Open in Colab

In [ ]:

```
#library import - tensorflow/keras/sklearn/matplotlib
import os
from os.path import join

import numpy as np
import pandas as pd

import tensorflow as tf
import keras
from keras import layers, Input, models
from tensorflow.keras.utils import to_categorical
from keras.wrappers.scikit_learn import KerasClassifier

from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score

from sklearn.model_selection import train_test_split

import matplotlib.pyplot as plt
```

In [ ]:

```
#dataset 구성
datapath = join('data', 'wafer')
url = "E:/WaferMap"
#print(os.listdir(url))  #dir list

#경고 메시지 끄기(ignore), 켜기(default)
import warnings
warnings.filterwarnings("ignore")

#read pickle 파일
#https://www.kaggle.com/code/kcs93023/keras-wafer-classification-cnn2d-with-augmentation/data
df=pd.read_pickle(url+"/LSWMD.pkl")
```

> pickle 파일구성 (이미 학습할 수 있도록, 분류가 된 파일)
>
> - waferMap file 개수: 811,457 rows(2차원 행렬 data, 행*열=waferMapDim에 있음)

- 6개 컬럼(wafer map, die size, lot name, index, T/T type, failType) --> failuretype: 불량 유형 (none, edge-ring...)

데이터 구성

```
# none_label: 638,507 - 78.7%
# label: 172,950 - 21.3%
   - ng: 25,519     14.8%(3.1%) --> 불량 항목 별로도 데이터 불균형
   - ok: 147,431    85.2%(18.2%)
```

In [ ]:
```
#data file 정보
df.info()
```

In [ ]:
```
#해더 내용
df.head()
```

Out[ ]:

	waferMap	dieSize	lotName	trianTestLabel	failureType	waferMapDim
0	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)
1	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)
2	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)
3	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)
4	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)

In [ ]:
```
#tail 내용
df.tail()
```

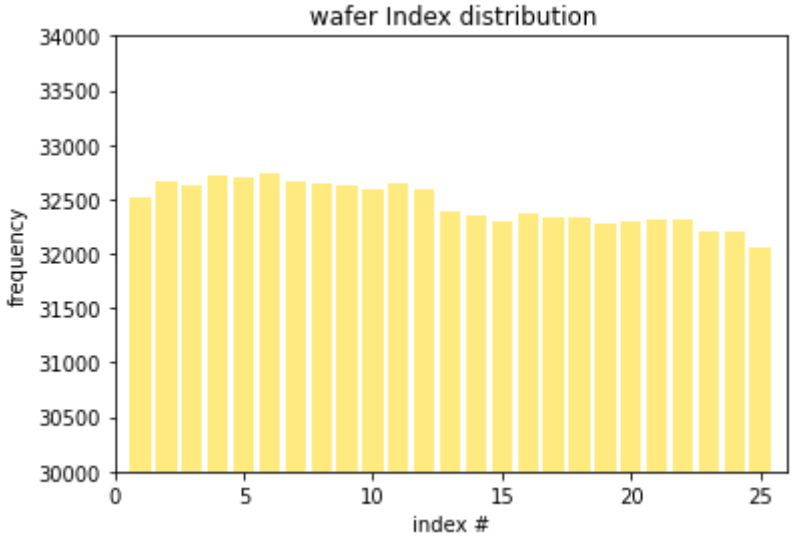
Out[ ]:

	waferMap	dieSize	lotName	trianTestLabel	failureType	waferMapDim
811452	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 2, 1, 1,...	600.0	lot47542	[[Test]]	[[Edge-Ring]]	(26, 30)
811453	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 2, 1, 1,...	600.0	lot47542	[[Test]]	[[Edge-Loc]]	(26, 30)
811454	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 2, 1, 1,...	600.0	lot47542	[[Test]]	[[Edge-Ring]]	(26, 30)
811455	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1,...	600.0	lot47543	[]	[]	(26, 30)

811456	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 2, 1, 1,...	600.0	lot47543	[]	[]	(26, 30)

