In [1]:

```
# import packages
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import torch
from torch.utils.data import DataLoader
from google.colab import files
import io
import warnings
from sklearn.model_selection import train_test_split
warnings.filterwarnings(action='ignore')
```

We will give you the preproceesed titanic data.

File is on your Icampus, Please download train_preprocessed.csv

It is preprocessed based on last week's lab.

In [2]:

```
uploaded = files.upload()
data = pd.read_csv(io.BytesIO(uploaded['train_preprocessed.csv']))
```

파일 선택 선택된 파일 없음

Upload widget is only available when the cell has been executed in the current browser session.
Please rerun this cell to enable.

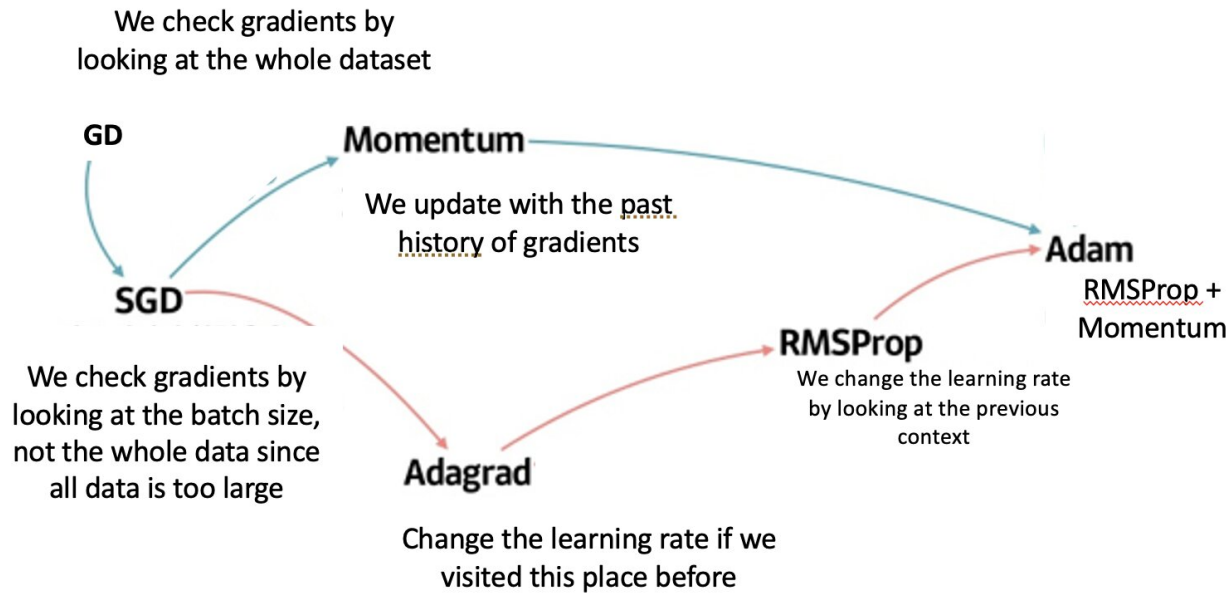
Saving train_preprocessed.csv to train_preprocessed.csv

In [3]:

```
train, test = train_test_split(data, test_size = 0.1, random_state = 55)
```

1. Optimization Method

So far, we only used SGD to update our weights! There are more optimization functions below..



Problem 1. Explain 2 pros and 2 cons of momentum compared to the other optimization methods (10pts)

In [4]:

```
# Your answer on problem 1
# 장점: 기울기가 0인 안장점을 잘 탈출할 수 있다, SGD에 비해 효율적인 학습을 할 수 있다
# 단점: overfitting이 일어날수 있다. 변수에 대한 메모리가 2배로 든다
```

In [5]:

```
MLP1 = torch.nn.Linear(3,4)     #nn.Linear(input_dim, output_dim)
MLP1.weight, MLP1.bias
MLP2 = torch.nn.Linear(4,1)
MLP2.weight, MLP2.bias
```

Out[5]:

```
(Parameter containing:
 tensor([[-0.1100,  0.2949,  0.4206, -0.2606]], requires_grad=True),
 Parameter containing:
 tensor([-0.2470], requires_grad=True))
```

In [6]:

```
x = torch.tensor([1., 0., 1.])
target = torch.tensor(0.5)
optim = torch.optim.SGD([MLP1.weight, MLP1.bias, MLP2.weight, MLP2.bias], lr=0.1)
loss_func = torch.nn.MSELoss()
```

In [7]:

```
for i in range(5):
  y = MLP1(x)
  y = torch.nn.functional.sigmoid(y)
  y = MLP2(y)
  y = torch.nn.functional.sigmoid(y)
  loss = loss_func(y, target)
  # pytorch automaticaaly calculates the gradient and applies EBP(Error Back Propagation)
  optim.zero_grad()     #zero_grad() function is making the gradient zero..this time is for init
ialization
  loss.backward()          #pytorch automatically calculates the gradient
  optim.step()          #update the weights
  print(loss)
```

```
tensor(0.0019, grad_fn=<MseLossBackward0>)
tensor(0.0018, grad_fn=<MseLossBackward0>)
tensor(0.0017, grad_fn=<MseLossBackward0>)
tensor(0.0016, grad_fn=<MseLossBackward0>)
tensor(0.0015, grad_fn=<MseLossBackward0>)
```

In [8]:

```
x = torch.tensor([1., 0., 1.])
target = torch.tensor(0.5)
optim = torch.optim.Adam([MLP1.weight, MLP1.bias, MLP2.weight, MLP2.bias], lr=0.1)
loss_func = torch.nn.MSELoss()
```

In [9]:

```
for i in range(5):
  y = MLP1(x)
  y = torch.nn.functional.sigmoid(y)
  y = MLP2(y)
  y = torch.nn.functional.sigmoid(y)
  loss = loss_func(y, target)
  # pytorch automaticaaly calculates the gradient and applies EBP(Error Back Propagation)
  optim.zero_grad()     #zero_grad() function is making the gradient zero..this time is for init
ialization
  loss.backward()          #pytorch automatically calculates the gradient
  optim.step()          #update the weights
  print(loss)
```

```
tensor(0.0014, grad_fn=<MseLossBackward0>)
tensor(0.0047, grad_fn=<MseLossBackward0>)
tensor(0.0011, grad_fn=<MseLossBackward0>)
tensor(0.0003, grad_fn=<MseLossBackward0>)
tensor(0.0019, grad_fn=<MseLossBackward0>)
```

In [10]:

```
# Momentum is caring about the past gradient and uses the past gradient as well!
# momentum can be assigned in the SGD function torch implemented
MLP1 = torch.nn.Linear(3, 1)
optimizer = torch.optim.SGD(MLP1.parameters(), lr= 0.001, momentum=0.9)
```

