
training loss: 0.21769649
validation loss: 0.20527180
=====
Epoch 185
training loss: 0.23270705
validation loss: 0.22047855
=====
Epoch 186
training loss: 0.22823642
validation loss: 0.15793136
=====
Epoch 187
training loss: 0.16654107
validation loss: 0.22708054
=====
Epoch 188
```

```
training loss: 0.19181865
validation loss: 0.17759083
=====
Epoch 189
training loss: 0.16949522
validation loss: 0.18365029
=====
Epoch 190
training loss: 0.15567233
validation loss: 0.23393860
=====
Epoch 191
training loss: 0.18138450
validation loss: 0.26656577
=====
Epoch 192
training loss: 0.20704149
validation loss: 0.19438682
=====
Epoch 193
training loss: 0.20949505
validation loss: 0.22631934
=====
Epoch 194
training loss: 0.22199152
validation loss: 0.17610396
=====
Epoch 195
training loss: 0.20374329
validation loss: 0.16909392
=====
Epoch 196
training loss: 0.19724035
validation loss: 0.20567340
=====
Epoch 197
training loss: 0.25783971
validation loss: 0.20441073
=====
Epoch 198
training loss: 0.19799902
validation loss: 0.19965404
=====
Epoch 199
training loss: 0.20430808
validation loss: 0.16340615
=====
Epoch 200
```

```
training loss: 0.19241105
validation loss: 0.21071072
=====
Epoch 201
training loss: 0.18876651
validation loss: 0.22201052
=====
Epoch 202
training loss: 0.23411259
validation loss: 0.21773587
=====
Epoch 203
training loss: 0.31771716
validation loss: 0.24180838
=====
Epoch 204
training loss: 0.18512943
validation loss: 0.25550249
=====
Epoch 205
training loss: 0.25619638
validation loss: 0.18861263
=====
Epoch 206
training loss: 0.23788014
validation loss: 0.17093554
=====
Epoch 207
training loss: 0.18874216
validation loss: 0.22977065
=====
Epoch 208
training loss: 0.23338264
validation loss: 0.21779189
=====
Epoch 209
training loss: 0.22949928
validation loss: 0.17125237
=====
Epoch 210
training loss: 0.19595215
validation loss: 0.25008839
=====
Epoch 211
training loss: 0.18828188
validation loss: 0.21694374
=====
Epoch 212
```



```
training loss: 0.22253661
validation loss: 0.23061740
=====
Epoch 213
training loss: 0.21490335
validation loss: 0.17820889
=====
Epoch 214
training loss: 0.21354602
validation loss: 0.20821032
=====
Epoch 215
training loss: 0.22142175
validation loss: 0.18599184
=====
Epoch 216
training loss: 0.21533896
validation loss: 0.21707110
=====
Epoch 217
training loss: 0.19651471
validation loss: 0.17295462
=====
Epoch 218
training loss: 0.19395012
validation loss: 0.22474515
=====
Epoch 219
training loss: 0.16298938
validation loss: 0.19931987
=====
Epoch 220
training loss: 0.18970045
validation loss: 0.19819866
=====
Epoch 221
training loss: 0.18083662
validation loss: 0.19842748
=====
Epoch 222
training loss: 0.21820727
validation loss: 0.17779285
=====
Epoch 223
training loss: 0.19259566
validation loss: 0.18221705
=====
Epoch 224
```

```
training loss: 0.18737604
validation loss: 0.17864168
=====
Epoch 225
training loss: 0.19907464
validation loss: 0.18289293
=====
Epoch 226
training loss: 0.18633613
validation loss: 0.19456568
=====
Epoch 227
training loss: 0.20760556
validation loss: 0.19499162
=====
Epoch 228
training loss: 0.18432568
validation loss: 0.18329924
=====
Epoch 229
training loss: 0.21364716
validation loss: 0.20337871
=====
Epoch 230
training loss: 0.20525149
validation loss: 0.24438797
=====
Epoch 231
training loss: 0.18832847
validation loss: 0.19717608
=====
Epoch 232
training loss: 0.20603155
validation loss: 0.18916099
=====
Epoch 233
training loss: 0.21013109
validation loss: 0.18867421
=====
Epoch 234
training loss: 0.19413596
validation loss: 0.19933517
=====
Epoch 235
training loss: 0.22714886
validation loss: 0.16153376
=====
Epoch 236
```

```
training loss: 0.20107614
validation loss: 0.17808993
=====
Epoch 237
training loss: 0.20634574
validation loss: 0.17165014
=====
Epoch 238
training loss: 0.19910629
validation loss: 0.17097104
=====
Epoch 239
training loss: 0.23226827
validation loss: 0.16971225
=====
Epoch 240
training loss: 0.23708315
validation loss: 0.17524537
=====
Epoch 241
training loss: 0.19238862
validation loss: 0.37592417
=====
Epoch 242
training loss: 0.17992859
validation loss: 0.17434411
=====
Epoch 243
training loss: 0.16509958
validation loss: 0.19250071
=====
Epoch 244
training loss: 0.27187127
validation loss: 0.40078452
=====
Epoch 245
training loss: 0.28352216
validation loss: 0.17406279
=====
Epoch 246
training loss: 0.20033573
validation loss: 0.17929175
=====
Epoch 247
training loss: 0.16827080
validation loss: 0.17336741
=====
Epoch 248
```