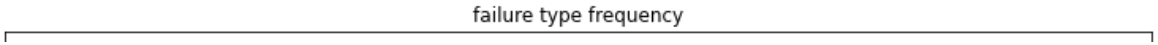
In [ ]:
```
#csv 파일로도 한번 받아 봄(583mb)
df.to_csv(path_or_buf = 'wafermap.csv', ₩
          sep=str(','), header=True, index=True, mode='w', encoding='CP949')
```

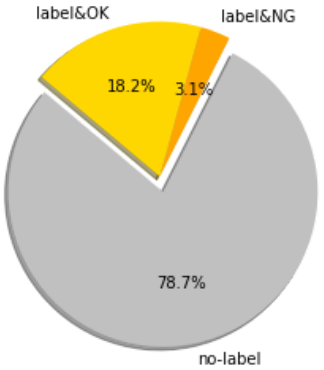
In [ ]:
```
# 1lot = 25장 wafer인데(1lot / wafer index = 1~25)
# lot의 wafer index 별로 보면, 없는 데이터도 존재 함
import matplotlib.pyplot as plt

uni_Index=np.unique(df.waferIndex, return_counts=True)
plt.bar(uni_Index[0],uni_Index[1], color='gold', align='center', alpha=0.5)
plt.title("wafer Index distribution")
plt.xlabel("index #")
plt.ylabel("frequency")
plt.xlim(0,26)
plt.ylim(30000,34000)
plt.show()
```