In [11]:

```
# RMSProp adjusts the learning rate for each weight, if the gradient was large at the past histo
ry, learning rate becomes smallar
# RMSProp
optimizer = torch.optim.RMSprop(MLP1.parameters(), lr =0.001)
```

In [12]:

```
# Adam is somewhat having characteristics of both the momentum and RMSProp as you can figure out
in the figure
optimizer = torch.optim.Adam(MLP1.parameters(), lr = 0.001)
```

For today's lecture, we will use Adam optimizer

In [13]:

```
x_train = train.drop(['Survived'], axis=1)
y_train = train['Survived']
x_test = test.drop(['Survived'], axis=1)
y_test = test['Survived']
```

In [14]:

```
import torch
from torch.utils.data import DataLoader, TensorDataset
```

In [15]:

```
x_train = torch.FloatTensor(x_train.to_numpy())
y_train = torch.FloatTensor(y_train.to_numpy())
y_train = y_train.reshape(-1, 1)
x_test = torch.FloatTensor(x_test.to_numpy())
y_test = torch.FloatTensor(y_test.to_numpy())
y_test = y_test.reshape(-1, 1)
train_data = TensorDataset(x_train, y_train)
test_data = TensorDataset(x_test, y_test)
train_dataloader = DataLoader(train_data, batch_size=64, shuffle=True)
test_dataloader = DataLoader(test_data, batch_size=64, shuffle=False)
```

Let's recall last week's titanic_layer

In [16]:

```
class Titanic_layer(torch.nn.Module):
  def __init__(self):
    super(Titanic_layer, self).__init__()
    ## define your own layers!
    self.MLP1 = torch.nn.Linear(10, 32)
    self.MLP2 = torch.nn.Linear(32, 64)
    self.MLP3 = torch.nn.Linear(64, 32)
    self.MLP4 = torch.nn.Linear(32, 16)
    self.MLP5 = torch.nn.Linear(16, 4)
    self.MLP6 = torch.nn.Linear(4, 1)

  def forward(self, x):
    # define the forward function
    y = self.MLP1(x)
    y = torch.nn.functional.relu(y) # we will use relu as our activation function. relu has adva
ntage when layers go deeper!
    y = self.MLP2(y)
    y = torch.nn.functional.relu(y)
    y = self.MLP3(y)
    y = torch.nn.functional.relu(y)
    y = self.MLP4(y)
    y = torch.nn.functional.relu(y)
    y = self.MLP5(y)
    y = torch.nn.functional.relu(y)
    y = self.MLP6(y)
    y = torch.nn.functional.sigmoid(y) #last element should be with 0~1, therefore, we can't use
relu
    return y
```

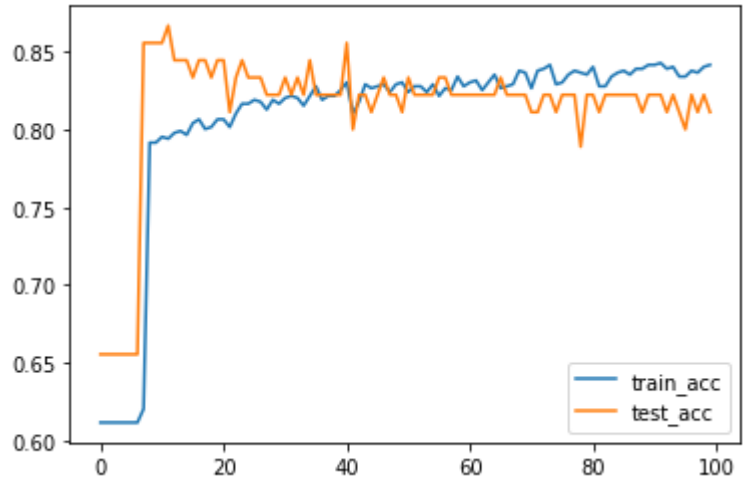
In [17]:

```
epochs =  100      # please write your own epoch
model = Titanic_layer()
loss_func = torch.nn.BCELoss()
optim = torch.optim.Adam(model.parameters(), lr = 0.001)
train_total_acc = []
test_total_acc = []
for epoch in range(1, epochs+1):
  train_acc = 0
  train_total = 0
  test_acc = 0
  test_total = 0
  for i, data in enumerate(train_dataloader):
    x, target = data
    model.train() # this code indicates that model is in training mode
    y = model(x)
    loss = loss_func(y, target)
    real_y = (y>=0.5).float()
    train_acc += (real_y == target).float().sum()
    train_total += target.shape[0]
    optim.zero_grad()
    loss.backward()
    optim.step()
  for i, data in enumerate(test_dataloader):
    x, target = data
    model.eval() # this code indicates that model is in evaluation mode
    with torch.no_grad():
      y = model(x)
      loss = loss_func(y, target)
      real_y = (y>=0.5).float()
      test_acc += (real_y == target).float().sum()
      test_total += target.shape[0]
  train_total_acc.append(train_acc/train_total)
  test_total_acc.append(test_acc/test_total)
```

In [18]:

```
import matplotlib.pyplot as plt

plt.plot(np.arange(len(train_total_acc)), train_total_acc, label='train_acc')
plt.plot(np.arange(len(test_total_acc)), test_total_acc, label='test_acc')
plt.legend()
plt.show()
```



As you can find out from the figure above, train_acc keeps increasing while test_acc becomes degrading.

This is called overfitting. It fits too well to the training dataset not giving right accuracy to the test dataset.

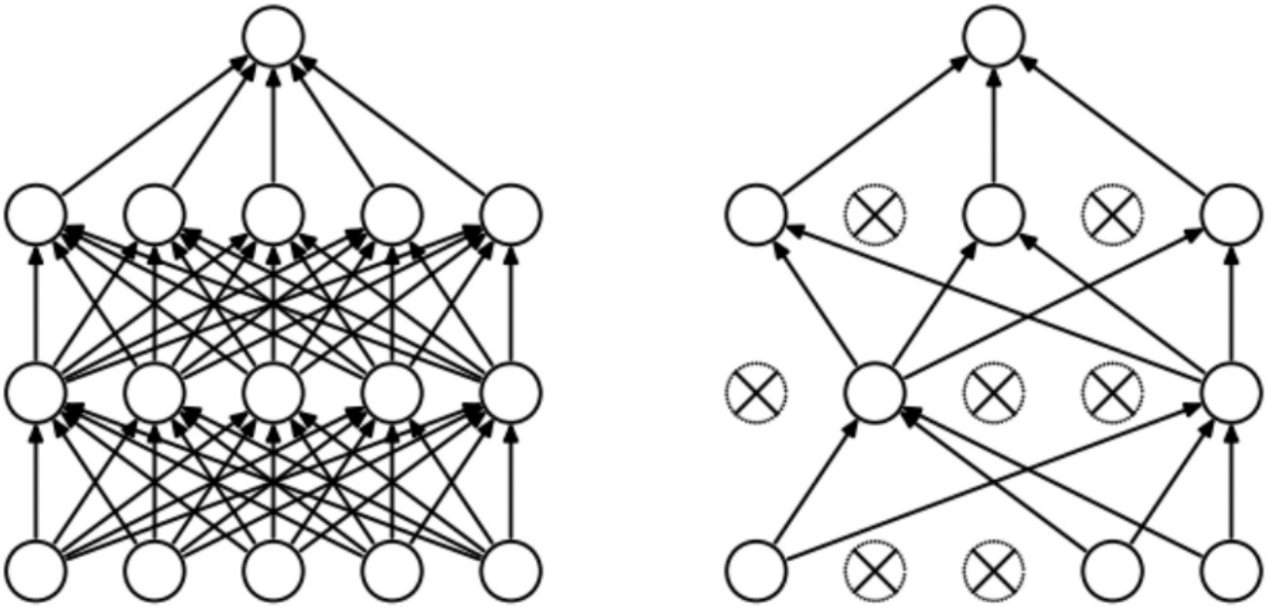
From now on, we will learn some useful tips to avoid overfitting.