```
training loss: 0.19539829
validation loss: 0.21673159
=====
Epoch 249
training loss: 0.22450694
validation loss: 0.18019727
=====
Epoch 250
training loss: 0.20744267
validation loss: 0.20866022
=====
Epoch 251
training loss: 0.21130049
validation loss: 0.24289498
=====
Epoch 252
training loss: 0.21114053
validation loss: 0.18044722
=====
Epoch 253
training loss: 0.20605989
validation loss: 0.24138926
=====
Epoch 254
training loss: 0.19955809
validation loss: 0.23651190
=====
Epoch 255
training loss: 0.16788110
validation loss: 0.18375841
=====
Epoch 256
training loss: 0.16457920
validation loss: 0.17482305
=====
Epoch 257
training loss: 0.18936856
validation loss: 0.16900887
=====
Epoch 258
training loss: 0.17183469
validation loss: 0.18787800
=====
Epoch 259
training loss: 0.18475018
validation loss: 0.16519567
=====
Epoch 260
```

```
training loss: 0.20103474
validation loss: 0.18446106
=====
Epoch 261
training loss: 0.21419042
validation loss: 0.17623483
=====
Epoch 262
training loss: 0.23061131
validation loss: 0.18648070
=====
Epoch 263
training loss: 0.19646266
validation loss: 0.23406254
=====
Epoch 264
training loss: 0.20648134
validation loss: 0.19671433
=====
Epoch 265
training loss: 0.21053238
validation loss: 0.19149813
=====
Epoch 266
training loss: 0.20394504
validation loss: 0.25225818
=====
Epoch 267
training loss: 0.18667680
validation loss: 0.17894593
=====
Epoch 268
training loss: 0.17180555
validation loss: 0.20142226
=====
Epoch 269
training loss: 0.19245489
validation loss: 0.23685689
=====
Epoch 270
training loss: 0.18605876
validation loss: 0.18501858
=====
Epoch 271
training loss: 0.16745682
validation loss: 0.26252392
=====
Epoch 272
```

```
training loss: 0.17708905
validation loss: 0.18692841
=====
Epoch 273
training loss: 0.16996734
validation loss: 0.20602497
=====
Epoch 274
training loss: 0.15959479
validation loss: 0.29901192
=====
Epoch 275
training loss: 0.21982235
validation loss: 0.26573616
=====
Epoch 276
training loss: 0.21899545
validation loss: 0.17014673
=====
Epoch 277
training loss: 0.20912246
validation loss: 0.18322295
=====
Epoch 278
training loss: 0.20417883
validation loss: 0.19774485
=====
Epoch 279
training loss: 0.30536875
validation loss: 0.27158737
=====
Epoch 280
training loss: 0.23934790
validation loss: 0.25869808
=====
Epoch 281
training loss: 0.17865685
validation loss: 0.19157775
=====
Epoch 282
training loss: 0.17149261
validation loss: 0.17200725
=====
Epoch 283
training loss: 0.20098300
validation loss: 0.20204079
=====
Epoch 284
```