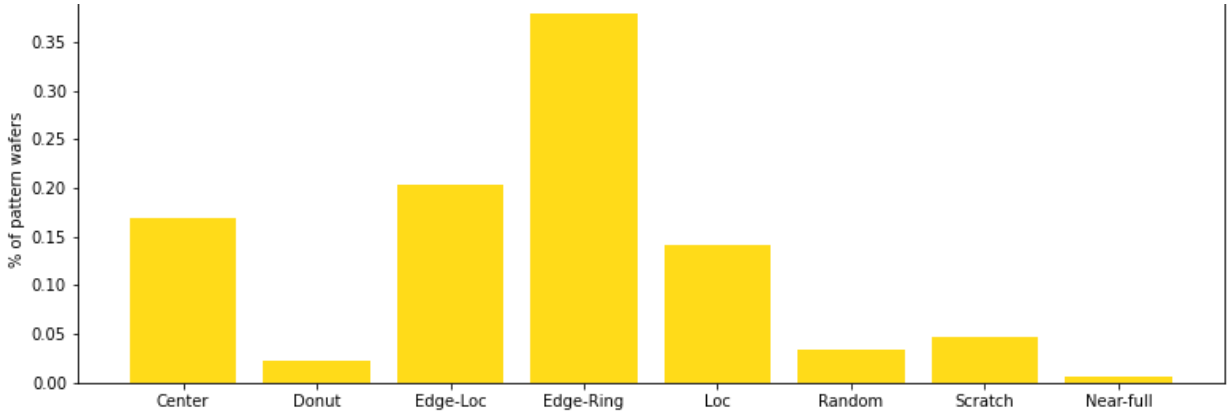


In [ ]:
```
#데이터 분포 라벨링율 = 21.3%
#데이터 분포 ok : ng = 85.2:14.8
#데이터 분포 ng(detection) 내 원 code별 분포
```

```
#데이터 분포 ng(detection) 데 이 code를 분포
df['failureNum']=df.failureType #컬럼 추가
df['trainTestNum']=df.trianTestLabel    #컬럼 추가
mapping_type={'Center':0,'Donut':1,'Edge-Loc':2,'Edge-Ring':3,'Loc':4,'Random':5,'Scratch':6,'Near-full':7,'none':8}    #불
mapping_traintest={'Training':0,'Test':1}   #train:0, test:1 로 라벨링
df=df.replace({'failureNum':mapping_type, 'trainTestNum':mapping_traintest})    #replace

#failureType의 label이 존재
df_withlabel = df[(df['failureNum']>=0) & (df['failureNum']<=8)]
df_withlabel = df_withlabel.reset_index()
#failureType의 label이 존재 && 불량z코드 존재 (0~7번 코드)
df_withpattern = df[(df['failureNum']>=0) & (df['failureNum']<=7)]
df_withpattern = df_withpattern.reset_index()
#failureType의 label이 존재 && OK품(8번 코드, none)
df_nonpattern = df[(df['failureNum']==8)]
df_withlabel.shape[0], df_withpattern.shape[0], df_nonpattern.shape[0]

#graph - pie
from matplotlib import gridspec
fig = plt.figure(figsize=(20, 4.5))
gs = gridspec.GridSpec(1, 2, width_ratios=[1, 2.5])
ax1 = plt.subplot(gs[0])
ax2 = plt.subplot(gs[1])

tol_wafers = df.shape[0]
no_wafers=[tol_wafers-df_withlabel.shape[0], df_withpattern.shape[0], df_nonpattern.shape[0]]

colors = ['silver', 'orange', 'gold']
explode = (0.1, 0, 0)  # pie에서 sclicing해서 차트에서 벗어나게
labels = ['no-label','label&NG','label&OK']
ax1.pie(no_wafers, explode=explode, labels=labels, colors=colors, autopct='%1.1f%%', shadow=True, startangle=140)

#graph - bar
uni_pattern=np.unique(df_withpattern.failureNum, return_counts=True)
labels2 = ['','Center','Donut','Edge-Loc','Edge-Ring','Loc','Random','Scratch','Near-full']
ax2.bar(uni_pattern[0],uni_pattern[1]/df_withpattern.shape[0], color='gold', align='center', alpha=0.9)
ax2.set_title("failure type frequency")
ax2.set_ylabel("% of pattern wafers")
ax2.set_xticklabels(labels2)

plt.show()
#
```







In [ ]:
```
#df head()
df[(df['failureNum']==8)].head()
```

Out[ ]:

	waferMap	dieSize	lotName	trianTestLabel	failureType	waferMapDim	failureNum	trainTestNum
0	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)	8	0
1	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)	8	0
2	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)	8	0
3	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)	8	0
4	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1683.0	lot1	[[Training]]	[[none]]	(45, 48)	8	0

In [ ]:
```
# 구분별 개수 찍어 봄
print("total: ", tol_wafers)
print("none-label: ", tol_wafers -df_withlabel.shape[0])
print("label: ", df_withlabel.shape[0])
print("ng: ", df_withpattern.shape[0])
print("ok: ", df_nonpattern.shape[0])
```

In [ ]:
```
#wafer index 제외
df = df.drop(['waferIndex'], axis = 1)
```

In [ ]:

In [ ]:
```
#각 wafer map의 해상도 size가 다름 -- 해상도 size에 대한(행렬size) 컬럼과 데이터 생성
def find_dim(x):
    dim0=np.size(x,axis=0)
    dim1=np.size(x,axis=1)
    return dim0,dim1
df['waferMapDim']=df.waferMap.apply(find_dim)
df.sample(5)
```

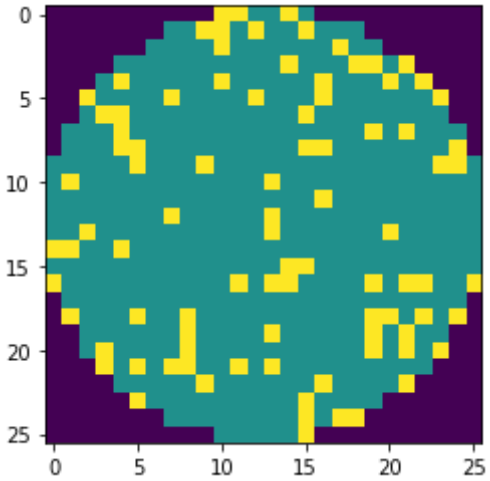
Out[ ]:

	waferMap	dieSize	lotName	trianTestLabel	failureType	waferMapDim
158981	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 2, 1, 2, 1,...	515.0	lot10237	[[Training]]	[[Center]]	(25, 27)
487489	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 2,...	710.0	lot30167	[]	[]	(32, 29)
600371	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	1513.0	lot37728	[]	[]	(49, 39)
502224	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1,...	710.0	lot31209	[]	[]	(32, 29)
341368	[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,...	3642.0	lot20474	[]	[]	(64, 72)