2. Dropout

We randomly make some weights to 0 so this weights aren't used in training and also updating

We can use dropout like this

```
dropout = torch.nn.Dropout(p=0.5)
dropout(input)
```



Problem 2: use nn.Dropout on our previous titanic_layer and find out the difference of our plot! Also, explain why the dropout alleviates the overfitting problem (10 points)

In [19]:

```
# why does the dropout alleviates the overfitting problem?
# 학습 시에 인공 신경망이 특정 뉴런 또는 특정 조합에 너무 의존적이게 되는 것을 방지해주고,
# 매번 랜덤 선택으로 뉴런들을 사용하지 않으므로 서로 다른 신경망들을 앙상블하여 사용하는 것 같은 효과를 내어 과적합을 방지합니다.

class Titanic_layer(torch.nn.Module):
  def __init__(self):
    super(Titanic_layer, self).__init__()
    ## define your own layers!
    self.MLP1 = torch.nn.Linear(10, 64)
    self.MLP2 = torch.nn.Linear(64, 16)
    self.MLP3 = torch.nn.Linear(16, 4)
    self.MLP4 = torch.nn.Linear(4, 1)
    # write down the dropout as you want
    self.drop1 = torch.nn.Dropout(0.2)
    self.drop2 = torch.nn.Dropout(0.2)
    self.drop3 = torch.nn.Dropout(0.2)


  def forward(self, x):
    # define the forward function
    # use the dropout function after the activation function
    y = self.MLP1(x)
    y = torch.nn.functional.relu(y) # we will use relu as our activation function. relu has advantage when layers go deeper!
    y = self.drop1(y)
    y = self.MLP2(y)
    y = torch.nn.functional.relu(y)
    y = self.drop2(y)
    y = self.MLP3(y)
    y = torch.nn.functional.relu(y)
    y = self.drop3(y)
    y = self.MLP4(y)
    y = torch.nn.functional.sigmoid(y) #last element should be with 0~1, therefore, we can't use relu
    return y
```

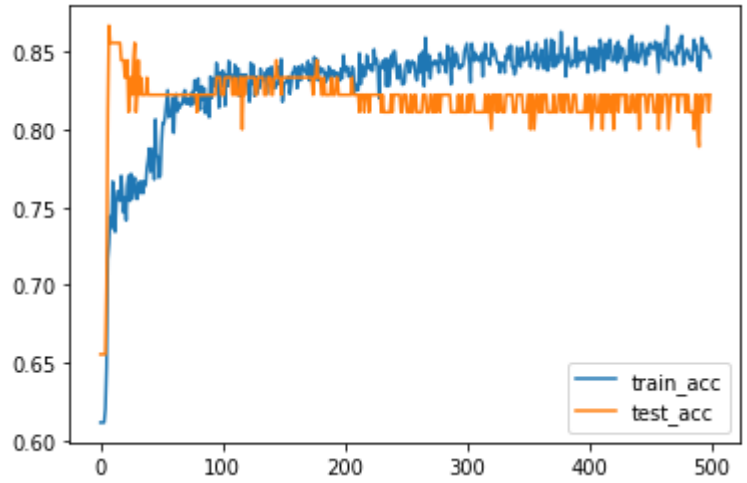
In [20]:

```
epoches =  500      # please write your own number of epoch
model = Titanic_layer()
loss_func = torch.nn.BCELoss()
optim = torch.optim.Adam(model.parameters(), lr = 0.001)
train_total_acc = []
test_total_acc = []
for epoch in range(1, epoches+1):
  train_acc = 0
  train_total = 0
  test_acc = 0
  test_total = 0
  for i, data in enumerate(train_dataloader):
    x, target = data
    model.train() # this code indicates that model is in training mode
    y = model(x)
    loss = loss_func(y, target)
    real_y = (y>=0.5).float()
    train_acc += (real_y == target).float().sum()
    train_total += target.shape[0]
    optim.zero_grad()
    loss.backward()
    optim.step()
  for i, data in enumerate(test_dataloader):
    x, target = data
    model.eval() # this code indicates that model is in evaluation mode
    with torch.no_grad():
      y = model(x)
      loss = loss_func(y, target)
      real_y = (y>=0.5).float()
      test_acc += (real_y == target).float().sum()
      test_total += target.shape[0]
  train_total_acc.append(train_acc/train_total)
  test_total_acc.append(test_acc/test_total)
```

In [21]:

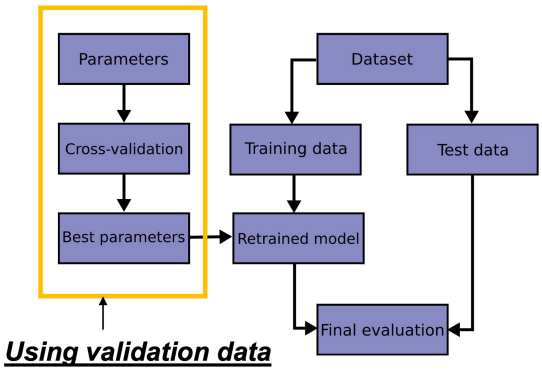
```
import matplotlib.pyplot as plt

plt.plot(np.arange(len(train_total_acc)), train_total_acc, label='train_acc')
plt.plot(np.arange(len(test_total_acc)), test_total_acc, label='test_acc')
plt.legend()
plt.show()
```



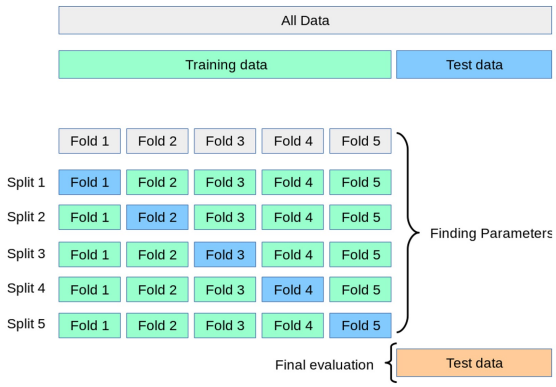
3. Hyper-parameter tuning: Split data into Train, Validation, Test dataset

- To update the performace of models, we can tune our model of hyper-parameters.
- The validation dataset is used for hyper-parameters tuning, not test datset. (Note: A test dataset is only used for a final evalutation)
- We can split the train dataset into train and validation dataset.