```
training loss: 0.18976147
validation loss: 0.21285316
=====
Epoch 285
training loss: 0.17668420
validation loss: 0.19787739
=====
Epoch 286
training loss: 0.16178708
validation loss: 0.17826129
=====
Epoch 287
training loss: 0.16249719
validation loss: 0.18926144
=====
Epoch 288
training loss: 0.14181413
validation loss: 0.20266037
=====
Epoch 289
training loss: 0.13451302
validation loss: 0.23016751
=====
Epoch 290
training loss: 0.16598348
validation loss: 0.19629489
=====
Epoch 291
training loss: 0.16854125
validation loss: 0.16630597
=====
Epoch 292
training loss: 0.16337180
validation loss: 0.28850192
=====
Epoch 293
training loss: 0.20536225
validation loss: 0.17635168
=====
Epoch 294
training loss: 0.19062583
validation loss: 0.17921308
=====
Epoch 295
training loss: 0.17109255
validation loss: 0.20143878
=====
Epoch 296
```

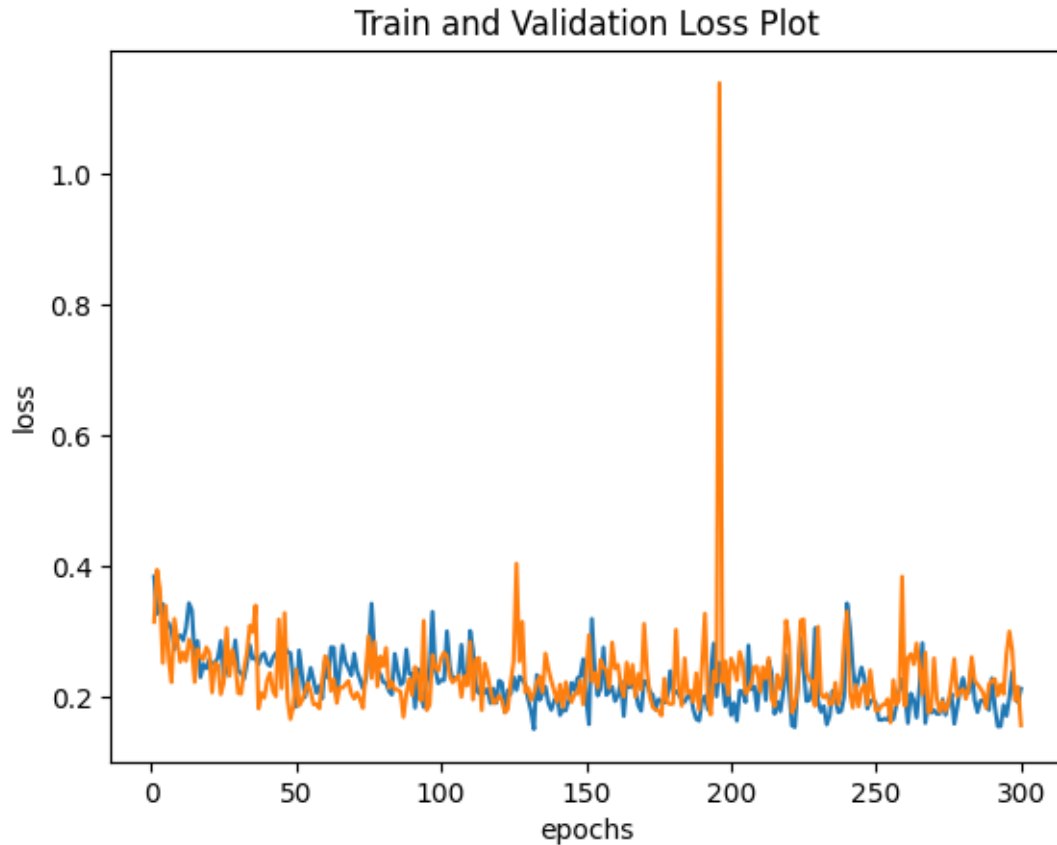
```
training loss: 0.18048795
validation loss: 0.22200151
=====
```

```
Epoch 297
training loss: 0.20631514
validation loss: 0.21386518
=====
```

```
Epoch 298
training loss: 0.17303161
validation loss: 0.18601361
=====
```

```
Epoch 299
training loss: 0.18239158
validation loss: 0.26559061
```

```
[ ]: import matplotlib.pyplot as plt
with torch.no_grad():
    plt.plot(range(1,epochs+1), train_mean_losses)
    plt.plot(range(1,epochs+1), valid_mean_losses)
    plt.xlabel('epochs')
    plt.ylabel('loss')
    plt.title('Train and Validation Loss Plot')
    plt.ylim([0, 0.7])
    plt.show()
```

```
[ ]: net.load_state_dict(torch.load("best_model.pth"))
```

```
[ ]: <All keys matched successfully>
```

```
[ ]: test_predictions = np.empty((0,2))
with torch.no_grad():
    for iteration, batch_data in enumerate(test_loader):
        X_batch, y_batch = batch_data
        out = net(X_batch)

        test_predictions = np.append(test_predictions, out.numpy(),
                                    axis=0)

from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import f1_score
from sklearn.metrics import classification_report

test_predictions = np.array(test_predictions)
```

```

test_predictions = np.argmax(np.array(test_predictions), axis=1)

print("=====\n")
print("Predicted Class:")
print(test_predictions)
print("\nGround Truth:")
print(test_y)

print("\n=====\n")
print("Confusion Matrix:")
print(confusion_matrix(test_y, test_predictions))

print("\n=====\n")
accuracy = accuracy_score(test_y, test_predictions)
print("Accuracy: {}".format(accuracy))

f1 = f1_score(test_y, test_predictions, average='macro')
print("F1 Score: ", f1)

print("\n=====\n")
print("Classification Report:")
print(classification_report(test_y, test_predictions))

```

=====

Predicted Class:

```

[1 1 1 0 0 1 1 1 0 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 0 1 1 0 0 1
 0 1 1 0 1 0 1 0 1 0 1 0 1 1 1 0 0 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 0 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1
 0 0 1 0 1 0 0 0 1 1 0 1 0 1 0 1 0 1 1 1 0 0 1]

```

Ground Truth:

```

[1 1 1 0 0 1 1 1 1 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 1 0 1 1 1 0 1
 0 1 1 0 1 1 1 0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0
 1 1 0 1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1 1 1 0 1 0 1 1
 0 0 0 0 1 0 0 0 1 0 0 0 0 1 0 1 0 1 1 1 0 0 1]

```

=====

Confusion Matrix:

```

[[49  3]
 [ 7 75]]

```

=====

Accuracy: 0.9253731343283582

F1 Score: 0.9224537037037037

=====

Classification Report:

	precision	recall	f1-score	support
0	0.88	0.94	0.91	52
1	0.96	0.91	0.94	82
accuracy			0.93	134
macro avg	0.92	0.93	0.92	134
weighted avg	0.93	0.93	0.93	134