In [ ]:
```
#26*26 해상도의 wafer data 추출
sub_df = df.loc[df['waferMapDim'] == (26, 26)]
sub_wafer = sub_df['waferMap'].values

sw = np.ones((1, 26, 26))
label = list()

for i in range(len(sub_df)):
    # 불량코드에 null 라벨의 skip 처리
    if len(sub_df.iloc[i,:]['failureType']) == 0:
        continue
    sw = np.concatenate((sw, sub_df.iloc[i,:]['waferMap'].reshape(1, 26, 26)))
    label.append(sub_df.iloc[i,:]['failureType'][0][0])
```

In [ ]:
```
x = sw[1:]
y = np.array(label).reshape((-1,1))

# x, y shape
print('x shape : {}, y shape : {}'.format(x.shape, y.shape))
```

In [ ]:
```
# plot 1st data 보여주고
plt.imshow(x[0])
plt.show()

# check faulty case: failure type
print('Faulty case : {} '.format(y[0]))
```



In [ ]:
```
#add channel
x = x.reshape((-1, 26, 26, 1))

faulty_case = np.unique(y)
print('Faulty case list : {}'.format(faulty_case))
```

In [ ]:
```
#26*26 size map의 failure type별 데이터 개수
for f in faulty_case :
    print('{} : {}'.format(f, len(y[y==f])))
```

In [ ]:
```
# One-hot-Encoding faulty categorical variable as channel
new_x = np.zeros((len(x), 26, 26, 3))

for w in range(len(x)):
```

```
    for i in range(26):
        for j in range(26):
            new_x[w, i, j, int(x[w, i, j])] = 1
```

In [ ]:

```
#check new x dimension
new_x.shape
```

Out[ ]:

In [ ]:

```
# parameter
epoch=15
batch_size=1024

# Encoder
input_shape = (26, 26, 3)
input_tensor = Input(input_shape)
encode = layers.Conv2D(64, (3,3), padding='same', activation='relu')(input_tensor)

latent_vector = layers.MaxPool2D()(encode)

# Decoder
decode_layer_1 = layers.Conv2DTranspose(64, (3,3), padding='same', activation='relu')
decode_layer_2 = layers.UpSampling2D()
output_tensor = layers.Conv2DTranspose(3, (3,3), padding='same', activation='sigmoid')

# connect decoder layers
decode = decode_layer_1(latent_vector)
decode = decode_layer_2(decode)

ae = models.Model(input_tensor, output_tensor(decode))
ae.compile(optimizer = 'Adam',
              loss = 'mse',
             )

ae.summary()
```

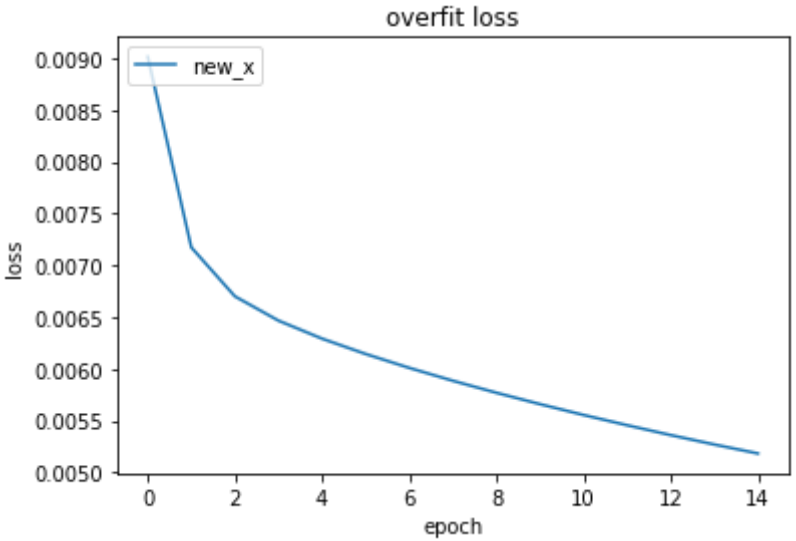
In [ ]:

```
# start train
ae_history = ae.fit(new_x, new_x,
       batch_size=batch_size,
```

```
        epochs=epoch,
        verbose=2)
```