4. Hyper-parameters tuning: cross-validated grid-search

When we split data into three sets, there is a risk of sampling bias(over-estimation or under-estimation), but also a limit to utilize the only part of dataset. A cross-validation (CV for short) is used as the solution for this problem. [Reference (https://scikit-learn.org/stable/modules/cross_validation.html)](https://scikit-learn.org/stable/modules/cross_validation.html)



In [22]:

```
from sklearn.model_selection import KFold
dataset = np.array(train.index)
kf = KFold(n_splits=3, shuffle=True, random_state=42)
for train_idx, val_idx in kf.split(dataset):
  display(train.loc[dataset[val_idx]].head(3))
```

	Survived	Pclass	Age	SibSp	Parch	Fare	Sex_female	Sex_male	Embarked_
26	0	1.0	0.310639	0	0	0.014102	0	1	
572	1	0.0	0.447097	0	0	0.051505	0	1	
300	1	1.0	0.310639	0	0	0.015127	1	0	

	Survived	Pclass	Age	SibSp	Parch	Fare	Sex_female	Sex_male	Embarked_
768	0	1.0	0.310639	1	0	0.047138	0	1	
294	0	1.0	0.296306	0	0	0.015412	0	1	
619	0	0.5	0.321438	0	0	0.020495	0	1	

	Survived	Pclass	Age	SibSp	Parch	Fare	Sex_female	Sex_male	Embarked_
598	0	1.0	0.310639	0	0	0.014102	0	1	
780	1	1.0	0.158080	0	0	0.014110	1	0	
233	1	1.0	0.057552	4	2	0.061264	1	0	

To tune multiple hyper-parameters, we can use ***cross-validated grid-search*** (https://en.wikipedia.org/wiki/Hyperparameter_optimization#Grid_search)method.

1. Select the hyper-parameters which you want to tune.
2. Set the candidate values for each hyper-parameters.
3. Apply into model using grid search method
4. Return the best set of hyper-parameters for the model.

In [23]:

```
# The goal of skorch is to make it possible to use PyTorch with sklearn.
# This is achieved by providing a wrapper around PyTorch that has an sklearn interface.
# https://skorch.readthedocs.io/en/stable/index.html
!pip install skorch
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheel
s/public/simple/
Collecting skorch
  Downloading skorch-0.11.0-py3-none-any.whl (155 kB)
     |████████████████████████████████| 155 kB 5.1 MB/s
Requirement already satisfied: tabulate>=0.7.7 in /usr/local/lib/python3.7/dist-pa
ckages (from skorch) (0.8.10)
Requirement already satisfied: scipy>=1.1.0 in /usr/local/lib/python3.7/dist-packa
ges (from skorch) (1.7.3)
Requirement already satisfied: numpy>=1.13.3 in /usr/local/lib/python3.7/dist-pack
ages (from skorch) (1.21.6)
Requirement already satisfied: scikit-learn>=0.19.1 in /usr/local/lib/python3.7/di
st-packages (from skorch) (1.0.2)
Requirement already satisfied: tqdm>=4.14.0 in /usr/local/lib/python3.7/dist-packa
ges (from skorch) (4.64.1)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.7/di
st-packages (from scikit-learn>=0.19.1->skorch) (3.1.0)
Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.7/dist-packa
ges (from scikit-learn>=0.19.1->skorch) (1.1.0)
Installing collected packages: skorch
Successfully installed skorch-0.11.0
```

In [24]:

```
X = np.array(train.drop(['Survived'], axis=1)).astype(np.float32)
y = np.array(train['Survived']).astype(np.float32).reshape(-1, 1)
```

In [25]:

```
def my_accuracy(net, X, y):
  real_y = (net.predict_proba(X)>=0.5)
  val_acc = (real_y == y).sum()
  val_total = y.shape[0]
  return (val_acc/val_total)
```

In [26]:

```
from skorch import NeuralNet

net = NeuralNet(Titanic_layer,
                max_epochs = 20,
                lr=0.01,
                criterion=torch.nn.BCELoss,
                optimizer=torch.optim.Adam,
                verbose=0,
                device='cpu')
net.fit(X, y)
print(f'Accuracy of training dataset: {my_accuracy(net, X, y): .2f}%')
```

```
Accuracy of training dataset:  0.81%
```

In [27]:

```
# 1. Select the hyper-parameters which you want to tune
print(net.get_params().keys())
```

```
dict_keys(['module', 'criterion', 'optimizer', 'lr', 'max_epochs', 'batch_size',
'iterator_train', 'iterator_valid', 'dataset', 'train_split', 'callbacks', 'predic
t_nonlinearity', 'warm_start', 'verbose', 'device', '_kwargs', 'callbacks__epoch_t
imer', 'callbacks__train_loss', 'callbacks__train_loss__name', 'callbacks__train_l
oss__lower_is_better', 'callbacks__train_loss__on_train', 'callbacks__valid_loss',
'callbacks__valid_loss__name', 'callbacks__valid_loss__lower_is_better', 'callback
s__valid_loss__on_train', 'callbacks__print_log', 'callbacks__print_log__keys_igno
red', 'callbacks__print_log__sink', 'callbacks__print_log__tablefmt', 'callbacks__
print_log__floatfmt', 'callbacks__print_log__stralign'])
```

In [28]:

```
# 2. Set the candidate values for each hyper-parameters.
params = {'optimizer':[torch.optim.Adam,torch.optim.RMSprop],
          'lr':[0.001, 0.005, 0.01]}
```

In [29]:

```
# 3. Apply into model using cross validated grid search method
from sklearn.model_selection import GridSearchCV
gs = GridSearchCV(estimator=net,
                  param_grid=params,
                  scoring=my_accuracy,
                  cv=3,
                  verbose=0)

gs.fit(X, y)
# 4. Return the best set of hyper-parameters for the model.
print(f'Accuracy: {gs.best_score_ * 100 :.2f}%')
print(gs.best_params_)
```

```
Accuracy: 80.15%
{'lr': 0.001, 'optimizer': <class 'torch.optim.rmsprop.RMSprop'>}
```