In [ ]:

```
# loss chart - 데이터 불균형 그대로 .. 과적합 검증
# loss plot
plt.plot(ae_history.history['loss'])
plt.title('overfit loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['new_x'], loc='upper left')
plt.show()
```



In [ ]:

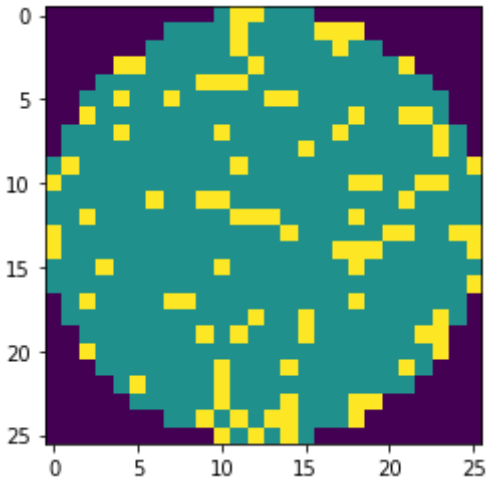
```
# Make encoder model with part of autoencoder model layers
encoder = models.Model(input_tensor, latent_vector)

# Make decoder model with part of autoencoder model layers
decoder_input = Input((13, 13, 64))
decode = decode_layer_1(decoder_input)
decode = decode_layer_2(decode)
decoder = models.Model(decoder_input, output_tensor(decode))

# Encode original faulty wafer
encoded_x = encoder.predict(new_x)
```

```
# Add noise to encoded latent faulty wafers vector.
noised_encoded_x = encoded_x + np.random.normal(loc=0, scale=0.1, size = (len(encoded_x), 13, 13, 64))
```

In [ ]:

```
# check original faulty wafer data
plt.imshow(np.argmax(new_x[3], axis=2))
```

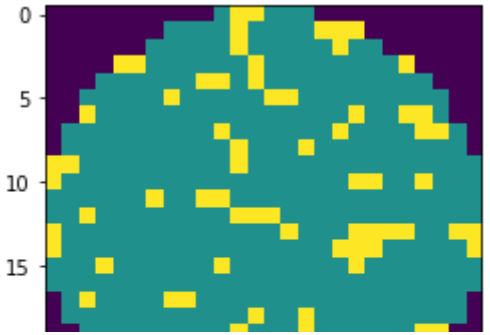
Out[ ]:

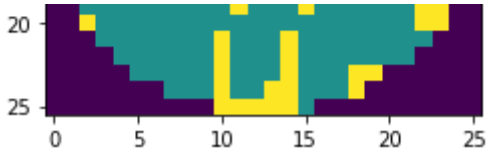


In [ ]:

```
# check new noised faulty wafer data
noised_gen_x = np.argmax(decoder.predict(noised_encoded_x), axis=3)
plt.imshow(noised_gen_x[3])
```

Out[ ]:

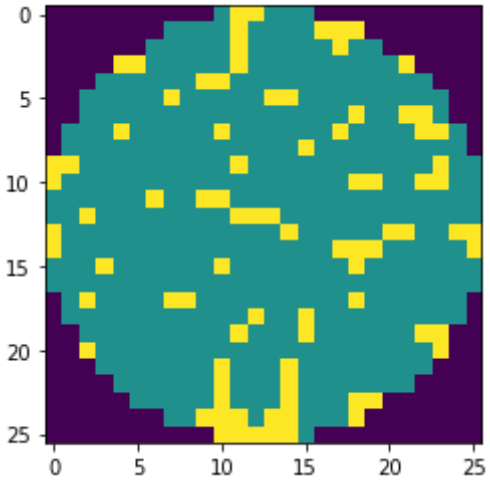




In [ ]:

```
# check reconstructed original faulty wafer data
gen_x = np.argmax(ae.predict(new_x), axis=3)
plt.imshow(gen_x[3])


# ------------------ Data augmentation ----------------------
```