In [30]:

```
gs.cv_results_['params']
```

Out[30]:

```
[{'lr': 0.001, 'optimizer': torch.optim.adam.Adam},
 {'lr': 0.001, 'optimizer': torch.optim.rmsprop.RMSprop},
 {'lr': 0.005, 'optimizer': torch.optim.adam.Adam},
 {'lr': 0.005, 'optimizer': torch.optim.rmsprop.RMSprop},
 {'lr': 0.01, 'optimizer': torch.optim.adam.Adam},
 {'lr': 0.01, 'optimizer': torch.optim.rmsprop.RMSprop}]
```

In [31]:

```
gs.cv_results_["mean_test_score"]
```

Out[31]:

```
array([0.75280899, 0.80149813, 0.79275905, 0.79900125, 0.80149813,
       0.79775281])
```

Problem 3: Using cross-validated grid search method, decide the proper size of epochs to avoid overfitting. (10 points)

In machine learning, early stopping is a form of regularization used to avoid overfitting when training a learner with an iterative method, such as gradient descent. Such methods update the learner so as to make it better fit the training data with each iteration. (Reference (https://en.wikipedia.org/wiki/Early_stopping))

In [32]:

```
# You can refer the above plot of accuray to decide the range of epochs
params = {'max_epochs': [200,1000, 2000],
          'lr':[0.001, 0.005, 0.01]}

gs = GridSearchCV(estimator=net,
                  param_grid=params,
                  scoring=my_accuracy,
                  cv=3,
                  verbose=0)

gs.fit(X, y)

print(f'Accuracy: {gs.best_score_ * 100 :.2f}%')
print(gs.best_params_)
```

```
Accuracy: 80.27%
{'lr': 0.001, 'max_epochs': 1000}
```

5. Final model

Problem 4: Evaluate your model applying K-fold Cross-validation with optimal hyper-parameters which you found (10 points)

In [33]:

```
kf = KFold(n_splits=3, shuffle=True, random_state=42)


df = pd.read_csv(io.BytesIO(uploaded['train_preprocessed.csv']))
X_df = df.drop(['Survived'], axis=1)
y_df = df['Survived']

X_df = torch.FloatTensor(X_df.to_numpy())
y_df= torch.FloatTensor(y_df.to_numpy()).reshape(-1, 1)
```

In [34]:

```
optimal_epochs = 1000
optimal_lr = 0.001

kf = KFold(n_splits=5, shuffle=True, random_state=42)
for fold, (train_idx,val_idx) in enumerate(kf.split(range(len(df)))):

  print('Fold {}'.format(fold + 1))
  train_X = X_df[train_idx]
  train_Y = y_df[train_idx]
  valid_X = X_df[val_idx]
  valid_Y = y_df[val_idx]
  train_dataset = TensorDataset(train_X, train_Y)
  valid_dataset = TensorDataset(valid_X, valid_Y)
  train_dataloader = DataLoader(train_dataset, batch_size=64)
  test_dataloader = DataLoader(valid_dataset, batch_size=64)

  model = Titanic_layer()
  loss_func = torch.nn.BCELoss()
  optim = torch.optim.Adam(model.parameters(), lr = optimal_lr)

  history = {'train_acc':[],'test_acc':[]}

  train_acc_lst = []
  test_acc_lst = []

  for epoch in range(1, optimal_epochs+1):
    train_acc = 0
    train_total = 0
    test_acc = 0
    test_total = 0

    for i, data in enumerate(train_dataloader):
      x, target = data
      model.train() # this code indicates that model is in training mode
      y = model(x)
      loss = loss_func(y, target)
      real_y = (y>=0.5).float()
      train_acc += (real_y == target).float().sum()
      train_total += target.shape[0]
      optim.zero_grad()
      loss.backward()
      optim.step()

    for i, data in enumerate(test_dataloader):
      x, target = data
      model.eval() # this code indicates that model is in evaluation mode
      with torch.no_grad():
        y = model(x)
        loss = loss_func(y, target)
        real_y = (y>=0.5).float()
        test_acc += (real_y == target).float().sum()
        test_total += target.shape[0]

    train_acc_lst.append(train_acc/train_total)
    test_acc_lst.append(test_acc/test_total)

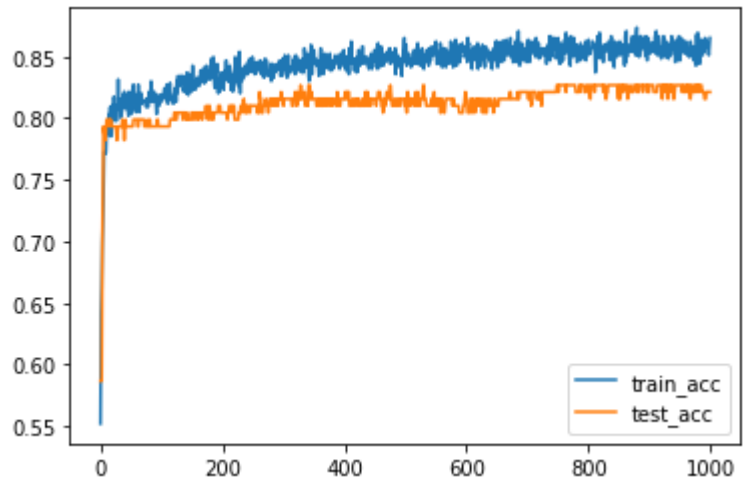
  plt.plot(np.arange(len(train_acc_lst)), train_acc_lst, label='train_acc')
  plt.plot(np.arange(len(test_acc_lst)), test_acc_lst, label='test_acc')
  plt.legend()
```

```
    plt.show()

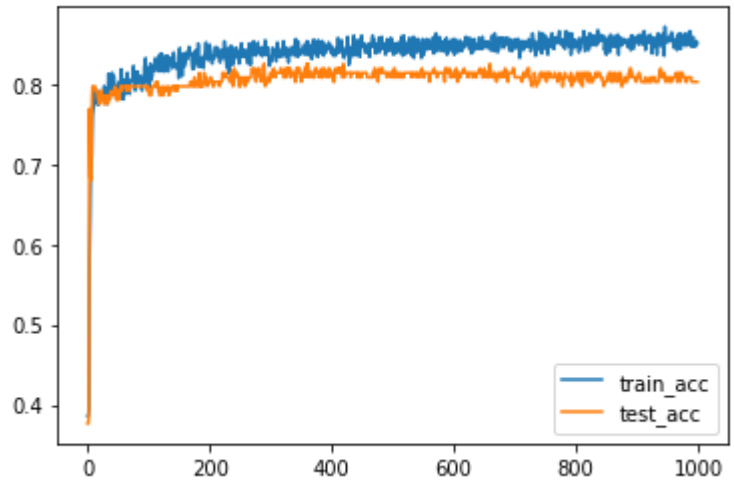
    history['train_acc'].append(train_acc_lst[-1])
    history['test_acc'].append(test_acc_lst[-1])

avg_acc_train = np.mean(history['train_acc'])
avg_acc_test = np.mean(history['test_acc'])
print(f'Average Accuracy of train dataset: {avg_acc_train * 100 :.2f}%')
print(f'Average Accuracy of test dataset: {avg_acc_test * 100 :.2f}%')
```

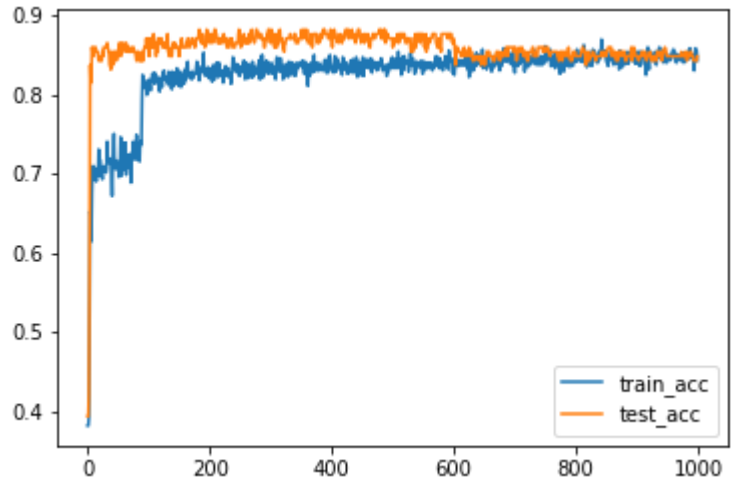
Fold 1



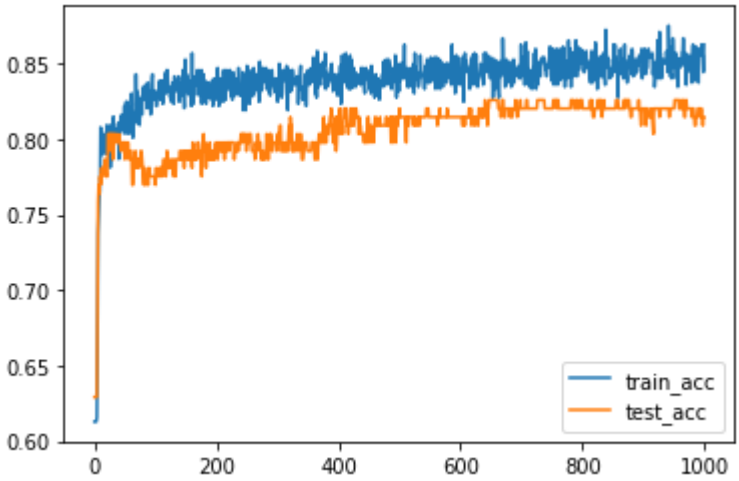
Fold 2



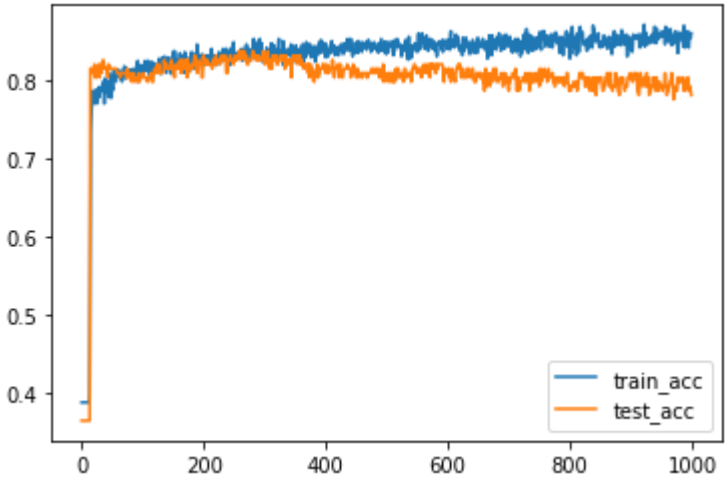
Fold 3



Fold 4



Fold 5




```
Average Accuracy of train dataset: 85.97%
Average Accuracy of test dataset: 78.09%
```