Out[ ]:



In [ ]:

```
# augment function define
def gen_data(wafer, label):
    # Encode input wafer
    encoded_x = encoder.predict(wafer)

    # dummy array for collecting noised wafer
    gen_x = np.zeros((1, 26, 26, 3))

    # Make wafer until total # of wafer to 2000
    for i in range((2000//len(wafer)) + 1):
        noised_encoded_x = encoded_x + np.random.normal(loc=0, scale=0.1, size = (len(encoded_x), 13, 13, 64))
        noised_gen_x = decoder.predict(noised_encoded_x)
```

```
        noised_gen_x = decoder.predict(noised_encoded_x)
        gen_x = np.concatenate((gen_x, noised_gen_x), axis=0)
    # also make label vector with same length
    gen_y = np.full((len(gen_x), 1), label)

    # return date without 1st dummy data.
    return gen_x[1:], gen_y[1:]
```

In [ ]:
```
# Augmentation for all faulty case.
for f in faulty_case :
    # skip none case
    if f == 'none' :
        continue

    gen_x, gen_y = gen_data(new_x[np.where(y==f)[0]], f)
    new_x = np.concatenate((new_x, gen_x), axis=0)
    y = np.concatenate((y, gen_y))
```

In [ ]:
```
print('After Generate new_x shape : {}, new_y shape : {}'.format(new_x.shape, y.shape))
```

In [ ]:
```
for f in faulty_case :
    print('{} : {}'.format(f, len(y[y==f])))
```

In [ ]:
```
# choice index without replace.
none_idx = np.where(y=='none')[0][np.random.choice(len(np.where(y=='none')[0]), size=11000, replace=False)]
```

In [ ]:
```
# delete choiced index data.
new_x = np.delete(new_x, none_idx, axis=0)
new_y = np.delete(y, none_idx, axis=0)

print('After Delete "none" class new_x shape : {}, new_y shape : {}'.format(new_x.shape, new_y.shape))
```

In [ ]:
```
# faulty_case count
for f in faulty_case :
```

```
for f in faulty_case:
    print('{} : {}'.format(f, len(new_y[new_y==f])))
```

In [ ]:

```
# make string label data to numerical data
for i, l in enumerate(faulty_case):
    new_y[new_y==l] = i

# one-hot-encoding
new_y = to_categorical(new_y)

# split data train, test
x_train, x_test, y_train, y_test = train_test_split(new_x, new_y,
                                                    test_size=0.33,
                                                    random_state=2019)

print('Train x : {}, y : {}'.format(x_train.shape, y_train.shape))
print('Test x: {}, y : {}'.format(x_test.shape, y_test.shape))
```

In [ ]:

```
# The data is ready. As wafer data is image. simply use cnn for classification.
```

In [ ]:

```
# The data is ready. As wafer data is image. simply use cnn for classification.
# Make model
# define create model function, because we will validate model with sklearn kfold cross validation.
def create_model():
    input_shape = (26, 26, 3)
    input_tensor = Input(input_shape)

    conv_1 = layers.Conv2D(16, (3,3), activation='relu', padding='same')(input_tensor)
    conv_2 = layers.Conv2D(64, (3,3), activation='relu', padding='same')(conv_1)
    conv_3 = layers.Conv2D(128, (3,3), activation='relu', padding='same')(conv_2)

    flat = layers.Flatten()(conv_3)

    dense_1 = layers.Dense(512, activation='relu')(flat)
    dense_2 = layers.Dense(128, activation='relu')(dense_1)
    output_tensor = layers.Dense(9, activation='softmax')(dense_2)

    model = models.Model(input_tensor, output_tensor)
    model.compile(optimizer='Adam'
```

```
    model.compile(optimizer='Adam',
                  loss='categorical_crossentropy',
                  metrics=['accuracy'])

    return model
```