In [ ]:

```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
from google.colab import drive
drive.mount('/content/drive')
!jupyter nbconvert --to html '/content/drive/MyDrive/인공지능프로젝트/week4_lab.ipynb'
```

```
Reading package lists... Done
Building dependency tree
Reading state information... Done
pandoc is already the newest version (1.19.2.4~dfsg-1build4).
pandoc set to manually installed.
The following package was automatically installed and is no longer required:
  libnvidia-common-460
Use 'apt autoremove' to remove it.
The following additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
Suggested packages:
  fonts-noto apache2 | lighttpd | httpd poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf-reader
  | pdf-viewer texlive-fonts-recommended-doc texlive-latex-base-doc
  python-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
  texlive-latex-recommended-doc texlive-pstricks dot2tex prerex ruby-tcltk
  | libtcltk-ruby texlive-pictures-doc vprerex
The following NEW packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa
0 upgraded, 47 newly installed, 0 to remove and 20 not upgraded.
Need to get 146 MB of archives.
After this operation, 460 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-droid-fallback all
1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lato all 2.0-2 [2,6
98 kB]
Get:3 http://archive.ubuntu.com/ubuntu bionic/main amd64 poppler-data all 0.4.8-2
[1,479 kB]
Get:4 http://archive.ubuntu.com/ubuntu bionic/main amd64 tex-common all 6.09 [33.0
kB]
Get:5 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lmodern all 2.004.5
-3 [4,551 kB]
Get:6 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-noto-mono all 20171
026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all 201
60520-1 [8,761 kB]
Get:8 http://archive.ubuntu.com/ubuntu bionic/main amd64 javascript-common all 11
[6,066 B]
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsfilters1 a
md64 1.20.2-0ubuntu3.1 [108 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2 am
```

```
d64 2.2.7-1ubuntu2.9 [18.6 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64 0.35-1
3 [15.5 kB]
Get:12 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjbig2dec0 amd64 0.13-
6 [55.9 kB]
Get:13 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common al
l 9.26~dfsg+0-0ubuntu0.18.04.16 [5,093 kB]
Get:14 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64 9.2
6~dfsg+0-0ubuntu0.18.04.16 [2,265 kB]
Get:15 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjs-jquery all 3.2.1-1
[152 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libkpathsea6 amd
64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
Get:17 http://archive.ubuntu.com/ubuntu bionic/main amd64 libpotrace0 amd64 1.14-2
[17.4 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libptexenc1 amd6
4 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic/main amd64 rubygems-integration all
1.11 [4,994 B]
Get:20 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 ruby2.5 amd64 2.
5.1-1ubuntu1.12 [48.6 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby amd64 1:2.5.1 [5,71
2 B]
Get:22 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 rake all 12.3.1-
1ubuntu0.1 [44.9 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-did-you-mean all 1.
2.0-2 [9,700 B]
Get:24 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-minitest all 5.10.3
-1 [38.6 kB]
Get:25 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-net-telnet all 0.1.
1-2 [12.6 kB]
Get:26 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-power-assert all 0.
3.0-1 [7,952 B]
Get:27 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-test-unit all 3.2.5
-1 [61.1 kB]
Get:28 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libruby2.5 amd64
2.5.1-1ubuntu1.12 [3,073 kB]
Get:29 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libsynctex1 amd6
4 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
Get:30 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexlua52 amd6
4 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
Get:31 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexluajit2 am
d64 2017.20170613.44572-8ubuntu0.1 [230 kB]
Get:32 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libzzip-0-13 amd
64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
Get:33 http://archive.ubuntu.com/ubuntu bionic/main amd64 lmodern all 2.004.5-3
[9,631 kB]
Get:34 http://archive.ubuntu.com/ubuntu bionic/main amd64 preview-latex-style all
11.91-1ubuntu1 [185 kB]
Get:35 http://archive.ubuntu.com/ubuntu bionic/main amd64 t1utils amd64 1.41-2 [5
6.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all 2016052
0-1 [4,998 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-binaries
amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
Get:38 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all 2017.20
180305-1 [18.7 MB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-recomm
ended all 2017.20180305-1 [5,262 kB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all 2
017.20180305-1 [951 kB]
```

```
Get:41 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-recommende
d all 2017.20180305-1 [14.9 MB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive all 2017.201
80305-1 [14.4 kB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures all
2017.20180305-1 [4,026 kB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-extra
all 2017.20180305-2 [10.6 MB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-generi
c all 2017.20180305-2 [23.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all 20
17.20180305-1 [10.7 MB]
Fetched 146 MB in 7s (21.6 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-droid-fallback.
(Reading database ... 157604 files and directories currently installed.)
Preparing to unpack .../00-fonts-droid-fallback_1%3a6.0.1r16-1.1_all.deb ...
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1) ...
Selecting previously unselected package fonts-lato.
Preparing to unpack .../01-fonts-lato_2.0-2_all.deb ...
Unpacking fonts-lato (2.0-2) ...
Selecting previously unselected package poppler-data.
Preparing to unpack .../02-poppler-data_0.4.8-2_all.deb ...
Unpacking poppler-data (0.4.8-2) ...
Selecting previously unselected package tex-common.
Preparing to unpack .../03-tex-common_6.09_all.deb ...
Unpacking tex-common (6.09) ...
Selecting previously unselected package fonts-lmodern.
Preparing to unpack .../04-fonts-lmodern_2.004.5-3_all.deb ...
Unpacking fonts-lmodern (2.004.5-3) ...
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack .../05-fonts-noto-mono_20171026-2_all.deb ...
Unpacking fonts-noto-mono (20171026-2) ...
Selecting previously unselected package fonts-texgyre.
Preparing to unpack .../06-fonts-texgyre_20160520-1_all.deb ...
Unpacking fonts-texgyre (20160520-1) ...
Selecting previously unselected package javascript-common.
Preparing to unpack .../07-javascript-common_11_all.deb ...
Unpacking javascript-common (11) ...
Selecting previously unselected package libcupsfilters1:amd64.
Preparing to unpack .../08-libcupsfilters1_1.20.2-0ubuntu3.1_amd64.deb ...
Unpacking libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) ...
Selecting previously unselected package libcupsimage2:amd64.
Preparing to unpack .../09-libcupsimage2_2.2.7-1ubuntu2.9_amd64.deb ...
Unpacking libcupsimage2:amd64 (2.2.7-1ubuntu2.9) ...
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack .../10-libijs-0.35_0.35-13_amd64.deb ...
Unpacking libijs-0.35:amd64 (0.35-13) ...
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack .../11-libjbig2dec0_0.13-6_amd64.deb ...
Unpacking libjbig2dec0:amd64 (0.13-6) ...
Selecting previously unselected package libgs9-common.
Preparing to unpack .../12-libgs9-common_9.26~dfsg+0-0ubuntu0.18.04.16_all.deb ...
Unpacking libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.16) ...
Selecting previously unselected package libgs9:amd64.
Preparing to unpack .../13-libgs9_9.26~dfsg+0-0ubuntu0.18.04.16_amd64.deb ...
Unpacking libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.16) ...
Selecting previously unselected package libjs-jquery.
```

```
Preparing to unpack .../14-libjs-jquery_3.2.1-1_all.deb ...
Unpacking libjs-jquery (3.2.1-1) ...
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack .../15-libkpathsea6_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libpotrace0.
Preparing to unpack .../16-libpotrace0_1.14-2_amd64.deb ...
Unpacking libpotrace0 (1.14-2) ...
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack .../17-libptexenc1_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package rubygems-integration.
Preparing to unpack .../18-rubygems-integration_1.11_all.deb ...
Unpacking rubygems-integration (1.11) ...
Selecting previously unselected package ruby2.5.
Preparing to unpack .../19-ruby2.5_2.5.1-1ubuntu1.12_amd64.deb ...
Unpacking ruby2.5 (2.5.1-1ubuntu1.12) ...
Selecting previously unselected package ruby.
Preparing to unpack .../20-ruby_1%3a2.5.1_amd64.deb ...
Unpacking ruby (1:2.5.1) ...
Selecting previously unselected package rake.
Preparing to unpack .../21-rake_12.3.1-1ubuntu0.1_all.deb ...
Unpacking rake (12.3.1-1ubuntu0.1) ...
Selecting previously unselected package ruby-did-you-mean.
Preparing to unpack .../22-ruby-did-you-mean_1.2.0-2_all.deb ...
Unpacking ruby-did-you-mean (1.2.0-2) ...
Selecting previously unselected package ruby-minitest.
Preparing to unpack .../23-ruby-minitest_5.10.3-1_all.deb ...
Unpacking ruby-minitest (5.10.3-1) ...
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack .../24-ruby-net-telnet_0.1.1-2_all.deb ...
Unpacking ruby-net-telnet (0.1.1-2) ...
Selecting previously unselected package ruby-power-assert.
Preparing to unpack .../25-ruby-power-assert_0.3.0-1_all.deb ...
Unpacking ruby-power-assert (0.3.0-1) ...
Selecting previously unselected package ruby-test-unit.
Preparing to unpack .../26-ruby-test-unit_3.2.5-1_all.deb ...
Unpacking ruby-test-unit (3.2.5-1) ...
Selecting previously unselected package libruby2.5:amd64.
Preparing to unpack .../27-libruby2.5_2.5.1-1ubuntu1.12_amd64.deb ...
Unpacking libruby2.5:amd64 (2.5.1-1ubuntu1.12) ...
Selecting previously unselected package libsynctex1:amd64.
Preparing to unpack .../28-libsynctex1_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libtexlua52:amd64.
Preparing to unpack .../29-libtexlua52_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack .../30-libtexluajit2_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack .../31-libzzip-0-13_0.13.62-3.1ubuntu0.18.04.1_amd64.deb ...
Unpacking libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) ...
Selecting previously unselected package lmodern.
Preparing to unpack .../32-lmodern_2.004.5-3_all.deb ...
Unpacking lmodern (2.004.5-3) ...
```

```
Selecting previously unselected package preview-latex-style.
Preparing to unpack .../33-preview-latex-style_11.91-1ubuntu1_all.deb ...
Unpacking preview-latex-style (11.91-1ubuntu1) ...
Selecting previously unselected package t1utils.
Preparing to unpack .../34-t1utils_1.41-2_amd64.deb ...
Unpacking t1utils (1.41-2) ...
Selecting previously unselected package tex-gyre.
Preparing to unpack .../35-tex-gyre_20160520-1_all.deb ...
Unpacking tex-gyre (20160520-1) ...
Selecting previously unselected package texlive-binaries.
Preparing to unpack .../36-texlive-binaries_2017.20170613.44572-8ubuntu0.1_amd64.d
eb ...
Unpacking texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package texlive-base.
Preparing to unpack .../37-texlive-base_2017.20180305-1_all.deb ...
Unpacking texlive-base (2017.20180305-1) ...
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack .../38-texlive-fonts-recommended_2017.20180305-1_all.deb ...
Unpacking texlive-fonts-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-base.
Preparing to unpack .../39-texlive-latex-base_2017.20180305-1_all.deb ...
Unpacking texlive-latex-base (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack .../40-texlive-latex-recommended_2017.20180305-1_all.deb ...
Unpacking texlive-latex-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive.
Preparing to unpack .../41-texlive_2017.20180305-1_all.deb ...
Unpacking texlive (2017.20180305-1) ...
Selecting previously unselected package texlive-pictures.
Preparing to unpack .../42-texlive-pictures_2017.20180305-1_all.deb ...
Unpacking texlive-pictures (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack .../43-texlive-latex-extra_2017.20180305-2_all.deb ...
Unpacking texlive-latex-extra (2017.20180305-2) ...
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack .../44-texlive-plain-generic_2017.20180305-2_all.deb ...
Unpacking texlive-plain-generic (2017.20180305-2) ...
Selecting previously unselected package tipa.
Preparing to unpack .../45-tipa_2%3a1.3-20_all.deb ...
Unpacking tipa (2:1.3-20) ...
Selecting previously unselected package texlive-xetex.
Preparing to unpack .../46-texlive-xetex_2017.20180305-1_all.deb ...
Unpacking texlive-xetex (2017.20180305-1) ...
Setting up libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.16) ...
Setting up libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up libjs-jquery (3.2.1-1) ...
Setting up libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up fonts-droid-fallback (1:6.0.1r16-1.1) ...
Setting up libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up tex-common (6.09) ...
update-language: texlive-base not installed and configured, doing nothing!
Setting up poppler-data (0.4.8-2) ...
Setting up tex-gyre (20160520-1) ...
Setting up preview-latex-style (11.91-1ubuntu1) ...
Setting up fonts-texgyre (20160520-1) ...
Setting up fonts-noto-mono (20171026-2) ...
Setting up fonts-lato (2.0-2) ...
Setting up libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) ...
Setting up libcupsimage2:amd64 (2.2.7-1ubuntu2.9) ...
Setting up libjbig2dec0:amd64 (0.13-6) ...
```

```
Setting up ruby-did-you-mean (1.2.0-2) ...
Setting up t1utils (1.41-2) ...
Setting up ruby-net-telnet (0.1.1-2) ...
Setting up libijs-0.35:amd64 (0.35-13) ...
Setting up rubygems-integration (1.11) ...
Setting up libpotrace0 (1.14-2) ...
Setting up javascript-common (11) ...
Setting up ruby-minitest (5.10.3-1) ...
Setting up libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) ...
Setting up libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.16) ...
Setting up libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Setting up fonts-lmodern (2.004.5-3) ...
Setting up ruby-power-assert (0.3.0-1) ...
Setting up texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin (xdvi.bi
n) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex (bi
btex) in auto mode
Setting up texlive-base (2017.20180305-1) ...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST...
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN...
mktexlsr: Updating /var/lib/texmf/ls-R...
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4: /var/lib/texmf/dvips/config/config-p
aper.ps
tl-paper: setting paper size for dvipdfmx to a4: /var/lib/texmf/dvipdfmx/dvipdfmx-
paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
tl-paper: setting paper size for pdftex to a4: /var/lib/texmf/tex/generic/config/p
dftexconfig.tex
Setting up texlive-fonts-recommended (2017.20180305-1) ...
Setting up texlive-plain-generic (2017.20180305-2) ...
Setting up texlive-latex-base (2017.20180305-1) ...
Setting up lmodern (2.004.5-3) ...
Setting up texlive-latex-recommended (2017.20180305-1) ...
Setting up texlive-pictures (2017.20180305-1) ...
Setting up tipa (2:1.3-20) ...
Regenerating '/var/lib/texmf/fmtutil.cnf-DEBIAN'... done.
Regenerating '/var/lib/texmf/fmtutil.cnf-TEXLIVEDIST'... done.
update-fmtutil has updated the following file(s):
        /var/lib/texmf/fmtutil.cnf-DEBIAN
        /var/lib/texmf/fmtutil.cnf-TEXLIVEDIST
If you want to activate the changes in the above file(s),
you should run fmtutil-sys or fmtutil.
Setting up texlive (2017.20180305-1) ...
Setting up texlive-latex-extra (2017.20180305-2) ...
Setting up texlive-xetex (2017.20180305-1) ...
Setting up ruby2.5 (2.5.1-1ubuntu1.12) ...
Setting up ruby (1:2.5.1) ...
Setting up ruby-test-unit (3.2.5-1) ...
Setting up rake (12.3.1-1ubuntu0.1) ...
Setting up libruby2.5:amd64 (2.5.1-1ubuntu1.12) ...
Processing triggers for mime-support (3.60ubuntu1) ...
Processing triggers for libc-bin (2.27-3ubuntu1.5) ...
Processing triggers for man-db (2.8.3-2ubuntu0.1) ...
Processing triggers for fontconfig (2.12.6-0ubuntu2) ...
Processing triggers for tex-common (6.09) ...
Running updmap-sys. This may take some time... done.
Running mktexlsr /var/lib/texmf ... done.
Building format(s) --all.
        This may take some time... done.
```

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Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheel
s/public/simple/
Collecting pypandoc
  Downloading pypandoc-1.9-py3-none-any.whl (20 kB)
Installing collected packages: pypandoc
Successfully installed pypandoc-1.9
```