In [ ]:
```
# Cross validate model: Using sklearn KFold Cross validation, we validate our simple cnn.

# Make keras model to sklearn classifier.
model = KerasClassifier(build_fn=create_model, epochs=10, batch_size=1024, verbose=2)
# 3-Fold Crossvalidation
kfold = KFold(n_splits=3, shuffle=True, random_state=2019)
results = cross_val_score(model, x_train, y_train, cv=kfold)
# Check 3-fold model's mean accuracy
print('Simple CNN Cross validation score : {:.4f}'.format(np.mean(results)))
```

In [ ]:
```
batch_size
```

Out[ ]:

In [ ]:
```
print(x_test.shape)
print(y_test.shape)
```

In [ ]:
```
print(x_train.shape)
print(y_train.shape)
```

In [ ]:
```
y_train.dtype
```

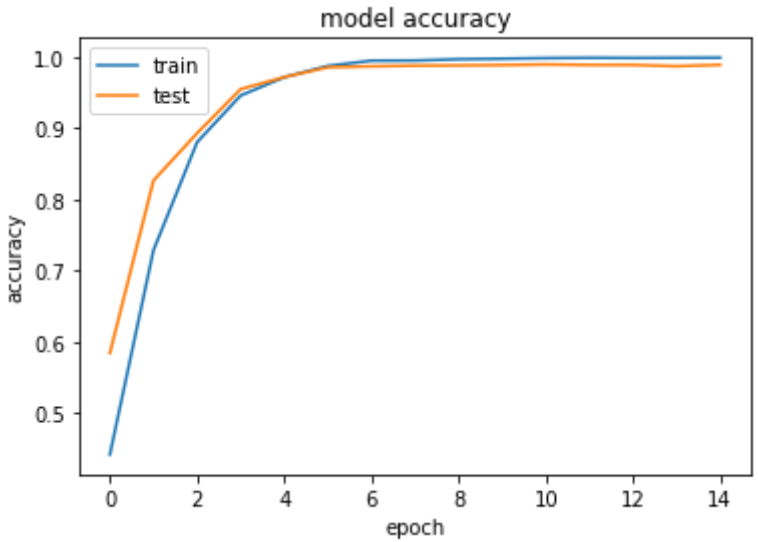
Out[ ]:

In [ ]:
```
# Our model seems quite a good model.
history = model.fit(x_train, y_train,
          epochs=epoch,
```

```
        batch_size=batch_size,
        validation_data=(x_test, y_test)
        )
```

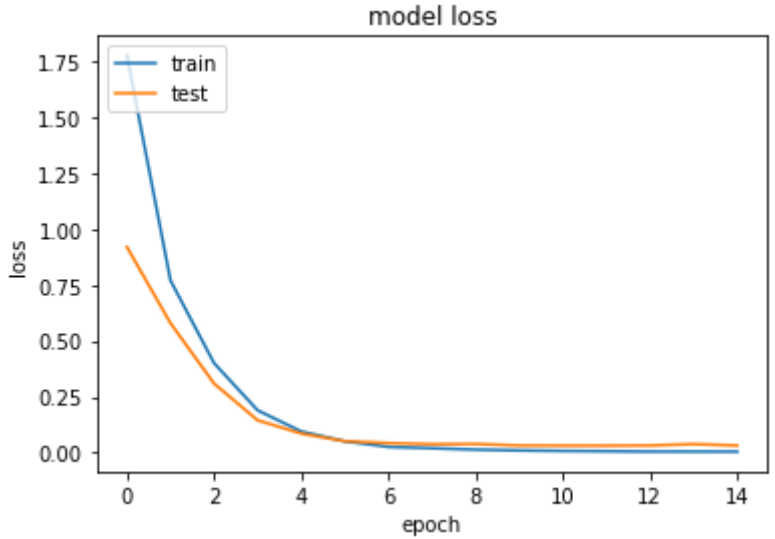
In [ ]:

```
# accuracy chart
# accuracy plot
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='upper left')
plt.show()
```



In [ ]:

```
# loss plot
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='upper left')
plt.show()
```


model loss
train
test
loss
epoch
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
2
4
6
8
10
12
14

In [ ]: