FinalAssignment_S1155135359

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1 Keypoint Detection and Image Generation

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- Presentation: 6:30pm, May 4. Each student has 2-3 minutes.

2 Data

[84]:
```
from google.colab import drive
drive.mount('/content/gdrive/')
ROOT_FOLDER = './gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/'

import glob
print('\nContents in the data folder:')
for x in glob.glob(ROOT_FOLDER+'data/*'):
    print(x)
```

```
Drive already mounted at /content/gdrive/; to attempt to forcibly remount, call
drive.mount("/content/gdrive/", force_remount=True).

Contents in the data folder:
./gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/data/imgs1.npy
./gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/data/imgs2.npy
./gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/data/kpts3.npy
./gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/data/kpts1.npy
./gdrive/My Drive/Colab Notebooks/MAEG5735-2020-Assignment4/data/README.txt
```

There should be 4 files: * `imgs1.npy` * `kpts1.npy` * `imgs2.npy` * `kpts3.npy`

[85]:
```
import matplotlib.pyplot as plt
import numpy as np

def draw_points(image, kpts):
    plt.figure()
    plt.imshow(image, cmap='gray')
    keypoints = (kpts+0.5)*IMG_SIZE
    plt.scatter(keypoints[:, 0], keypoints[:, 1], s=50, marker='.', c='r')
```

```
# load the data
IMG_SIZE = 200
IMG_TRAIN = np.load(ROOT_FOLDER+'data/imgs1.npy')
IMG_TRAIN = np.unpackbits(IMG_TRAIN).reshape((-1,IMG_SIZE,IMG_SIZE))
KPT_TRAIN = np.load(ROOT_FOLDER+'data/kpts1.npy')/IMG_SIZE - 0.5

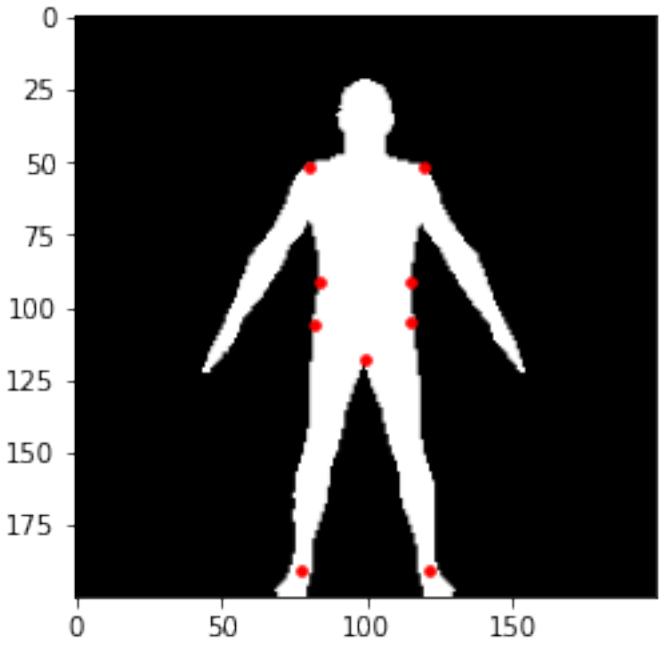
IMG_TEST = np.load(ROOT_FOLDER+'data/imgs2.npy')
IMG_TEST = np.unpackbits(IMG_TEST).reshape((-1,IMG_SIZE,IMG_SIZE))

KPT_TEST = np.load(ROOT_FOLDER+'data/kpts3.npy')/IMG_SIZE - 0.5

# show one
idx = 10
draw_points(IMG_TRAIN[idx,:,:], KPT_TRAIN[idx,:,:])

print(np.shape(IMG_TRAIN))
print(np.shape(KPT_TRAIN))
```

```
(1000, 200, 200)
(1000, 9, 2)
```



3 Task 1: Keypoint Detection

3.1 Keypoints Dataset loader

[0]:
```
import torch
from torch.utils.data import Dataset

class KeypointsDataset(Dataset):
    '''Keypoints Dataset'''
    def __init__(self, img, kpt, train=True, transform=None):
        self.img = img
        self.kpt = kpt
        self.train = train
        self.transform = transform

    def __len__(self):
        return self.img.shape[0]

    def __getitem__(self, idx):
        image = self.img[idx,:,:].astype(np.float32)
        if self.train:
            keypoints = self.kpt[idx,:,:].ravel().astype(np.float32)
        else:
            keypoints = None
        sample = {'image': image, 'keypoints': keypoints}
        if self.transform:
            sample = self.transform(sample)
        return sample
```

[0]:
```
from torch.utils.data.sampler import SubsetRandomSampler

def prepare_train_valid_loaders(trainset, valid_size=0.2,
                                batch_size=128):
    '''
    Split trainset data and prepare DataLoader for training and validation

    Args:
        trainset (Dataset): data
        valid_size (float): validation size, defalut=0.2
        batch_size (int) : batch size, default=128
    '''

    # obtain training indices that will be used for validation
    num_train = len(trainset)
    indices = list(range(num_train))
    np.random.shuffle(indices)
    split = int(np.floor(valid_size * num_train))
    train_idx, valid_idx = indices[split:], indices[:split]
```

```
    # define samplers for obtaining training and validation batches
    train_sampler = SubsetRandomSampler(train_idx)
    valid_sampler = SubsetRandomSampler(valid_idx)

    # prepare data loaders
    train_loader = torch.utils.data.DataLoader(trainset, batch_size=batch_size,␣
 ↪sampler=train_sampler)
    valid_loader = torch.utils.data.DataLoader(trainset, batch_size=batch_size,␣
 ↪sampler=valid_sampler)

    return train_loader, valid_loader
```

[0]:
```
from torchvision import transforms
import cv2

class Rescale(object):
    def __init__(self, output_size):
        assert isinstance(output_size, (int, tuple))
        self.output_size = output_size

    def __call__(self, sample):
        image, key_pts = sample['image'], sample['keypoints']
        h, w = image.shape[:2]
        new_w = np.random.randint(w, self.output_size)
        new_h = new_w
        new_h, new_w = int(new_h), int(new_w)
        img = cv2.resize(image, (new_w, new_h))
        if key_pts is not None:
            return {'image': img, 'keypoints': key_pts}
        else:
            return {'image': img}

class RandomCrop(object):
    def __init__(self, output_size):
        assert isinstance(output_size, (int, tuple))
        if isinstance(output_size, int):
            self.output_size = (output_size, output_size)
        else:
            assert len(output_size) == 2
            self.output_size = output_size

    def __call__(self, sample):
        image, key_pts = sample['image'], sample['keypoints']
        h, w = image.shape[:2]
        new_h, new_w = self.output_size
        if h == new_h:
```

```
            return sample
        top = np.random.randint(0, h - new_h)
        left = np.random.randint(0, w - new_w)
        #left = top # temp
        image = image[top: top + new_h,
                      left: left + new_w]
        if key_pts is not None:
            #key_pts = key_pts - [left/output_size, top/output_size]
            key_pts[0::2] = ((key_pts[0::2]+0.5)*w-left)/new_w-0.5
            key_pts[1::2] = ((key_pts[1::2]+0.5)*h-top)/new_h-0.5
            return {'image': image, 'keypoints': key_pts}
        else:
            return {'image': image}

class ToTensor(object):
    '''Convert ndarrays in sample to Tensors.'''
    def __call__(self, sample):
        image, keypoints = sample['image'], sample['keypoints']
        # swap color axis because
        # numpy image: H x W x C
        # torch image: C X H X W
        image = image.reshape(1, IMG_SIZE, IMG_SIZE)
        image = torch.from_numpy(image)
        if keypoints is not None:
            keypoints = torch.from_numpy(keypoints)
            return {'image': image, 'keypoints': keypoints}
        else:
            return {'image': image}
```

[89]:
```
batch_size = 64
valid_size = 0.3 # percentage of training set to use as validation

# Define a transform to normalize the data
tsfm_train = transforms.Compose([Rescale(205), RandomCrop(200), ToTensor()])
tsfm_test = transforms.Compose([ToTensor()])

print(KPT_TRAIN.shape)
# Load the training data and test data of FRONT view
trainset_front = KeypointsDataset(IMG_TRAIN, KPT_TRAIN, transform=tsfm_train)
testset_front = KeypointsDataset(IMG_TEST, None, train=False,␣
 ↪transform=tsfm_test)

# prepare data loaders for front view
train_loader_front, valid_loader_front =␣
 ↪prepare_train_valid_loaders(trainset_front, valid_size, batch_size)
test_loader_front = torch.utils.data.DataLoader(testset_front,␣
 ↪batch_size=batch_size)
```

```
(1000, 9, 2)
```

3.2 Prediction model setting

3.2.1 MLP model

[0]:
```
from torch import nn, optim
import torch.nn.functional as F

class MLP(nn.Module):
    def __init__(self, input_size, output_size, hidden_layers, drop_p =0.5):
        '''
        Buid a forward network with arbitrary hidden layers.
        Arguments
            ---------
            input_size (integer): size of the input layer
            output_size (integer): size of the output layer
            hidden_layers (list of integers):, the sizes of each hidden layers
        '''
        super(MLP, self).__init__()
        # hidden layers
        layer_sizes = [(input_size, hidden_layers[0])] \
                      + list(zip(hidden_layers[:-1], hidden_layers[1:]))
        self.hidden_layers = nn.ModuleList([nn.Linear(h1, h2) for h1, h2 in␣
 ↪layer_sizes])
        self.output = nn.Linear(hidden_layers[-1], output_size)
        self.dropout = nn.Dropout(drop_p)

    def forward(self, x):
        ''' Forward pass through the network, returns the output logits '''
        # flatten inputs
        x = x.view(x.shape[0], -1)
        for layer in self.hidden_layers:
            x = F.relu(layer(x))
            x = self.dropout(x)
        x = self.output(x)
        return x
```

[0]:
```
def train(train_loader, valid_loader, model, criterion, optimizer,
          n_epochs=50, saved_model='model.pt'):
    '''
    Train the model

    Args:
        train_loader (DataLoader): DataLoader for train Dataset
        valid_loader (DataLoader): DataLoader for valid Dataset
        model (nn.Module): model to be trained on
        criterion (torch.nn): loss funtion
```

```
        optimizer (torch.optim): optimization algorithms
        n_epochs (int): number of epochs to train the model
        saved_model (str): file path for saving model

    Return:
        tuple of train_losses, valid_losses
    '''

    # initialize tracker for minimum validation loss
    valid_loss_min = np.Inf # set initial "min" to infinity

    train_losses = []
    valid_losses = []

    for epoch in range(n_epochs):
        # monitor training loss
        train_loss = 0.0
        valid_loss = 0.0

        ###################
        # train the model #
        ###################
        model.train() # prep model for training
        for batch in train_loader:
            # clear the gradients of all optimized variables
            optimizer.zero_grad()
            # forward pass: compute predicted outputs by passing inputs to the␣
↪model
            output = model(batch['image'].to(device))
            # calculate the loss
            loss = criterion(output, batch['keypoints'].to(device))
            # backward pass: compute gradient of the loss with respect to model␣
↪parameters
            loss.backward()
            # perform a single optimization step (parameter update)
            optimizer.step()
            # update running training loss
            train_loss += loss.item()*batch['image'].size(0)

        ######################
        # validate the model #
        ######################
        model.eval() # prep model for evaluation
        for batch in valid_loader:
            # forward pass: compute predicted outputs by passing inputs to the␣
↪model
            output = model(batch['image'].to(device))
```

```
            # calculate the loss
            loss = criterion(output, batch['keypoints'].to(device))
            # update running validation loss
            valid_loss += loss.item()*batch['image'].size(0)

        # print training/validation statistics
        # calculate average Root Mean Square loss over an epoch
        train_loss = np.sqrt(train_loss/len(train_loader.sampler.indices))
        valid_loss = np.sqrt(valid_loss/len(valid_loader.sampler.indices))

        train_losses.append(train_loss)
        valid_losses.append(valid_loss)

        print('Epoch: {} \tTraining Loss: {:.6f} \tValidation Loss: {:.6f}'
              .format(epoch+1, train_loss, valid_loss))

        # save model if validation loss has decreased
        if valid_loss <= valid_loss_min:
            print('Validation loss decreased ({:.6f} --> {:.6f}).  Saving model␣
↪...'
                  .format(valid_loss_min, valid_loss))
            torch.save(model.state_dict(), saved_model)
            model_temp = model.state_dict()
            valid_loss_min = valid_loss
    return train_losses, valid_losses
```

[0]:
```
from torch import optim
device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')

def predict(data_loader, model):
    '''
    Predict keypoints
    Args:
        data_loader (DataLoader): DataLoader for Dataset
        model (nn.Module): trained model for prediction.
    Return:
        predictions (array-like): keypoints in float (no. of images x␣
↪keypoints).
    '''

    model.eval() # prep model for evaluation

    with torch.no_grad():
        for i, batch in enumerate(data_loader):
            # forward pass: compute predicted outputs by passing inputs to the␣
↪model
            output = model(batch['image'].to(device)).cpu().numpy()
```

```
            if i == 0:
                predictions = output
            else:
                predictions = np.vstack((predictions, output))

    return predictions
```

3.2.2 CNN model

[0]:
```
class CNN(nn.Module):
      def __init__(self, output_size):
        super(CNN, self).__init__()
        # 200 x 200
        self.conv1 = nn.Conv2d(1, 32, 5, padding=2)
        # (w-f)/s+1 = 200
        self.pool1 = nn.MaxPool2d(4, 4)
        # 50
        self.conv2 = nn.Conv2d(32, 64, 3, padding=2)
        # (54-3)/1 + 1 = 52
        self.pool2 = nn.MaxPool2d(2, 2)
        # 26
        self.conv3 = nn.Conv2d(64, 128, 3)
        # (26-3)/1 + 1 = 24
        self.pool3 = nn.MaxPool2d(2, 2)
        # 12
        self.conv4 = nn.Conv2d(128, 256, 3, stride=2)
        # (12-3)/2 + 1 = 5
        self.conv5 = nn.Conv2d(256, 512, 1)
        # (5-1)/1+1 = 5

        # Fully Connected Layer
        self.fc1 = nn.Linear(512*5*5, 1024)
        self.fc2 = nn.Linear(1024, output_size)
        self.drop1 = nn.Dropout(p=0.1)
        self.drop2 = nn.Dropout(p=0.25)
        self.drop3 = nn.Dropout(p=0.25)
        self.drop4 = nn.Dropout(p=0.25)
        self.drop5 = nn.Dropout(p=0.35)
        self.drop6 = nn.Dropout(p=0.4)

      def forward(self, x):
        x = self.pool1(F.relu(self.conv1(x)))
        x = self.drop1(x)
        x = self.pool2(F.relu(self.conv2(x)))
        x = self.drop2(x)
        x = self.pool3(F.relu(self.conv3(x)))
        x = self.drop3(x)
```

```
        x = F.relu(self.conv4(x))
        x = self.drop4(x)
        x = F.relu(self.conv5(x))
        x = self.drop5(x)
        x = x.view(x.size(0), -1)
        x = F.relu(self.fc1(x))
        x = self.drop6(x)
        x = self.fc2(x)
        return x
```

3.3 Train the model using CNN

The following parameters are chosen:

- Batch_size: 64
- Valid spiltp: 3/7
- Learning rate: 0.0005
- Number of epochs: 220
- With 5 conv-network and 2 full connect network and the matched parameters are shown above.

[94]:
```
model_front = CNN(output_size=18)
model_front = model_front.to(device)
criterion = nn.MSELoss()
optimizer = optim.Adam(model_front.parameters(), lr=0.0001)

train_losses, valid_losses = train(train_loader_front, valid_loader_front,
                   model_front, criterion, optimizer,
                   n_epochs=500,
                   saved_model=ROOT_FOLDER+'model_front.pt')
```

```
Epoch: 1        Training Loss: 0.090174         Validation Loss: 0.024724
Validation loss decreased (inf --> 0.024724).  Saving model ...
Epoch: 2        Training Loss: 0.041324         Validation Loss: 0.014640
Validation loss decreased (0.024724 --> 0.014640).  Saving model ...
Epoch: 3        Training Loss: 0.036031         Validation Loss: 0.016622
Epoch: 4        Training Loss: 0.033536         Validation Loss: 0.013995
Validation loss decreased (0.014640 --> 0.013995).  Saving model ...
Epoch: 5        Training Loss: 0.032273         Validation Loss: 0.015669
Epoch: 6        Training Loss: 0.031027         Validation Loss: 0.013902
Validation loss decreased (0.013995 --> 0.013902).  Saving model ...
Epoch: 7        Training Loss: 0.030036         Validation Loss: 0.015097
Epoch: 8        Training Loss: 0.029699         Validation Loss: 0.013928
Epoch: 9        Training Loss: 0.029263         Validation Loss: 0.014426
Epoch: 10       Training Loss: 0.028350         Validation Loss: 0.013540
Validation loss decreased (0.013902 --> 0.013540).  Saving model ...
Epoch: 11       Training Loss: 0.028272         Validation Loss: 0.014169
```

```
Epoch: 12       Training Loss: 0.027828         Validation Loss: 0.014340
Epoch: 13       Training Loss: 0.027156         Validation Loss: 0.013575
Epoch: 14       Training Loss: 0.026840         Validation Loss: 0.013410
Validation loss decreased (0.013540 --> 0.013410).  Saving model ...
Epoch: 15       Training Loss: 0.026603         Validation Loss: 0.013780
Epoch: 16       Training Loss: 0.025958         Validation Loss: 0.012912
Validation loss decreased (0.013410 --> 0.012912).  Saving model ...
Epoch: 17       Training Loss: 0.026353         Validation Loss: 0.012953
Epoch: 18       Training Loss: 0.025388         Validation Loss: 0.013403
Epoch: 19       Training Loss: 0.024885         Validation Loss: 0.012703
Validation loss decreased (0.012912 --> 0.012703).  Saving model ...
Epoch: 20       Training Loss: 0.024356         Validation Loss: 0.012414
Validation loss decreased (0.012703 --> 0.012414).  Saving model ...
Epoch: 21       Training Loss: 0.024120         Validation Loss: 0.013011
Epoch: 22       Training Loss: 0.023591         Validation Loss: 0.010592
Validation loss decreased (0.012414 --> 0.010592).  Saving model ...
Epoch: 23       Training Loss: 0.022983         Validation Loss: 0.010861
Epoch: 24       Training Loss: 0.022277         Validation Loss: 0.012299
Epoch: 25       Training Loss: 0.021718         Validation Loss: 0.008491
Validation loss decreased (0.010592 --> 0.008491).  Saving model ...
Epoch: 26       Training Loss: 0.021389         Validation Loss: 0.009709
Epoch: 27       Training Loss: 0.021387         Validation Loss: 0.010069
Epoch: 28       Training Loss: 0.020779         Validation Loss: 0.008425
Validation loss decreased (0.008491 --> 0.008425).  Saving model ...
Epoch: 29       Training Loss: 0.021055         Validation Loss: 0.011009
Epoch: 30       Training Loss: 0.020276         Validation Loss: 0.008334
Validation loss decreased (0.008425 --> 0.008334).  Saving model ...
Epoch: 31       Training Loss: 0.020951         Validation Loss: 0.008258
Validation loss decreased (0.008334 --> 0.008258).  Saving model ...
Epoch: 32       Training Loss: 0.020537         Validation Loss: 0.008800
Epoch: 33       Training Loss: 0.019983         Validation Loss: 0.007510
Validation loss decreased (0.008258 --> 0.007510).  Saving model ...
Epoch: 34       Training Loss: 0.019710         Validation Loss: 0.008639
Epoch: 35       Training Loss: 0.019834         Validation Loss: 0.007821
Epoch: 36       Training Loss: 0.019788         Validation Loss: 0.007805
Epoch: 37       Training Loss: 0.019807         Validation Loss: 0.009757
Epoch: 38       Training Loss: 0.019370         Validation Loss: 0.007758
Epoch: 39       Training Loss: 0.018948         Validation Loss: 0.007756
Epoch: 40       Training Loss: 0.019340         Validation Loss: 0.007457
Validation loss decreased (0.007510 --> 0.007457).  Saving model ...
Epoch: 41       Training Loss: 0.018778         Validation Loss: 0.007302
Validation loss decreased (0.007457 --> 0.007302).  Saving model ...
Epoch: 42       Training Loss: 0.018204         Validation Loss: 0.007117
Validation loss decreased (0.007302 --> 0.007117).  Saving model ...
Epoch: 43       Training Loss: 0.018493         Validation Loss: 0.007688
Epoch: 44       Training Loss: 0.018305         Validation Loss: 0.007261
Epoch: 45       Training Loss: 0.018224         Validation Loss: 0.007487
Epoch: 46       Training Loss: 0.018551         Validation Loss: 0.009125
```

```
Epoch: 47       Training Loss: 0.018309         Validation Loss: 0.007647
Epoch: 48       Training Loss: 0.018042         Validation Loss: 0.007923
Epoch: 49       Training Loss: 0.017956         Validation Loss: 0.007042
Validation loss decreased (0.007117 --> 0.007042).  Saving model ...
Epoch: 50       Training Loss: 0.017384         Validation Loss: 0.007827
Epoch: 51       Training Loss: 0.017352         Validation Loss: 0.007182
Epoch: 52       Training Loss: 0.017566         Validation Loss: 0.007119
Epoch: 53       Training Loss: 0.017133         Validation Loss: 0.007253
Epoch: 54       Training Loss: 0.017284         Validation Loss: 0.007198
Epoch: 55       Training Loss: 0.016785         Validation Loss: 0.006772
Validation loss decreased (0.007042 --> 0.006772).  Saving model ...
Epoch: 56       Training Loss: 0.017025         Validation Loss: 0.007095
Epoch: 57       Training Loss: 0.016674         Validation Loss: 0.007663
Epoch: 58       Training Loss: 0.016505         Validation Loss: 0.006970
Epoch: 59       Training Loss: 0.016634         Validation Loss: 0.007093
Epoch: 60       Training Loss: 0.016583         Validation Loss: 0.008366
Epoch: 61       Training Loss: 0.017272         Validation Loss: 0.007711
Epoch: 62       Training Loss: 0.016525         Validation Loss: 0.006853
Epoch: 63       Training Loss: 0.016504         Validation Loss: 0.007467
Epoch: 64       Training Loss: 0.016168         Validation Loss: 0.006736
Validation loss decreased (0.006772 --> 0.006736).  Saving model ...
Epoch: 65       Training Loss: 0.016652         Validation Loss: 0.006978
Epoch: 66       Training Loss: 0.016557         Validation Loss: 0.006973
Epoch: 67       Training Loss: 0.016826         Validation Loss: 0.008958
Epoch: 68       Training Loss: 0.016022         Validation Loss: 0.007444
Epoch: 69       Training Loss: 0.015627         Validation Loss: 0.006779
Epoch: 70       Training Loss: 0.016162         Validation Loss: 0.006627
Validation loss decreased (0.006736 --> 0.006627).  Saving model ...
Epoch: 71       Training Loss: 0.015883         Validation Loss: 0.006797
Epoch: 72       Training Loss: 0.015695         Validation Loss: 0.006746
Epoch: 73       Training Loss: 0.015656         Validation Loss: 0.007973
Epoch: 74       Training Loss: 0.015454         Validation Loss: 0.006728
Epoch: 75       Training Loss: 0.015199         Validation Loss: 0.006793
Epoch: 76       Training Loss: 0.015621         Validation Loss: 0.006481
Validation loss decreased (0.006627 --> 0.006481).  Saving model ...
Epoch: 77       Training Loss: 0.015044         Validation Loss: 0.007498
Epoch: 78       Training Loss: 0.014969         Validation Loss: 0.008367
Epoch: 79       Training Loss: 0.015354         Validation Loss: 0.006917
Epoch: 80       Training Loss: 0.015635         Validation Loss: 0.007364
Epoch: 81       Training Loss: 0.015357         Validation Loss: 0.006573
Epoch: 82       Training Loss: 0.015190         Validation Loss: 0.006295
Validation loss decreased (0.006481 --> 0.006295).  Saving model ...
Epoch: 83       Training Loss: 0.014701         Validation Loss: 0.006500
Epoch: 84       Training Loss: 0.015043         Validation Loss: 0.006536
Epoch: 85       Training Loss: 0.014860         Validation Loss: 0.006187
Validation loss decreased (0.006295 --> 0.006187).  Saving model ...
Epoch: 86       Training Loss: 0.014540         Validation Loss: 0.006923
Epoch: 87       Training Loss: 0.014908         Validation Loss: 0.006545
```

```
Epoch: 88       Training Loss: 0.014466         Validation Loss: 0.006841
Epoch: 89       Training Loss: 0.014617         Validation Loss: 0.007949
Epoch: 90       Training Loss: 0.014834         Validation Loss: 0.006223
Epoch: 91       Training Loss: 0.014633         Validation Loss: 0.007552
Epoch: 92       Training Loss: 0.015067         Validation Loss: 0.006965
Epoch: 93       Training Loss: 0.014163         Validation Loss: 0.007690
Epoch: 94       Training Loss: 0.014347         Validation Loss: 0.006012
Validation loss decreased (0.006187 --> 0.006012).  Saving model ...
Epoch: 95       Training Loss: 0.014473         Validation Loss: 0.006184
Epoch: 96       Training Loss: 0.013646         Validation Loss: 0.006463
Epoch: 97       Training Loss: 0.014236         Validation Loss: 0.005972
Validation loss decreased (0.006012 --> 0.005972).  Saving model ...
Epoch: 98       Training Loss: 0.013677         Validation Loss: 0.007576
Epoch: 99       Training Loss: 0.014286         Validation Loss: 0.005847
Validation loss decreased (0.005972 --> 0.005847).  Saving model ...
Epoch: 100      Training Loss: 0.014247         Validation Loss: 0.006224
Epoch: 101      Training Loss: 0.013756         Validation Loss: 0.005935
Epoch: 102      Training Loss: 0.013898         Validation Loss: 0.007692
Epoch: 103      Training Loss: 0.013983         Validation Loss: 0.006247
Epoch: 104      Training Loss: 0.013915         Validation Loss: 0.006381
Epoch: 105      Training Loss: 0.013808         Validation Loss: 0.006087
Epoch: 106      Training Loss: 0.013574         Validation Loss: 0.007065
Epoch: 107      Training Loss: 0.014452         Validation Loss: 0.007322
Epoch: 108      Training Loss: 0.013241         Validation Loss: 0.005918
Epoch: 109      Training Loss: 0.013938         Validation Loss: 0.005767
Validation loss decreased (0.005847 --> 0.005767).  Saving model ...
Epoch: 110      Training Loss: 0.013490         Validation Loss: 0.005709
Validation loss decreased (0.005767 --> 0.005709).  Saving model ...
Epoch: 111      Training Loss: 0.013961         Validation Loss: 0.005880
Epoch: 112      Training Loss: 0.013469         Validation Loss: 0.005644
Validation loss decreased (0.005709 --> 0.005644).  Saving model ...
Epoch: 113      Training Loss: 0.013574         Validation Loss: 0.006866
Epoch: 114      Training Loss: 0.013797         Validation Loss: 0.005664
Epoch: 115      Training Loss: 0.013583         Validation Loss: 0.007513
Epoch: 116      Training Loss: 0.013691         Validation Loss: 0.006337
Epoch: 117      Training Loss: 0.013136         Validation Loss: 0.005665
Epoch: 118      Training Loss: 0.013377         Validation Loss: 0.006067
Epoch: 119      Training Loss: 0.012863         Validation Loss: 0.006009
Epoch: 120      Training Loss: 0.013676         Validation Loss: 0.006095
Epoch: 121      Training Loss: 0.013404         Validation Loss: 0.006086
Epoch: 122      Training Loss: 0.013452         Validation Loss: 0.005819
Epoch: 123      Training Loss: 0.012807         Validation Loss: 0.009341
Epoch: 124      Training Loss: 0.013660         Validation Loss: 0.005525
Validation loss decreased (0.005644 --> 0.005525).  Saving model ...
Epoch: 125      Training Loss: 0.012806         Validation Loss: 0.005940
Epoch: 126      Training Loss: 0.013352         Validation Loss: 0.006491
Epoch: 127      Training Loss: 0.012644         Validation Loss: 0.005567
Epoch: 128      Training Loss: 0.012584         Validation Loss: 0.005334
```

```
Validation loss decreased (0.005525 --> 0.005334).  Saving model ...
Epoch: 129      Training Loss: 0.012853         Validation Loss: 0.005432
Epoch: 130      Training Loss: 0.013288         Validation Loss: 0.005301
Validation loss decreased (0.005334 --> 0.005301).  Saving model ...
Epoch: 131      Training Loss: 0.012833         Validation Loss: 0.005399
Epoch: 132      Training Loss: 0.012849         Validation Loss: 0.005460
Epoch: 133      Training Loss: 0.012917         Validation Loss: 0.005996
Epoch: 134      Training Loss: 0.013406         Validation Loss: 0.006640
Epoch: 135      Training Loss: 0.012796         Validation Loss: 0.005121
Validation loss decreased (0.005301 --> 0.005121).  Saving model ...
Epoch: 136      Training Loss: 0.012634         Validation Loss: 0.007272
Epoch: 137      Training Loss: 0.012909         Validation Loss: 0.005734
Epoch: 138      Training Loss: 0.012783         Validation Loss: 0.005223
Epoch: 139      Training Loss: 0.013103         Validation Loss: 0.006479
Epoch: 140      Training Loss: 0.012777         Validation Loss: 0.005235
Epoch: 141      Training Loss: 0.012592         Validation Loss: 0.006889
Epoch: 142      Training Loss: 0.012651         Validation Loss: 0.004776
Validation loss decreased (0.005121 --> 0.004776).  Saving model ...
Epoch: 143      Training Loss: 0.012449         Validation Loss: 0.005242
Epoch: 144      Training Loss: 0.012125         Validation Loss: 0.006304
Epoch: 145      Training Loss: 0.011872         Validation Loss: 0.004916
Epoch: 146      Training Loss: 0.012366         Validation Loss: 0.004962
Epoch: 147      Training Loss: 0.012140         Validation Loss: 0.005127
Epoch: 148      Training Loss: 0.012338         Validation Loss: 0.005325
Epoch: 149      Training Loss: 0.012404         Validation Loss: 0.004673
Validation loss decreased (0.004776 --> 0.004673).  Saving model ...
Epoch: 150      Training Loss: 0.012923         Validation Loss: 0.006817
Epoch: 151      Training Loss: 0.012327         Validation Loss: 0.005090
Epoch: 152      Training Loss: 0.011961         Validation Loss: 0.005793
Epoch: 153      Training Loss: 0.012217         Validation Loss: 0.005190
Epoch: 154      Training Loss: 0.012459         Validation Loss: 0.004946
Epoch: 155      Training Loss: 0.012376         Validation Loss: 0.004761
Epoch: 156      Training Loss: 0.012261         Validation Loss: 0.005728
Epoch: 157      Training Loss: 0.012535         Validation Loss: 0.007615
Epoch: 158      Training Loss: 0.012407         Validation Loss: 0.005525
Epoch: 159      Training Loss: 0.012602         Validation Loss: 0.008071
Epoch: 160      Training Loss: 0.012510         Validation Loss: 0.004853
Epoch: 161      Training Loss: 0.011931         Validation Loss: 0.004837
Epoch: 162      Training Loss: 0.011866         Validation Loss: 0.005210
Epoch: 163      Training Loss: 0.012271         Validation Loss: 0.005692
Epoch: 164      Training Loss: 0.011450         Validation Loss: 0.005542
Epoch: 165      Training Loss: 0.011873         Validation Loss: 0.005047
Epoch: 166      Training Loss: 0.012351         Validation Loss: 0.004727
Epoch: 167      Training Loss: 0.011401         Validation Loss: 0.004851
Epoch: 168      Training Loss: 0.012318         Validation Loss: 0.007487
Epoch: 169      Training Loss: 0.011749         Validation Loss: 0.004705
Epoch: 170      Training Loss: 0.011877         Validation Loss: 0.004904
Epoch: 171      Training Loss: 0.011622         Validation Loss: 0.005338
```

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Epoch: 172      Training Loss: 0.011835         Validation Loss: 0.004643
Validation loss decreased (0.004673 --> 0.004643).  Saving model ...
Epoch: 173      Training Loss: 0.012044         Validation Loss: 0.005594
Epoch: 174      Training Loss: 0.012463         Validation Loss: 0.005663
Epoch: 175      Training Loss: 0.011348         Validation Loss: 0.005718
Epoch: 176      Training Loss: 0.011533         Validation Loss: 0.004886
Epoch: 177      Training Loss: 0.012089         Validation Loss: 0.005196
Epoch: 178      Training Loss: 0.012154         Validation Loss: 0.004798
Epoch: 179      Training Loss: 0.011965         Validation Loss: 0.007128
Epoch: 180      Training Loss: 0.010996         Validation Loss: 0.004694
Epoch: 181      Training Loss: 0.012448         Validation Loss: 0.006228
Epoch: 182      Training Loss: 0.012386         Validation Loss: 0.007564
Epoch: 183      Training Loss: 0.011686         Validation Loss: 0.005121
Epoch: 184      Training Loss: 0.011206         Validation Loss: 0.004639
Validation loss decreased (0.004643 --> 0.004639).  Saving model ...
Epoch: 185      Training Loss: 0.011232         Validation Loss: 0.004726
Epoch: 186      Training Loss: 0.011536         Validation Loss: 0.005534
Epoch: 187      Training Loss: 0.011282         Validation Loss: 0.006088
Epoch: 188      Training Loss: 0.011690         Validation Loss: 0.006342
Epoch: 189      Training Loss: 0.011357         Validation Loss: 0.004693
Epoch: 190      Training Loss: 0.011363         Validation Loss: 0.005146
Epoch: 191      Training Loss: 0.010912         Validation Loss: 0.004416
Validation loss decreased (0.004639 --> 0.004416).  Saving model ...
Epoch: 192      Training Loss: 0.011341         Validation Loss: 0.005211
Epoch: 193      Training Loss: 0.011183         Validation Loss: 0.005418
Epoch: 194      Training Loss: 0.011540         Validation Loss: 0.004732
Epoch: 195      Training Loss: 0.011186         Validation Loss: 0.004660
Epoch: 196      Training Loss: 0.011310         Validation Loss: 0.004407
Validation loss decreased (0.004416 --> 0.004407).  Saving model ...
Epoch: 197      Training Loss: 0.011149         Validation Loss: 0.005201
Epoch: 198      Training Loss: 0.011221         Validation Loss: 0.004078
Validation loss decreased (0.004407 --> 0.004078).  Saving model ...
Epoch: 199      Training Loss: 0.011132         Validation Loss: 0.004973
Epoch: 200      Training Loss: 0.012148         Validation Loss: 0.007206
Epoch: 201      Training Loss: 0.011640         Validation Loss: 0.006658
Epoch: 202      Training Loss: 0.011103         Validation Loss: 0.005051
Epoch: 203      Training Loss: 0.011498         Validation Loss: 0.004801
Epoch: 204      Training Loss: 0.011105         Validation Loss: 0.005983
Epoch: 205      Training Loss: 0.011484         Validation Loss: 0.005264
Epoch: 206      Training Loss: 0.011347         Validation Loss: 0.004462
Epoch: 207      Training Loss: 0.011391         Validation Loss: 0.004816
Epoch: 208      Training Loss: 0.010959         Validation Loss: 0.004412
Epoch: 209      Training Loss: 0.010908         Validation Loss: 0.004342
Epoch: 210      Training Loss: 0.010748         Validation Loss: 0.004335
Epoch: 211      Training Loss: 0.011365         Validation Loss: 0.007130
Epoch: 212      Training Loss: 0.011237         Validation Loss: 0.007530
Epoch: 213      Training Loss: 0.010859         Validation Loss: 0.004933
Epoch: 214      Training Loss: 0.010533         Validation Loss: 0.006997
```

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Epoch: 215      Training Loss: 0.010971         Validation Loss: 0.004262
Epoch: 216      Training Loss: 0.011521         Validation Loss: 0.007979
Epoch: 217      Training Loss: 0.011159         Validation Loss: 0.007150
Epoch: 218      Training Loss: 0.011538         Validation Loss: 0.003885
Validation loss decreased (0.004078 --> 0.003885).  Saving model ...
Epoch: 219      Training Loss: 0.011203         Validation Loss: 0.004142
Epoch: 220      Training Loss: 0.010615         Validation Loss: 0.004941
Epoch: 221      Training Loss: 0.010799         Validation Loss: 0.005884
Epoch: 222      Training Loss: 0.010639         Validation Loss: 0.004162
Epoch: 223      Training Loss: 0.010630         Validation Loss: 0.004626
Epoch: 224      Training Loss: 0.010486         Validation Loss: 0.007393
Epoch: 225      Training Loss: 0.010964         Validation Loss: 0.004949
Epoch: 226      Training Loss: 0.010614         Validation Loss: 0.005383
Epoch: 227      Training Loss: 0.010786         Validation Loss: 0.005796
Epoch: 228      Training Loss: 0.010845         Validation Loss: 0.005446
Epoch: 229      Training Loss: 0.011058         Validation Loss: 0.004430
Epoch: 230      Training Loss: 0.011012         Validation Loss: 0.004630
Epoch: 231      Training Loss: 0.011095         Validation Loss: 0.006834
Epoch: 232      Training Loss: 0.010877         Validation Loss: 0.007265
Epoch: 233      Training Loss: 0.011292         Validation Loss: 0.004856
Epoch: 234      Training Loss: 0.012161         Validation Loss: 0.009983
Epoch: 235      Training Loss: 0.011498         Validation Loss: 0.004090
Epoch: 236      Training Loss: 0.010992         Validation Loss: 0.007590
Epoch: 237      Training Loss: 0.010499         Validation Loss: 0.005826
Epoch: 238      Training Loss: 0.010155         Validation Loss: 0.005156
Epoch: 239      Training Loss: 0.010726         Validation Loss: 0.005320
Epoch: 240      Training Loss: 0.010714         Validation Loss: 0.004335
Epoch: 241      Training Loss: 0.011117         Validation Loss: 0.009608
Epoch: 242      Training Loss: 0.011423         Validation Loss: 0.004174
Epoch: 243      Training Loss: 0.010690         Validation Loss: 0.006830
Epoch: 244      Training Loss: 0.010555         Validation Loss: 0.004530
Epoch: 245      Training Loss: 0.010909         Validation Loss: 0.005726
Epoch: 246      Training Loss: 0.010534         Validation Loss: 0.003712
Validation loss decreased (0.003885 --> 0.003712).  Saving model ...
Epoch: 247      Training Loss: 0.010724         Validation Loss: 0.009592
Epoch: 248      Training Loss: 0.010473         Validation Loss: 0.004515
Epoch: 249      Training Loss: 0.011602         Validation Loss: 0.004433
Epoch: 250      Training Loss: 0.010739         Validation Loss: 0.005368
Epoch: 251      Training Loss: 0.010218         Validation Loss: 0.004833
Epoch: 252      Training Loss: 0.010141         Validation Loss: 0.004915
Epoch: 253      Training Loss: 0.010311         Validation Loss: 0.007475
Epoch: 254      Training Loss: 0.010222         Validation Loss: 0.005745
Epoch: 255      Training Loss: 0.010516         Validation Loss: 0.005640
Epoch: 256      Training Loss: 0.010313         Validation Loss: 0.004154
Epoch: 257      Training Loss: 0.010042         Validation Loss: 0.007480
Epoch: 258      Training Loss: 0.010740         Validation Loss: 0.004375
Epoch: 259      Training Loss: 0.010617         Validation Loss: 0.006842
Epoch: 260      Training Loss: 0.010218         Validation Loss: 0.004227
```

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Epoch: 261      Training Loss: 0.010180         Validation Loss: 0.005058
Epoch: 262      Training Loss: 0.010185         Validation Loss: 0.003923
Epoch: 263      Training Loss: 0.009803         Validation Loss: 0.006099
Epoch: 264      Training Loss: 0.010242         Validation Loss: 0.005686
Epoch: 265      Training Loss: 0.010136         Validation Loss: 0.004096
Epoch: 266      Training Loss: 0.009961         Validation Loss: 0.004604
Epoch: 267      Training Loss: 0.010235         Validation Loss: 0.005083
Epoch: 268      Training Loss: 0.010195         Validation Loss: 0.006619
Epoch: 269      Training Loss: 0.009806         Validation Loss: 0.004527
Epoch: 270      Training Loss: 0.010171         Validation Loss: 0.006489
Epoch: 271      Training Loss: 0.010424         Validation Loss: 0.005547
Epoch: 272      Training Loss: 0.009936         Validation Loss: 0.005215
Epoch: 273      Training Loss: 0.009975         Validation Loss: 0.004148
Epoch: 274      Training Loss: 0.010166         Validation Loss: 0.006285
Epoch: 275      Training Loss: 0.010463         Validation Loss: 0.004422
Epoch: 276      Training Loss: 0.010645         Validation Loss: 0.006096
Epoch: 277      Training Loss: 0.010344         Validation Loss: 0.007042
Epoch: 278      Training Loss: 0.010309         Validation Loss: 0.003828
Epoch: 279      Training Loss: 0.010151         Validation Loss: 0.004518
Epoch: 280      Training Loss: 0.010226         Validation Loss: 0.007048
Epoch: 281      Training Loss: 0.010841         Validation Loss: 0.004254
Epoch: 282      Training Loss: 0.010057         Validation Loss: 0.003773
Epoch: 283      Training Loss: 0.009887         Validation Loss: 0.006066
Epoch: 284      Training Loss: 0.010330         Validation Loss: 0.004194
Epoch: 285      Training Loss: 0.009846         Validation Loss: 0.006193
Epoch: 286      Training Loss: 0.010105         Validation Loss: 0.003612
Validation loss decreased (0.003712 --> 0.003612).  Saving model ...
Epoch: 287      Training Loss: 0.009944         Validation Loss: 0.003953
Epoch: 288      Training Loss: 0.009852         Validation Loss: 0.005473
Epoch: 289      Training Loss: 0.010121         Validation Loss: 0.006094
Epoch: 290      Training Loss: 0.010480         Validation Loss: 0.005064
Epoch: 291      Training Loss: 0.010115         Validation Loss: 0.006049
Epoch: 292      Training Loss: 0.010510         Validation Loss: 0.004988
Epoch: 293      Training Loss: 0.010192         Validation Loss: 0.003962
Epoch: 294      Training Loss: 0.009525         Validation Loss: 0.004819
Epoch: 295      Training Loss: 0.009721         Validation Loss: 0.003797
Epoch: 296      Training Loss: 0.009460         Validation Loss: 0.004400
Epoch: 297      Training Loss: 0.010071         Validation Loss: 0.006559
Epoch: 298      Training Loss: 0.010050         Validation Loss: 0.004062
Epoch: 299      Training Loss: 0.009941         Validation Loss: 0.006218
Epoch: 300      Training Loss: 0.010170         Validation Loss: 0.004086
Epoch: 301      Training Loss: 0.009817         Validation Loss: 0.006070
Epoch: 302      Training Loss: 0.009705         Validation Loss: 0.005801
Epoch: 303      Training Loss: 0.009436         Validation Loss: 0.004760
Epoch: 304      Training Loss: 0.009870         Validation Loss: 0.004258
Epoch: 305      Training Loss: 0.009857         Validation Loss: 0.006072
Epoch: 306      Training Loss: 0.010122         Validation Loss: 0.004927
Epoch: 307      Training Loss: 0.010135         Validation Loss: 0.003436
```

```
Validation loss decreased (0.003612 --> 0.003436).  Saving model ...
Epoch: 308      Training Loss: 0.009995         Validation Loss: 0.006233
Epoch: 309      Training Loss: 0.009902         Validation Loss: 0.006882
Epoch: 310      Training Loss: 0.009743         Validation Loss: 0.004729
Epoch: 311      Training Loss: 0.009896         Validation Loss: 0.008122
Epoch: 312      Training Loss: 0.010282         Validation Loss: 0.003902
Epoch: 313      Training Loss: 0.009926         Validation Loss: 0.007397
Epoch: 314      Training Loss: 0.009606         Validation Loss: 0.003604
Epoch: 315      Training Loss: 0.009541         Validation Loss: 0.007494
Epoch: 316      Training Loss: 0.009580         Validation Loss: 0.005361
Epoch: 317      Training Loss: 0.009602         Validation Loss: 0.004624
Epoch: 318      Training Loss: 0.010287         Validation Loss: 0.009856
Epoch: 319      Training Loss: 0.009863         Validation Loss: 0.004906
Epoch: 320      Training Loss: 0.009228         Validation Loss: 0.005385
Epoch: 321      Training Loss: 0.009808         Validation Loss: 0.007297
Epoch: 322      Training Loss: 0.009878         Validation Loss: 0.004398
Epoch: 323      Training Loss: 0.009853         Validation Loss: 0.004129
Epoch: 324      Training Loss: 0.009428         Validation Loss: 0.003685
Epoch: 325      Training Loss: 0.009444         Validation Loss: 0.003740
Epoch: 326      Training Loss: 0.009870         Validation Loss: 0.008396
Epoch: 327      Training Loss: 0.009916         Validation Loss: 0.005017
Epoch: 328      Training Loss: 0.009245         Validation Loss: 0.007278
Epoch: 329      Training Loss: 0.009556         Validation Loss: 0.004679
Epoch: 330      Training Loss: 0.009717         Validation Loss: 0.004890
Epoch: 331      Training Loss: 0.009794         Validation Loss: 0.006080
Epoch: 332      Training Loss: 0.009488         Validation Loss: 0.006454
Epoch: 333      Training Loss: 0.009616         Validation Loss: 0.006243
Epoch: 334      Training Loss: 0.009537         Validation Loss: 0.004327
Epoch: 335      Training Loss: 0.009368         Validation Loss: 0.005644
Epoch: 336      Training Loss: 0.009267         Validation Loss: 0.006527
Epoch: 337      Training Loss: 0.009786         Validation Loss: 0.003556
Epoch: 338      Training Loss: 0.009951         Validation Loss: 0.003682
Epoch: 339      Training Loss: 0.009381         Validation Loss: 0.006022
Epoch: 340      Training Loss: 0.009676         Validation Loss: 0.004487
Epoch: 341      Training Loss: 0.009758         Validation Loss: 0.003575
Epoch: 342      Training Loss: 0.010685         Validation Loss: 0.009163
Epoch: 343      Training Loss: 0.010113         Validation Loss: 0.003742
Epoch: 344      Training Loss: 0.009685         Validation Loss: 0.004670
Epoch: 345      Training Loss: 0.009707         Validation Loss: 0.005450
Epoch: 346      Training Loss: 0.009662         Validation Loss: 0.004033
Epoch: 347      Training Loss: 0.009598         Validation Loss: 0.006523
Epoch: 348      Training Loss: 0.008929         Validation Loss: 0.004687
Epoch: 349      Training Loss: 0.009131         Validation Loss: 0.005113
Epoch: 350      Training Loss: 0.009249         Validation Loss: 0.003805
Epoch: 351      Training Loss: 0.009078         Validation Loss: 0.003828
Epoch: 352      Training Loss: 0.008979         Validation Loss: 0.004827
Epoch: 353      Training Loss: 0.009380         Validation Loss: 0.005859
Epoch: 354      Training Loss: 0.009415         Validation Loss: 0.004830
```

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Epoch: 355      Training Loss: 0.009642         Validation Loss: 0.004005
Epoch: 356      Training Loss: 0.009613         Validation Loss: 0.006443
Epoch: 357      Training Loss: 0.009394         Validation Loss: 0.004462
Epoch: 358      Training Loss: 0.009264         Validation Loss: 0.004705
Epoch: 359      Training Loss: 0.009556         Validation Loss: 0.006988
Epoch: 360      Training Loss: 0.009448         Validation Loss: 0.004911
Epoch: 361      Training Loss: 0.009470         Validation Loss: 0.005612
Epoch: 362      Training Loss: 0.009265         Validation Loss: 0.003406
Validation loss decreased (0.003436 --> 0.003406).  Saving model ...
Epoch: 363      Training Loss: 0.009419         Validation Loss: 0.006743
Epoch: 364      Training Loss: 0.009007         Validation Loss: 0.004938
Epoch: 365      Training Loss: 0.009174         Validation Loss: 0.006790
Epoch: 366      Training Loss: 0.009107         Validation Loss: 0.004735
Epoch: 367      Training Loss: 0.009472         Validation Loss: 0.004173
Epoch: 368      Training Loss: 0.009251         Validation Loss: 0.005986
Epoch: 369      Training Loss: 0.009043         Validation Loss: 0.004953
Epoch: 370      Training Loss: 0.009113         Validation Loss: 0.005088
Epoch: 371      Training Loss: 0.009010         Validation Loss: 0.005626
Epoch: 372      Training Loss: 0.009118         Validation Loss: 0.003384
Validation loss decreased (0.003406 --> 0.003384).  Saving model ...
Epoch: 373      Training Loss: 0.009297         Validation Loss: 0.005182
Epoch: 374      Training Loss: 0.009222         Validation Loss: 0.005053
Epoch: 375      Training Loss: 0.009381         Validation Loss: 0.005956
Epoch: 376      Training Loss: 0.008977         Validation Loss: 0.006828
Epoch: 377      Training Loss: 0.009038         Validation Loss: 0.004731
Epoch: 378      Training Loss: 0.009313         Validation Loss: 0.005340
Epoch: 379      Training Loss: 0.009004         Validation Loss: 0.006963
Epoch: 380      Training Loss: 0.010293         Validation Loss: 0.003788
Epoch: 381      Training Loss: 0.009406         Validation Loss: 0.007204
Epoch: 382      Training Loss: 0.009222         Validation Loss: 0.004090
Epoch: 383      Training Loss: 0.009044         Validation Loss: 0.007854
Epoch: 384      Training Loss: 0.009520         Validation Loss: 0.004386
Epoch: 385      Training Loss: 0.009124         Validation Loss: 0.005869
Epoch: 386      Training Loss: 0.008955         Validation Loss: 0.004407
Epoch: 387      Training Loss: 0.009164         Validation Loss: 0.004975
Epoch: 388      Training Loss: 0.009127         Validation Loss: 0.004293
Epoch: 389      Training Loss: 0.008919         Validation Loss: 0.005385
Epoch: 390      Training Loss: 0.008931         Validation Loss: 0.004568
Epoch: 391      Training Loss: 0.009145         Validation Loss: 0.008395
Epoch: 392      Training Loss: 0.009507         Validation Loss: 0.003372
Validation loss decreased (0.003384 --> 0.003372).  Saving model ...
Epoch: 393      Training Loss: 0.009060         Validation Loss: 0.008246
Epoch: 394      Training Loss: 0.009083         Validation Loss: 0.004593
Epoch: 395      Training Loss: 0.009076         Validation Loss: 0.005719
Epoch: 396      Training Loss: 0.008664         Validation Loss: 0.006119
Epoch: 397      Training Loss: 0.008872         Validation Loss: 0.004048
Epoch: 398      Training Loss: 0.008991         Validation Loss: 0.005367
Epoch: 399      Training Loss: 0.008534         Validation Loss: 0.004016
```

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Epoch: 400      Training Loss: 0.008719         Validation Loss: 0.004427
Epoch: 401      Training Loss: 0.009233         Validation Loss: 0.003559
Epoch: 402      Training Loss: 0.008988         Validation Loss: 0.005059
Epoch: 403      Training Loss: 0.009036         Validation Loss: 0.007836
Epoch: 404      Training Loss: 0.009564         Validation Loss: 0.005335
Epoch: 405      Training Loss: 0.008670         Validation Loss: 0.003953
Epoch: 406      Training Loss: 0.008685         Validation Loss: 0.008051
Epoch: 407      Training Loss: 0.008792         Validation Loss: 0.003641
Epoch: 408      Training Loss: 0.009285         Validation Loss: 0.005144
Epoch: 409      Training Loss: 0.008806         Validation Loss: 0.005120
Epoch: 410      Training Loss: 0.008783         Validation Loss: 0.004590
Epoch: 411      Training Loss: 0.009250         Validation Loss: 0.006735
Epoch: 412      Training Loss: 0.009107         Validation Loss: 0.004467
Epoch: 413      Training Loss: 0.008992         Validation Loss: 0.003733
Epoch: 414      Training Loss: 0.008910         Validation Loss: 0.003963
Epoch: 415      Training Loss: 0.009130         Validation Loss: 0.008706
Epoch: 416      Training Loss: 0.008732         Validation Loss: 0.006350
Epoch: 417      Training Loss: 0.009055         Validation Loss: 0.004497
Epoch: 418      Training Loss: 0.008636         Validation Loss: 0.006141
Epoch: 419      Training Loss: 0.009013         Validation Loss: 0.005323
Epoch: 420      Training Loss: 0.008382         Validation Loss: 0.004411
Epoch: 421      Training Loss: 0.008747         Validation Loss: 0.005595
Epoch: 422      Training Loss: 0.008781         Validation Loss: 0.003723
Epoch: 423      Training Loss: 0.008988         Validation Loss: 0.004199
Epoch: 424      Training Loss: 0.008564         Validation Loss: 0.007167
Epoch: 425      Training Loss: 0.008676         Validation Loss: 0.006697
Epoch: 426      Training Loss: 0.008733         Validation Loss: 0.006208
Epoch: 427      Training Loss: 0.008377         Validation Loss: 0.005975
Epoch: 428      Training Loss: 0.008717         Validation Loss: 0.005519
Epoch: 429      Training Loss: 0.009004         Validation Loss: 0.003588
Epoch: 430      Training Loss: 0.009132         Validation Loss: 0.008587
Epoch: 431      Training Loss: 0.009103         Validation Loss: 0.004324
Epoch: 432      Training Loss: 0.008635         Validation Loss: 0.007321
Epoch: 433      Training Loss: 0.009008         Validation Loss: 0.004315
Epoch: 434      Training Loss: 0.008575         Validation Loss: 0.004161
Epoch: 435      Training Loss: 0.008905         Validation Loss: 0.004485
Epoch: 436      Training Loss: 0.008820         Validation Loss: 0.007955
Epoch: 437      Training Loss: 0.008925         Validation Loss: 0.006659
Epoch: 438      Training Loss: 0.008657         Validation Loss: 0.004735
Epoch: 439      Training Loss: 0.008911         Validation Loss: 0.006945
Epoch: 440      Training Loss: 0.009082         Validation Loss: 0.006913
Epoch: 441      Training Loss: 0.008927         Validation Loss: 0.003268
Validation loss decreased (0.003372 --> 0.003268).  Saving model ...
Epoch: 442      Training Loss: 0.008747         Validation Loss: 0.004709
Epoch: 443      Training Loss: 0.008813         Validation Loss: 0.005770
Epoch: 444      Training Loss: 0.008617         Validation Loss: 0.003785
Epoch: 445      Training Loss: 0.008868         Validation Loss: 0.007179
Epoch: 446      Training Loss: 0.008368         Validation Loss: 0.004114
```

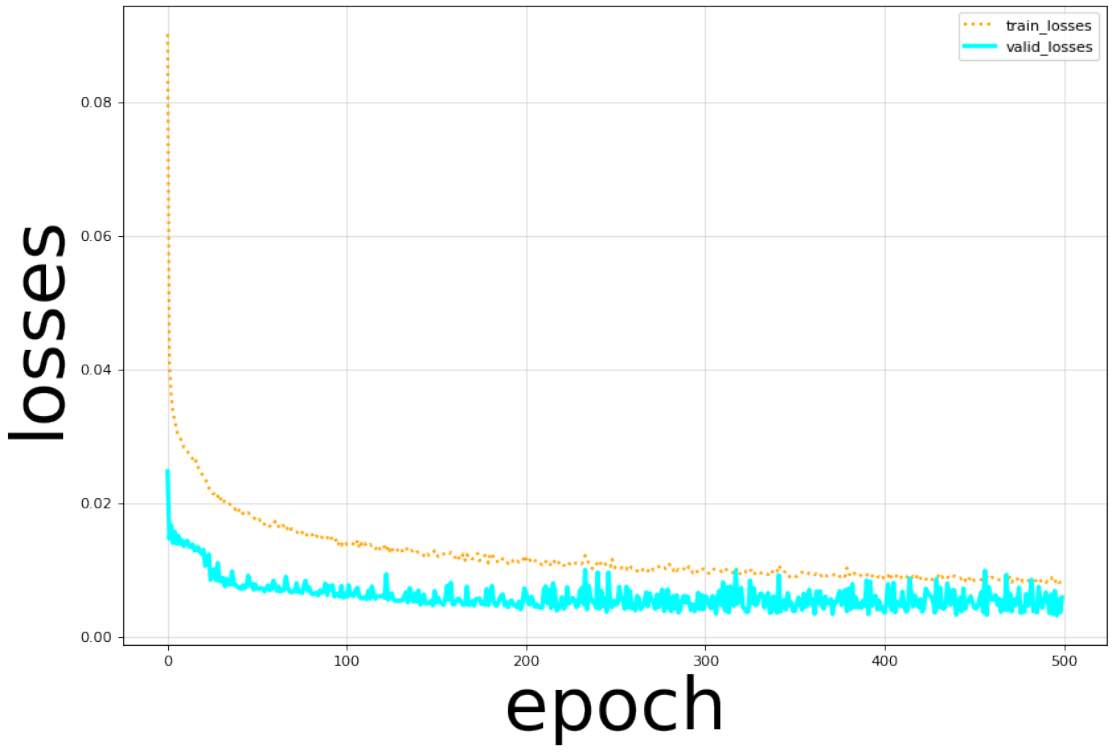
```
Epoch: 447      Training Loss: 0.009047         Validation Loss: 0.005411
Epoch: 448      Training Loss: 0.008784         Validation Loss: 0.005185
Epoch: 449      Training Loss: 0.008592         Validation Loss: 0.006026
Epoch: 450      Training Loss: 0.008934         Validation Loss: 0.005252
Epoch: 451      Training Loss: 0.008361         Validation Loss: 0.004367
Epoch: 452      Training Loss: 0.008424         Validation Loss: 0.004202
Epoch: 453      Training Loss: 0.008503         Validation Loss: 0.004560
Epoch: 454      Training Loss: 0.008525         Validation Loss: 0.005656
Epoch: 455      Training Loss: 0.008519         Validation Loss: 0.006674
Epoch: 456      Training Loss: 0.008608         Validation Loss: 0.003695
Epoch: 457      Training Loss: 0.009016         Validation Loss: 0.009855
Epoch: 458      Training Loss: 0.008880         Validation Loss: 0.003246
Validation loss decreased (0.003268 --> 0.003246).  Saving model ...
Epoch: 459      Training Loss: 0.009229         Validation Loss: 0.007493
Epoch: 460      Training Loss: 0.008814         Validation Loss: 0.006278
Epoch: 461      Training Loss: 0.008883         Validation Loss: 0.005536
Epoch: 462      Training Loss: 0.008701         Validation Loss: 0.005603
Epoch: 463      Training Loss: 0.008656         Validation Loss: 0.006202
Epoch: 464      Training Loss: 0.008419         Validation Loss: 0.004720
Epoch: 465      Training Loss: 0.008530         Validation Loss: 0.005669
Epoch: 466      Training Loss: 0.008611         Validation Loss: 0.003700
Epoch: 467      Training Loss: 0.008670         Validation Loss: 0.005445
Epoch: 468      Training Loss: 0.008891         Validation Loss: 0.003987
Epoch: 469      Training Loss: 0.009331         Validation Loss: 0.009247
Epoch: 470      Training Loss: 0.008692         Validation Loss: 0.003951
Epoch: 471      Training Loss: 0.008877         Validation Loss: 0.006406
Epoch: 472      Training Loss: 0.008105         Validation Loss: 0.003774
Epoch: 473      Training Loss: 0.008687         Validation Loss: 0.005624
Epoch: 474      Training Loss: 0.008428         Validation Loss: 0.004717
Epoch: 475      Training Loss: 0.008609         Validation Loss: 0.005044
Epoch: 476      Training Loss: 0.008749         Validation Loss: 0.007316
Epoch: 477      Training Loss: 0.008932         Validation Loss: 0.003534
Epoch: 478      Training Loss: 0.008211         Validation Loss: 0.004272
Epoch: 479      Training Loss: 0.008442         Validation Loss: 0.003692
Epoch: 480      Training Loss: 0.008440         Validation Loss: 0.006366
Epoch: 481      Training Loss: 0.008385         Validation Loss: 0.004655
Epoch: 482      Training Loss: 0.008365         Validation Loss: 0.005059
Epoch: 483      Training Loss: 0.008272         Validation Loss: 0.008517
Epoch: 484      Training Loss: 0.008411         Validation Loss: 0.003805
Epoch: 485      Training Loss: 0.008345         Validation Loss: 0.004926
Epoch: 486      Training Loss: 0.008466         Validation Loss: 0.003607
Epoch: 487      Training Loss: 0.008748         Validation Loss: 0.007465
Epoch: 488      Training Loss: 0.008289         Validation Loss: 0.005324
Epoch: 489      Training Loss: 0.008518         Validation Loss: 0.004304
Epoch: 490      Training Loss: 0.008343         Validation Loss: 0.005468
Epoch: 491      Training Loss: 0.008078         Validation Loss: 0.006590
Epoch: 492      Training Loss: 0.008359         Validation Loss: 0.005686
Epoch: 493      Training Loss: 0.008649         Validation Loss: 0.003506
```

```
Epoch: 494      Training Loss: 0.008870         Validation Loss: 0.006309
Epoch: 495      Training Loss: 0.008069         Validation Loss: 0.003375
Epoch: 496      Training Loss: 0.008056         Validation Loss: 0.006854
Epoch: 497      Training Loss: 0.008637         Validation Loss: 0.003165
Validation loss decreased (0.003246 --> 0.003165).  Saving model ...
Epoch: 498      Training Loss: 0.008124         Validation Loss: 0.005569
Epoch: 499      Training Loss: 0.008153         Validation Loss: 0.003614
Epoch: 500      Training Loss: 0.008401         Validation Loss: 0.005867
```

3.4 Check the model prediction ability

[0]:
```
# Evaluate this one
model_front.load_state_dict(torch.load(ROOT_FOLDER+'model_front.pt'))
KPT_PREDICT = predict(test_loader_front, model_front)
```

[96]:
```
# Draw the changing curve
n_epochs=500
x=range(0,n_epochs)
plt.figure(figsize=(12,8),dpi=80)
y1=train_losses
y2=valid_losses
plt.grid(alpha=0.4)
plt.plot(x,y1,label='train_losses',color='orange',linestyle=":",linewidth=2)
plt.plot(x,y2,label='valid_losses',color='cyan',linestyle="-",linewidth=3)
plt.xlabel('epoch',size=50)
plt.ylabel('losses',size=50)
plt.legend()
plt.show()
```



[97]:
```
#Show one prediction
idx = np.random.randint(KPT_PREDICT.shape[0])
print(idx)
draw_points(IMG_TEST[idx,:,:], KPT_PREDICT[idx,:].reshape((-1,2)))
```

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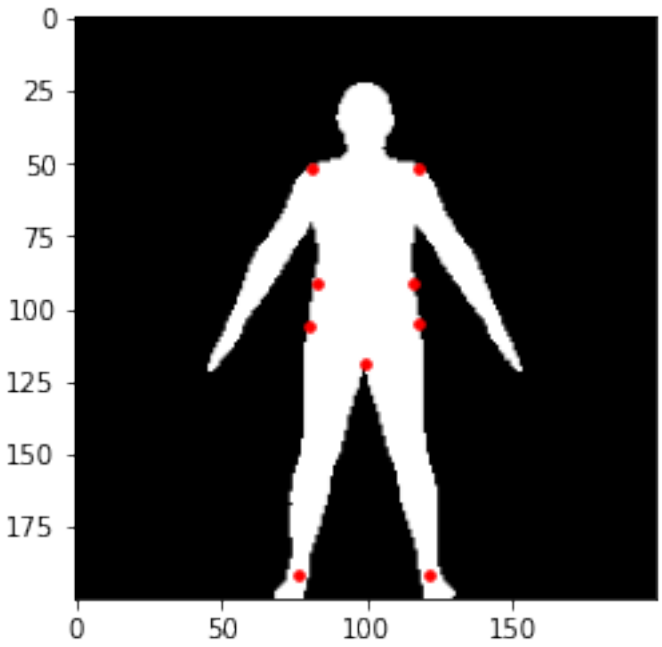


4 Task 2: Image Generation

In the previous task, we predict low dimensional data (keypoints `9x2`) from high dimensional input (images `200x200`). Let's consider a different case now.

- Train a image generation model to predict silhouette images from keypoints.
- Input: `9x2` keypoints coordinates
- Output: corresponding sihouette images
- All of the available data can be used, including the keypoints you predicted on `imgs2.npy` in the previous task.
- Predict silhouett images for keypoints in `kpts3.npy`.
- Visualize the generated image together with input keypoints.

4.1 Define the training function for task 2

[0]:
```
def train_img(train_loader, valid_loader, model, criterion, optimizer,
          n_epochs=50, saved_model='model.pt'):
    '''
    Train the model

    Args:
        train_loader (DataLoader): DataLoader for train Dataset
        valid_loader (DataLoader): DataLoader for valid Dataset
        model (nn.Module): model to be trained on
        criterion (torch.nn): loss funtion
```

```
        optimizer (torch.optim): optimization algorithms
        n_epochs (int): number of epochs to train the model
        saved_model (str): file path for saving model

    Return:
        tuple of train_losses, valid_losses
    '''

    # initialize tracker for minimum validation loss
    valid_loss_min = np.Inf # set initial "min" to infinity

    train_losses = []
    valid_losses = []

    for epoch in range(n_epochs):
        # monitor training loss
        train_loss = 0.0
        valid_loss = 0.0

        ###################
        # train the model #
        ###################
        model.train() # prep model for training
        for batch in train_loader:
            # clear the gradients of all optimized variables
            optimizer.zero_grad()
            # forward pass: compute predicted outputs by passing inputs to the␣
↪model
            output = model(batch['keypoints'].to(device))
            # calculate the loss
            img = batch['image']
            img = img.reshape([len(img),40000])
            loss = criterion(output, img.to(device))
            # backward pass: compute gradient of the loss with respect to model␣
↪parameters
            loss.backward()
            # perform a single optimization step (parameter update)
            optimizer.step()
            # update running training loss
            train_loss += loss.item()*batch['keypoints'].size(0)

        ######################
        # validate the model #
        ######################
        model.eval() # prep model for evaluation
        for batch in valid_loader:
```

```
            # forward pass: compute predicted outputs by passing inputs to the␣
↪model
            output = model(batch['keypoints'].to(device))
            # calculate the loss
            img2 = batch['image']
            img2 = img2.reshape([len(img2),40000])
            loss = criterion(output, img2.to(device))
            # update running validation loss
            valid_loss += loss.item()*batch['keypoints'].size(0)

        # print training/validation statistics
        # calculate average Root Mean Square loss over an epoch
        train_loss = np.sqrt(train_loss/len(train_loader.sampler.indices))
        valid_loss = np.sqrt(valid_loss/len(valid_loader.sampler.indices))

        train_losses.append(train_loss)
        valid_losses.append(valid_loss)

        print('Epoch: {} \tTraining Loss: {:.6f} \tValidation Loss: {:.6f}'
              .format(epoch+1, train_loss, valid_loss))

        # save model if validation loss has decreased
        if valid_loss <= valid_loss_min:
            print('Validation loss decreased ({:.6f} --> {:.6f}).  Saving model␣
↪...'
                  .format(valid_loss_min, valid_loss))
            torch.save(model.state_dict(), saved_model)
            model_temp = model.state_dict()
            valid_loss_min = valid_loss
    return train_losses, valid_losses
```

4.2 Train the model using MLP

The following parameters are chosen:

- Learning rate: 0.001
- Number of epochs: 150
- Some pooling layers and convolutional layers in the CNN has been changed and can be found in the code.

[131]:
```
device = torch.device('cuda' if torch.cuda.is_available() else 'CPU')
model_img = MLP(input_size=18, output_size=IMG_SIZE*IMG_SIZE,
            hidden_layers=[64, 128], drop_p=0.1)
model_img = model_img.to(device)
criterion = nn.MSELoss()
optimizer = optim.Adam(model_img.parameters(), lr=0.0001)
# optimizer = optim.SGD(model_img.parameters(), lr=0.001, momentum=0.95,␣
 ↪weight_decay=1e-5)
```

```
train_losses, valid_losses = train_img(train_loader_front, valid_loader_front,
                  model_img, criterion, optimizer,
                  n_epochs=300,
                  saved_model=ROOT_FOLDER+'model_adjusted.pt')
```

```
Epoch: 1        Training Loss: 0.382900         Validation Loss: 0.380007
Validation loss decreased (inf --> 0.380007).  Saving model ...
Epoch: 2        Training Loss: 0.379832         Validation Loss: 0.377143
Validation loss decreased (0.380007 --> 0.377143).  Saving model ...
Epoch: 3        Training Loss: 0.376955         Validation Loss: 0.373940
Validation loss decreased (0.377143 --> 0.373940).  Saving model ...
Epoch: 4        Training Loss: 0.373745         Validation Loss: 0.370545
Validation loss decreased (0.373940 --> 0.370545).  Saving model ...
Epoch: 5        Training Loss: 0.369799         Validation Loss: 0.366022
Validation loss decreased (0.370545 --> 0.366022).  Saving model ...
Epoch: 6        Training Loss: 0.364614         Validation Loss: 0.360271
Validation loss decreased (0.366022 --> 0.360271).  Saving model ...
Epoch: 7        Training Loss: 0.358361         Validation Loss: 0.353355
Validation loss decreased (0.360271 --> 0.353355).  Saving model ...
Epoch: 8        Training Loss: 0.350934         Validation Loss: 0.344873
Validation loss decreased (0.353355 --> 0.344873).  Saving model ...
Epoch: 9        Training Loss: 0.341577         Validation Loss: 0.334180
Validation loss decreased (0.344873 --> 0.334180).  Saving model ...
Epoch: 10       Training Loss: 0.330707         Validation Loss: 0.322179
Validation loss decreased (0.334180 --> 0.322179).  Saving model ...
Epoch: 11       Training Loss: 0.317634         Validation Loss: 0.307635
Validation loss decreased (0.322179 --> 0.307635).  Saving model ...
Epoch: 12       Training Loss: 0.302924         Validation Loss: 0.291507
Validation loss decreased (0.307635 --> 0.291507).  Saving model ...
Epoch: 13       Training Loss: 0.286546         Validation Loss: 0.273292
Validation loss decreased (0.291507 --> 0.273292).  Saving model ...
Epoch: 14       Training Loss: 0.267945         Validation Loss: 0.254076
Validation loss decreased (0.273292 --> 0.254076).  Saving model ...
Epoch: 15       Training Loss: 0.248308         Validation Loss: 0.233108
Validation loss decreased (0.254076 --> 0.233108).  Saving model ...
Epoch: 16       Training Loss: 0.228959         Validation Loss: 0.213278
Validation loss decreased (0.233108 --> 0.213278).  Saving model ...
Epoch: 17       Training Loss: 0.210488         Validation Loss: 0.193470
Validation loss decreased (0.213278 --> 0.193470).  Saving model ...
Epoch: 18       Training Loss: 0.191765         Validation Loss: 0.175228
Validation loss decreased (0.193470 --> 0.175228).  Saving model ...
Epoch: 19       Training Loss: 0.175993         Validation Loss: 0.160564
Validation loss decreased (0.175228 --> 0.160564).  Saving model ...
Epoch: 20       Training Loss: 0.162689         Validation Loss: 0.148107
Validation loss decreased (0.160564 --> 0.148107).  Saving model ...
Epoch: 21       Training Loss: 0.154043         Validation Loss: 0.138929
```

```
Validation loss decreased (0.148107 --> 0.138929).  Saving model ...
Epoch: 22       Training Loss: 0.147381         Validation Loss: 0.131964
Validation loss decreased (0.138929 --> 0.131964).  Saving model ...
Epoch: 23       Training Loss: 0.143994         Validation Loss: 0.129216
Validation loss decreased (0.131964 --> 0.129216).  Saving model ...
Epoch: 24       Training Loss: 0.140671         Validation Loss: 0.126193
Validation loss decreased (0.129216 --> 0.126193).  Saving model ...
Epoch: 25       Training Loss: 0.137593         Validation Loss: 0.125156
Validation loss decreased (0.126193 --> 0.125156).  Saving model ...
Epoch: 26       Training Loss: 0.137084         Validation Loss: 0.122057
Validation loss decreased (0.125156 --> 0.122057).  Saving model ...
Epoch: 27       Training Loss: 0.136893         Validation Loss: 0.121060
Validation loss decreased (0.122057 --> 0.121060).  Saving model ...
Epoch: 28       Training Loss: 0.136311         Validation Loss: 0.121051
Validation loss decreased (0.121060 --> 0.121051).  Saving model ...
Epoch: 29       Training Loss: 0.135503         Validation Loss: 0.120152
Validation loss decreased (0.121051 --> 0.120152).  Saving model ...
Epoch: 30       Training Loss: 0.134952         Validation Loss: 0.120293
Epoch: 31       Training Loss: 0.134698         Validation Loss: 0.121233
Epoch: 32       Training Loss: 0.134474         Validation Loss: 0.120696
Epoch: 33       Training Loss: 0.133732         Validation Loss: 0.119223
Validation loss decreased (0.120152 --> 0.119223).  Saving model ...
Epoch: 34       Training Loss: 0.132940         Validation Loss: 0.118827
Validation loss decreased (0.119223 --> 0.118827).  Saving model ...
Epoch: 35       Training Loss: 0.133184         Validation Loss: 0.120945
Epoch: 36       Training Loss: 0.132702         Validation Loss: 0.119878
Epoch: 37       Training Loss: 0.133504         Validation Loss: 0.118692
Validation loss decreased (0.118827 --> 0.118692).  Saving model ...
Epoch: 38       Training Loss: 0.133372         Validation Loss: 0.119959
Epoch: 39       Training Loss: 0.133003         Validation Loss: 0.119662
Epoch: 40       Training Loss: 0.131728         Validation Loss: 0.119993
Epoch: 41       Training Loss: 0.132100         Validation Loss: 0.119941
Epoch: 42       Training Loss: 0.132326         Validation Loss: 0.120638
Epoch: 43       Training Loss: 0.131582         Validation Loss: 0.119773
Epoch: 44       Training Loss: 0.131456         Validation Loss: 0.118838
Epoch: 45       Training Loss: 0.132316         Validation Loss: 0.119901
Epoch: 46       Training Loss: 0.131521         Validation Loss: 0.119561
Epoch: 47       Training Loss: 0.131768         Validation Loss: 0.119539
Epoch: 48       Training Loss: 0.132149         Validation Loss: 0.119088
Epoch: 49       Training Loss: 0.131292         Validation Loss: 0.119815
Epoch: 50       Training Loss: 0.132354         Validation Loss: 0.119912
Epoch: 51       Training Loss: 0.131386         Validation Loss: 0.118957
Epoch: 52       Training Loss: 0.130564         Validation Loss: 0.120358
Epoch: 53       Training Loss: 0.131615         Validation Loss: 0.118932
Epoch: 54       Training Loss: 0.130477         Validation Loss: 0.120078
Epoch: 55       Training Loss: 0.130468         Validation Loss: 0.119124
Epoch: 56       Training Loss: 0.130216         Validation Loss: 0.119886
Epoch: 57       Training Loss: 0.130469         Validation Loss: 0.120180
```

```
Epoch: 58       Training Loss: 0.131278         Validation Loss: 0.119783
Epoch: 59       Training Loss: 0.129878         Validation Loss: 0.119653
Epoch: 60       Training Loss: 0.130193         Validation Loss: 0.118975
Epoch: 61       Training Loss: 0.130853         Validation Loss: 0.120113
Epoch: 62       Training Loss: 0.129794         Validation Loss: 0.119489
Epoch: 63       Training Loss: 0.130058         Validation Loss: 0.120220
Epoch: 64       Training Loss: 0.129854         Validation Loss: 0.118714
Epoch: 65       Training Loss: 0.129829         Validation Loss: 0.119067
Epoch: 66       Training Loss: 0.129345         Validation Loss: 0.119375
Epoch: 67       Training Loss: 0.129879         Validation Loss: 0.119420
Epoch: 68       Training Loss: 0.129132         Validation Loss: 0.120484
Epoch: 69       Training Loss: 0.129532         Validation Loss: 0.120108
Epoch: 70       Training Loss: 0.130402         Validation Loss: 0.120056
Epoch: 71       Training Loss: 0.129537         Validation Loss: 0.120287
Epoch: 72       Training Loss: 0.129467         Validation Loss: 0.119637
Epoch: 73       Training Loss: 0.128616         Validation Loss: 0.119583
Epoch: 74       Training Loss: 0.129032         Validation Loss: 0.117758
Validation loss decreased (0.118692 --> 0.117758).  Saving model ...
Epoch: 75       Training Loss: 0.128797         Validation Loss: 0.120492
Epoch: 76       Training Loss: 0.129117         Validation Loss: 0.120160
Epoch: 77       Training Loss: 0.128341         Validation Loss: 0.119970
Epoch: 78       Training Loss: 0.129408         Validation Loss: 0.120078
Epoch: 79       Training Loss: 0.128251         Validation Loss: 0.120081
Epoch: 80       Training Loss: 0.129367         Validation Loss: 0.119127
Epoch: 81       Training Loss: 0.128499         Validation Loss: 0.120208
Epoch: 82       Training Loss: 0.128454         Validation Loss: 0.119380
Epoch: 83       Training Loss: 0.128211         Validation Loss: 0.119384
Epoch: 84       Training Loss: 0.128842         Validation Loss: 0.119560
Epoch: 85       Training Loss: 0.128545         Validation Loss: 0.118294
Epoch: 86       Training Loss: 0.127296         Validation Loss: 0.119012
Epoch: 87       Training Loss: 0.128223         Validation Loss: 0.120146
Epoch: 88       Training Loss: 0.127944         Validation Loss: 0.119479
Epoch: 89       Training Loss: 0.127691         Validation Loss: 0.119817
Epoch: 90       Training Loss: 0.127161         Validation Loss: 0.118776
Epoch: 91       Training Loss: 0.128273         Validation Loss: 0.119240
Epoch: 92       Training Loss: 0.128200         Validation Loss: 0.120256
Epoch: 93       Training Loss: 0.127605         Validation Loss: 0.119143
Epoch: 94       Training Loss: 0.127465         Validation Loss: 0.120149
Epoch: 95       Training Loss: 0.127792         Validation Loss: 0.118097
Epoch: 96       Training Loss: 0.128109         Validation Loss: 0.120633
Epoch: 97       Training Loss: 0.127578         Validation Loss: 0.119954
Epoch: 98       Training Loss: 0.127367         Validation Loss: 0.118531
Epoch: 99       Training Loss: 0.127227         Validation Loss: 0.118223
Epoch: 100      Training Loss: 0.127694         Validation Loss: 0.119439
Epoch: 101      Training Loss: 0.127627         Validation Loss: 0.120615
Epoch: 102      Training Loss: 0.127391         Validation Loss: 0.118603
Epoch: 103      Training Loss: 0.127227         Validation Loss: 0.119092
Epoch: 104      Training Loss: 0.127485         Validation Loss: 0.119259
```

```
Epoch: 105      Training Loss: 0.127316         Validation Loss: 0.119099
Epoch: 106      Training Loss: 0.126806         Validation Loss: 0.119090
Epoch: 107      Training Loss: 0.126881         Validation Loss: 0.119926
Epoch: 108      Training Loss: 0.127141         Validation Loss: 0.119659
Epoch: 109      Training Loss: 0.126746         Validation Loss: 0.120026
Epoch: 110      Training Loss: 0.127096         Validation Loss: 0.119712
Epoch: 111      Training Loss: 0.126903         Validation Loss: 0.120574
Epoch: 112      Training Loss: 0.126931         Validation Loss: 0.117888
Epoch: 113      Training Loss: 0.126991         Validation Loss: 0.118696
Epoch: 114      Training Loss: 0.127006         Validation Loss: 0.119610
Epoch: 115      Training Loss: 0.127116         Validation Loss: 0.118506
Epoch: 116      Training Loss: 0.125829         Validation Loss: 0.119244
Epoch: 117      Training Loss: 0.126573         Validation Loss: 0.120369
Epoch: 118      Training Loss: 0.126085         Validation Loss: 0.119757
Epoch: 119      Training Loss: 0.126564         Validation Loss: 0.119460
Epoch: 120      Training Loss: 0.126388         Validation Loss: 0.118291
Epoch: 121      Training Loss: 0.126636         Validation Loss: 0.119777
Epoch: 122      Training Loss: 0.126262         Validation Loss: 0.120206
Epoch: 123      Training Loss: 0.125851         Validation Loss: 0.119669
Epoch: 124      Training Loss: 0.126306         Validation Loss: 0.118859
Epoch: 125      Training Loss: 0.125957         Validation Loss: 0.119215
Epoch: 126      Training Loss: 0.126325         Validation Loss: 0.119371
Epoch: 127      Training Loss: 0.126268         Validation Loss: 0.118998
Epoch: 128      Training Loss: 0.125496         Validation Loss: 0.119065
Epoch: 129      Training Loss: 0.125905         Validation Loss: 0.119708
Epoch: 130      Training Loss: 0.125039         Validation Loss: 0.119613
Epoch: 131      Training Loss: 0.125889         Validation Loss: 0.118578
Epoch: 132      Training Loss: 0.125493         Validation Loss: 0.120865
Epoch: 133      Training Loss: 0.126283         Validation Loss: 0.118452
Epoch: 134      Training Loss: 0.126423         Validation Loss: 0.119535
Epoch: 135      Training Loss: 0.126240         Validation Loss: 0.119471
Epoch: 136      Training Loss: 0.125399         Validation Loss: 0.119103
Epoch: 137      Training Loss: 0.125953         Validation Loss: 0.119233
Epoch: 138      Training Loss: 0.125253         Validation Loss: 0.119398
Epoch: 139      Training Loss: 0.125758         Validation Loss: 0.120082
Epoch: 140      Training Loss: 0.125280         Validation Loss: 0.119155
Epoch: 141      Training Loss: 0.126161         Validation Loss: 0.118451
Epoch: 142      Training Loss: 0.125256         Validation Loss: 0.119190
Epoch: 143      Training Loss: 0.124894         Validation Loss: 0.119716
Epoch: 144      Training Loss: 0.125616         Validation Loss: 0.119757
Epoch: 145      Training Loss: 0.125261         Validation Loss: 0.119958
Epoch: 146      Training Loss: 0.125543         Validation Loss: 0.118444
Epoch: 147      Training Loss: 0.125397         Validation Loss: 0.119557
Epoch: 148      Training Loss: 0.125035         Validation Loss: 0.119191
Epoch: 149      Training Loss: 0.125324         Validation Loss: 0.118291
Epoch: 150      Training Loss: 0.125514         Validation Loss: 0.119509
Epoch: 151      Training Loss: 0.125155         Validation Loss: 0.118396
Epoch: 152      Training Loss: 0.124967         Validation Loss: 0.118425
```

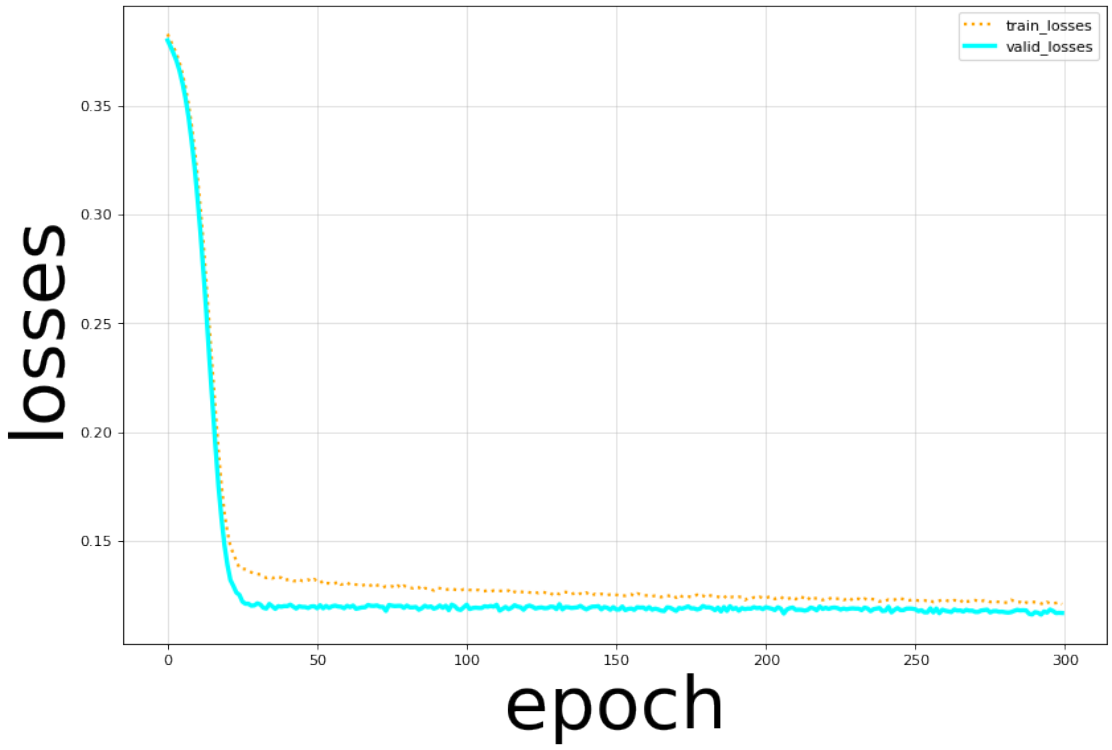
```
Epoch: 153      Training Loss: 0.124742         Validation Loss: 0.119771
Epoch: 154      Training Loss: 0.124744         Validation Loss: 0.118124
Epoch: 155      Training Loss: 0.125075         Validation Loss: 0.118662
Epoch: 156      Training Loss: 0.125376         Validation Loss: 0.118858
Epoch: 157      Training Loss: 0.124631         Validation Loss: 0.118252
Epoch: 158      Training Loss: 0.125747         Validation Loss: 0.119440
Epoch: 159      Training Loss: 0.125381         Validation Loss: 0.119265
Epoch: 160      Training Loss: 0.124930         Validation Loss: 0.119338
Epoch: 161      Training Loss: 0.124842         Validation Loss: 0.118445
Epoch: 162      Training Loss: 0.124621         Validation Loss: 0.119480
Epoch: 163      Training Loss: 0.124447         Validation Loss: 0.118337
Epoch: 164      Training Loss: 0.124767         Validation Loss: 0.118806
Epoch: 165      Training Loss: 0.124755         Validation Loss: 0.118443
Epoch: 166      Training Loss: 0.124082         Validation Loss: 0.117904
Epoch: 167      Training Loss: 0.124718         Validation Loss: 0.117687
Validation loss decreased (0.117758 --> 0.117687).  Saving model ...
Epoch: 168      Training Loss: 0.124772         Validation Loss: 0.119401
Epoch: 169      Training Loss: 0.124671         Validation Loss: 0.119221
Epoch: 170      Training Loss: 0.124996         Validation Loss: 0.118506
Epoch: 171      Training Loss: 0.123837         Validation Loss: 0.117755
Epoch: 172      Training Loss: 0.125162         Validation Loss: 0.119138
Epoch: 173      Training Loss: 0.124341         Validation Loss: 0.118755
Epoch: 174      Training Loss: 0.124597         Validation Loss: 0.119259
Epoch: 175      Training Loss: 0.124437         Validation Loss: 0.119862
Epoch: 176      Training Loss: 0.124071         Validation Loss: 0.118931
Epoch: 177      Training Loss: 0.124409         Validation Loss: 0.118920
Epoch: 178      Training Loss: 0.125189         Validation Loss: 0.118393
Epoch: 179      Training Loss: 0.124331         Validation Loss: 0.118773
Epoch: 180      Training Loss: 0.124712         Validation Loss: 0.120042
Epoch: 181      Training Loss: 0.124124         Validation Loss: 0.119378
Epoch: 182      Training Loss: 0.125008         Validation Loss: 0.119430
Epoch: 183      Training Loss: 0.124604         Validation Loss: 0.119021
Epoch: 184      Training Loss: 0.124452         Validation Loss: 0.118086
Epoch: 185      Training Loss: 0.124248         Validation Loss: 0.119290
Epoch: 186      Training Loss: 0.123918         Validation Loss: 0.117500
Validation loss decreased (0.117687 --> 0.117500).  Saving model ...
Epoch: 187      Training Loss: 0.124663         Validation Loss: 0.119553
Epoch: 188      Training Loss: 0.123471         Validation Loss: 0.117755
Epoch: 189      Training Loss: 0.124101         Validation Loss: 0.119940
Epoch: 190      Training Loss: 0.124150         Validation Loss: 0.118550
Epoch: 191      Training Loss: 0.123889         Validation Loss: 0.119131
Epoch: 192      Training Loss: 0.124194         Validation Loss: 0.117832
Epoch: 193      Training Loss: 0.124131         Validation Loss: 0.119064
Epoch: 194      Training Loss: 0.122769         Validation Loss: 0.118545
Epoch: 195      Training Loss: 0.123568         Validation Loss: 0.118851
Epoch: 196      Training Loss: 0.123514         Validation Loss: 0.118757
Epoch: 197      Training Loss: 0.123966         Validation Loss: 0.119480
Epoch: 198      Training Loss: 0.123493         Validation Loss: 0.119018
```

```
Epoch: 199      Training Loss: 0.124172         Validation Loss: 0.119212
Epoch: 200      Training Loss: 0.123702         Validation Loss: 0.118546
Epoch: 201      Training Loss: 0.123673         Validation Loss: 0.119460
Epoch: 202      Training Loss: 0.124171         Validation Loss: 0.119130
Epoch: 203      Training Loss: 0.124383         Validation Loss: 0.118741
Epoch: 204      Training Loss: 0.123249         Validation Loss: 0.118141
Epoch: 205      Training Loss: 0.123745         Validation Loss: 0.119422
Epoch: 206      Training Loss: 0.124236         Validation Loss: 0.118802
Epoch: 207      Training Loss: 0.123217         Validation Loss: 0.116537
Validation loss decreased (0.117500 --> 0.116537).  Saving model ...
Epoch: 208      Training Loss: 0.123189         Validation Loss: 0.118370
Epoch: 209      Training Loss: 0.123587         Validation Loss: 0.119012
Epoch: 210      Training Loss: 0.124093         Validation Loss: 0.119303
Epoch: 211      Training Loss: 0.123124         Validation Loss: 0.118241
Epoch: 212      Training Loss: 0.124490         Validation Loss: 0.118319
Epoch: 213      Training Loss: 0.124049         Validation Loss: 0.118243
Epoch: 214      Training Loss: 0.123689         Validation Loss: 0.117874
Epoch: 215      Training Loss: 0.122737         Validation Loss: 0.118254
Epoch: 216      Training Loss: 0.124348         Validation Loss: 0.119286
Epoch: 217      Training Loss: 0.123565         Validation Loss: 0.118866
Epoch: 218      Training Loss: 0.123532         Validation Loss: 0.118031
Epoch: 219      Training Loss: 0.123453         Validation Loss: 0.119790
Epoch: 220      Training Loss: 0.122756         Validation Loss: 0.118643
Epoch: 221      Training Loss: 0.123360         Validation Loss: 0.119208
Epoch: 222      Training Loss: 0.123143         Validation Loss: 0.118657
Epoch: 223      Training Loss: 0.123895         Validation Loss: 0.119173
Epoch: 224      Training Loss: 0.123414         Validation Loss: 0.119321
Epoch: 225      Training Loss: 0.123368         Validation Loss: 0.119028
Epoch: 226      Training Loss: 0.123590         Validation Loss: 0.118360
Epoch: 227      Training Loss: 0.122812         Validation Loss: 0.118877
Epoch: 228      Training Loss: 0.123221         Validation Loss: 0.118477
Epoch: 229      Training Loss: 0.123850         Validation Loss: 0.118793
Epoch: 230      Training Loss: 0.122510         Validation Loss: 0.118929
Epoch: 231      Training Loss: 0.123034         Validation Loss: 0.118796
Epoch: 232      Training Loss: 0.123368         Validation Loss: 0.118788
Epoch: 233      Training Loss: 0.122613         Validation Loss: 0.118107
Epoch: 234      Training Loss: 0.123413         Validation Loss: 0.119286
Epoch: 235      Training Loss: 0.122789         Validation Loss: 0.118866
Epoch: 236      Training Loss: 0.123248         Validation Loss: 0.117658
Epoch: 237      Training Loss: 0.123100         Validation Loss: 0.118544
Epoch: 238      Training Loss: 0.122841         Validation Loss: 0.118820
Epoch: 239      Training Loss: 0.122066         Validation Loss: 0.119091
Epoch: 240      Training Loss: 0.122608         Validation Loss: 0.117714
Epoch: 241      Training Loss: 0.122414         Validation Loss: 0.117880
Epoch: 242      Training Loss: 0.122958         Validation Loss: 0.119671
Epoch: 243      Training Loss: 0.122732         Validation Loss: 0.117091
Epoch: 244      Training Loss: 0.122873         Validation Loss: 0.118236
Epoch: 245      Training Loss: 0.123574         Validation Loss: 0.119080
```

```
Epoch: 246      Training Loss: 0.123467         Validation Loss: 0.118128
Epoch: 247      Training Loss: 0.123140         Validation Loss: 0.118125
Epoch: 248      Training Loss: 0.122817         Validation Loss: 0.118785
Epoch: 249      Training Loss: 0.122600         Validation Loss: 0.118842
Epoch: 250      Training Loss: 0.122973         Validation Loss: 0.118768
Epoch: 251      Training Loss: 0.122731         Validation Loss: 0.118488
Epoch: 252      Training Loss: 0.122495         Validation Loss: 0.117651
Epoch: 253      Training Loss: 0.122656         Validation Loss: 0.118100
Epoch: 254      Training Loss: 0.122618         Validation Loss: 0.117113
Epoch: 255      Training Loss: 0.122192         Validation Loss: 0.117118
Epoch: 256      Training Loss: 0.122655         Validation Loss: 0.118947
Epoch: 257      Training Loss: 0.121815         Validation Loss: 0.117064
Epoch: 258      Training Loss: 0.121990         Validation Loss: 0.118864
Epoch: 259      Training Loss: 0.122406         Validation Loss: 0.116700
Epoch: 260      Training Loss: 0.122914         Validation Loss: 0.118318
Epoch: 261      Training Loss: 0.122817         Validation Loss: 0.117846
Epoch: 262      Training Loss: 0.122279         Validation Loss: 0.117571
Epoch: 263      Training Loss: 0.121995         Validation Loss: 0.117242
Epoch: 264      Training Loss: 0.122695         Validation Loss: 0.118415
Epoch: 265      Training Loss: 0.122391         Validation Loss: 0.117914
Epoch: 266      Training Loss: 0.122877         Validation Loss: 0.117999
Epoch: 267      Training Loss: 0.121338         Validation Loss: 0.117463
Epoch: 268      Training Loss: 0.122098         Validation Loss: 0.118254
Epoch: 269      Training Loss: 0.122181         Validation Loss: 0.117858
Epoch: 270      Training Loss: 0.122441         Validation Loss: 0.117886
Epoch: 271      Training Loss: 0.122699         Validation Loss: 0.117281
Epoch: 272      Training Loss: 0.121989         Validation Loss: 0.117278
Epoch: 273      Training Loss: 0.122020         Validation Loss: 0.117961
Epoch: 274      Training Loss: 0.122664         Validation Loss: 0.118140
Epoch: 275      Training Loss: 0.122554         Validation Loss: 0.118324
Epoch: 276      Training Loss: 0.121847         Validation Loss: 0.117051
Epoch: 277      Training Loss: 0.122092         Validation Loss: 0.117655
Epoch: 278      Training Loss: 0.122017         Validation Loss: 0.117718
Epoch: 279      Training Loss: 0.121819         Validation Loss: 0.117322
Epoch: 280      Training Loss: 0.121500         Validation Loss: 0.117399
Epoch: 281      Training Loss: 0.121600         Validation Loss: 0.117129
Epoch: 282      Training Loss: 0.121668         Validation Loss: 0.116979
Epoch: 283      Training Loss: 0.122836         Validation Loss: 0.117193
Epoch: 284      Training Loss: 0.122140         Validation Loss: 0.117760
Epoch: 285      Training Loss: 0.121688         Validation Loss: 0.118248
Epoch: 286      Training Loss: 0.121837         Validation Loss: 0.117994
Epoch: 287      Training Loss: 0.120863         Validation Loss: 0.118089
Epoch: 288      Training Loss: 0.121662         Validation Loss: 0.117993
Epoch: 289      Training Loss: 0.121394         Validation Loss: 0.116440
Validation loss decreased (0.116537 --> 0.116440).  Saving model ...
Epoch: 290      Training Loss: 0.121850         Validation Loss: 0.116105
Validation loss decreased (0.116440 --> 0.116105).  Saving model ...
Epoch: 291      Training Loss: 0.121780         Validation Loss: 0.117189
```

```
Epoch: 292      Training Loss: 0.121718         Validation Loss: 0.116901
Epoch: 293      Training Loss: 0.121159         Validation Loss: 0.116041
Validation loss decreased (0.116105 --> 0.116041).  Saving model ...
Epoch: 294      Training Loss: 0.120647         Validation Loss: 0.117505
Epoch: 295      Training Loss: 0.121803         Validation Loss: 0.116976
Epoch: 296      Training Loss: 0.121221         Validation Loss: 0.118390
Epoch: 297      Training Loss: 0.121248         Validation Loss: 0.117742
Epoch: 298      Training Loss: 0.121388         Validation Loss: 0.116746
Epoch: 299      Training Loss: 0.121738         Validation Loss: 0.116857
Epoch: 300      Training Loss: 0.120874         Validation Loss: 0.116780
```

[132]:
```
# Draw the changing curve
n_epochs=300
x=range(0,n_epochs)
plt.figure(figsize=(12,8),dpi=80)
y1=train_losses
y2=valid_losses
plt.grid(alpha=0.4)
plt.plot(x,y1,label='train_losses',color='orange',linestyle=":",linewidth=2)
plt.plot(x,y2,label='valid_losses',color='cyan',linestyle="-",linewidth=3)
plt.xlabel('epoch',size=50)
plt.ylabel('losses',size=50)
plt.legend()
plt.show()
```



4.3 Define the prediction function and test dataloader for task 2

[0]:
```
def predict_img(data_loader, model):
    '''
    Predict keypoints
    Args:
        data_loader (DataLoader): DataLoader for Dataset
        model (nn.Module): trained model for prediction.
    Return:
        predictions (array-like): keypoints in float (no. of images x␣
 ↪keypoints).
    '''

    model.eval() # prep model for evaluation

    with torch.no_grad():
        for i, batch in enumerate(data_loader):
            # forward pass: compute predicted outputs by passing inputs to the␣
 ↪model
            output = model(batch.to(device)).cpu().numpy()
            if i == 0:
                predictions = output
            else:
                predictions = np.vstack((predictions, output))

    return predictions
```

[0]:
```
class KeypointsDataset_kpt(Dataset):
    '''Keypoints Dataset'''
    def __init__(self, kpt, train=True, transform=None):
        self.kpt = kpt
        self.train = train
        self.transform = transform

    def __len__(self):
        return self.kpt.shape[0]

    def __getitem__(self, idx):
        keypoints = self.kpt[idx,:,:].ravel().astype(np.float32)
        sample = keypoints
        if self.transform:
            sample = self.transform(sample)
        return sample

class ToTensor(object):
```

```
    '''Convert ndarrays in sample to Tensors.'''
    def __call__(self, sample):
      if sample is not None:
        keypoints = torch.from_numpy(sample)
        return keypoints
      else:
        return
```

4.4 Load test data and predict the images for given keypoints

[150]:
```
print(KPT_TEST.shape)
print(KPT_PREDICT.shape)
a=KPT_PREDICT.reshape((-1,9,2))
print(a.shape)
```

```
(100, 9, 2)
(1000, 18)
(1000, 9, 2)
```

[0]:
```
tsfm_test_kpt = transforms.Compose([ToTensor()])

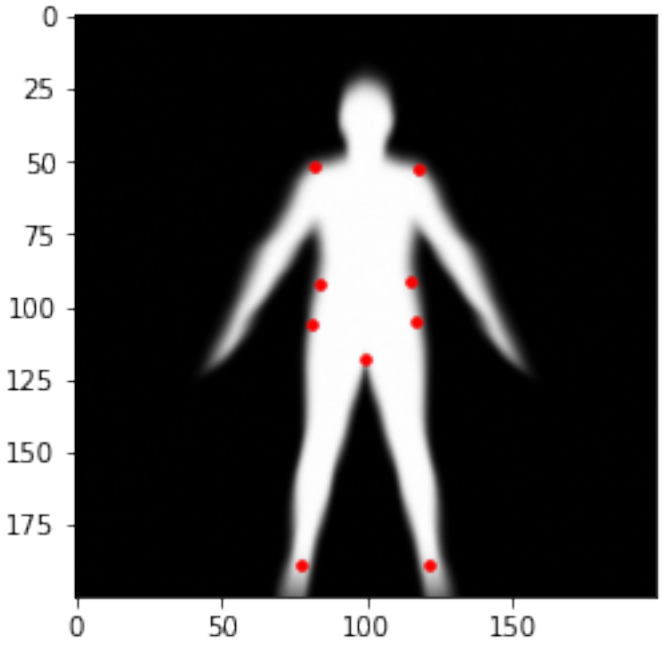
# Add the prediction result of the keypoints based on the imgs2
np.append(a,KPT_TEST)

testset_img = KeypointsDataset_kpt(KPT_TEST, train=False,␣
 ↪transform=tsfm_test_kpt)
test_loader_img = torch.utils.data.DataLoader(testset_img,␣
 ↪batch_size=batch_size)

model_img.load_state_dict(torch.load(ROOT_FOLDER+'model_adjusted.pt'))
IMG_PREDICT = predict_img(test_loader_img, model_img)
```

[156]:
```
#Show one prediction
idx = np.random.randint(IMG_PREDICT.shape[0])
print(idx)
draw_points(IMG_PREDICT[idx,:].reshape(-1,200), KPT_TRAIN[idx,:,:])
```

```
64
```



5 Conclusion

During the assignment 4, I have learned a lot about the deep learning basic concepts including CNN structure, MLP structure. Now based on the assignment2, using the MLP method I have finished the image generation function even it is not a good solution to finish it. Maybe the random-forest is the best way to set up the prediction model with feature engineering based on assignment3 but we just have a week left, it is fine to finish the task in such a way.

I have learned a lot in the MAEG5735 from Prof. Wang and TA. Liu, here to say thanks sincerely to them.

[162]:
```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
```

```
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 additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcups2 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 cups-common 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
The following packages will be upgraded:
  libcups2
1 upgraded, 47 newly installed, 0 to remove and 107 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
[2,698 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
20171026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all
20160520-1 [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 libcups2 amd64
2.2.7-1ubuntu2.8 [211 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64
```

```
libcupsfilters1 amd64 1.20.2-0ubuntu3.1 [108 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2
amd64 2.2.7-1ubuntu2.8 [18.6 kB]
Get:12 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64
0.35-13 [15.5 kB]
Get:13 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjbig2dec0 amd64
0.13-6 [55.9 kB]
Get:14 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common
all 9.26~dfsg+0-0ubuntu0.18.04.12 [5,092 kB]
Get:15 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64
9.26~dfsg+0-0ubuntu0.18.04.12 [2,264 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjs-jquery all
3.2.1-1 [152 kB]
Get:17 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libkpathsea6
amd64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic/main amd64 libpotrace0 amd64
1.14-2 [17.4 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libptexenc1
amd64 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
Get:20 http://archive.ubuntu.com/ubuntu bionic/main amd64 rubygems-integration
all 1.11 [4,994 B]
Get:21 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 ruby2.5 amd64
2.5.1-1ubuntu1.6 [48.6 kB]
Get:22 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby amd64 1:2.5.1
[5,712 B]
Get:23 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 rake all
12.3.1-1ubuntu0.1 [44.9 kB]
Get:24 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-did-you-mean all
1.2.0-2 [9,700 B]
Get:25 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-minitest all
5.10.3-1 [38.6 kB]
Get:26 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:27 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-power-assert all
0.3.0-1 [7,952 B]
Get:28 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-test-unit all
3.2.5-1 [61.1 kB]
Get:29 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libruby2.5
amd64 2.5.1-1ubuntu1.6 [3,069 kB]
Get:30 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libsynctex1
amd64 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
Get:31 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexlua52
amd64 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
Get:32 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexluajit2
amd64 2017.20170613.44572-8ubuntu0.1 [230 kB]
Get:33 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libzzip-0-13
amd64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
Get:34 http://archive.ubuntu.com/ubuntu bionic/main amd64 lmodern all 2.004.5-3
```

```
[9,631 kB]
Get:35 http://archive.ubuntu.com/ubuntu bionic/main amd64 preview-latex-style
all 11.91-1ubuntu1 [185 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/main amd64 t1utils amd64 1.41-2
[56.0 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all
20160520-1 [4,998 kB]
Get:38 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-
binaries amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all
2017.20180305-1 [18.7 MB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-
recommended all 2017.20180305-1 [5,262 kB]
Get:41 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all
2017.20180305-1 [951 kB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-
recommended all 2017.20180305-1 [14.9 MB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive all
2017.20180305-1 [14.4 kB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures
all 2017.20180305-1 [4,026 kB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-
extra all 2017.20180305-2 [10.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-
generic all 2017.20180305-2 [23.6 MB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:48 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all
2017.20180305-1 [10.7 MB]
Fetched 146 MB in 16s (9,004 kB/s)
Extracting templates from packages: 100%
Preconfiguring packages ...
Selecting previously unselected package fonts-droid-fallback.
(Reading database ... 144568 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) ...
Preparing to unpack .../08-libcups2_2.2.7-1ubuntu2.8_amd64.deb ...
Unpacking libcups2:amd64 (2.2.7-1ubuntu2.8) over (2.2.7-1ubuntu2.7) ...
Selecting previously unselected package libcupsfilters1:amd64.
Preparing to unpack .../09-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 .../10-libcupsimage2_2.2.7-1ubuntu2.8_amd64.deb ...
Unpacking libcupsimage2:amd64 (2.2.7-1ubuntu2.8) ...
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack .../11-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 .../12-libjbig2dec0_0.13-6_amd64.deb ...
Unpacking libjbig2dec0:amd64 (0.13-6) ...
Selecting previously unselected package libgs9-common.
Preparing to unpack .../13-libgs9-common_9.26~dfsg+0-0ubuntu0.18.04.12_all.deb
...
Unpacking libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.12) ...
Selecting previously unselected package libgs9:amd64.
Preparing to unpack .../14-libgs9_9.26~dfsg+0-0ubuntu0.18.04.12_amd64.deb ...
Unpacking libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.12) ...
Selecting previously unselected package libjs-jquery.
Preparing to unpack .../15-libjs-jquery_3.2.1-1_all.deb ...
Unpacking libjs-jquery (3.2.1-1) ...
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack .../16-libkpathsea6_2017.20170613.44572-8ubuntu0.1_amd64.deb
...
Unpacking libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package libpotrace0.
Preparing to unpack .../17-libpotrace0_1.14-2_amd64.deb ...
Unpacking libpotrace0 (1.14-2) ...
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack .../18-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 .../19-rubygems-integration_1.11_all.deb ...
Unpacking rubygems-integration (1.11) ...
Selecting previously unselected package ruby2.5.
```

```
Preparing to unpack .../20-ruby2.5_2.5.1-1ubuntu1.6_amd64.deb ...
Unpacking ruby2.5 (2.5.1-1ubuntu1.6) ...
Selecting previously unselected package ruby.
Preparing to unpack .../21-ruby_1%3a2.5.1_amd64.deb ...
Unpacking ruby (1:2.5.1) ...
Selecting previously unselected package rake.
Preparing to unpack .../22-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 .../23-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 .../24-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 .../25-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 .../26-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 .../27-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 .../28-libruby2.5_2.5.1-1ubuntu1.6_amd64.deb ...
Unpacking libruby2.5:amd64 (2.5.1-1ubuntu1.6) ...
Selecting previously unselected package libsynctex1:amd64.
Preparing to unpack .../29-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 .../30-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
.../31-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 .../32-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 .../33-lmodern_2.004.5-3_all.deb ...
Unpacking lmodern (2.004.5-3) ...
Selecting previously unselected package preview-latex-style.
Preparing to unpack .../34-preview-latex-style_11.91-1ubuntu1_all.deb ...
Unpacking preview-latex-style (11.91-1ubuntu1) ...
Selecting previously unselected package t1utils.
```

```
Preparing to unpack .../35-t1utils_1.41-2_amd64.deb ...
Unpacking t1utils (1.41-2) ...
Selecting previously unselected package tex-gyre.
Preparing to unpack .../36-tex-gyre_20160520-1_all.deb ...
Unpacking tex-gyre (20160520-1) ...
Selecting previously unselected package texlive-binaries.
Preparing to unpack .../37-texlive-
binaries_2017.20170613.44572-8ubuntu0.1_amd64.deb ...
Unpacking texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
Selecting previously unselected package texlive-base.
Preparing to unpack .../38-texlive-base_2017.20180305-1_all.deb ...
Unpacking texlive-base (2017.20180305-1) ...
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack .../39-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 .../40-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 .../41-texlive-latex-recommended_2017.20180305-1_all.deb ...
Unpacking texlive-latex-recommended (2017.20180305-1) ...
Selecting previously unselected package texlive.
Preparing to unpack .../42-texlive_2017.20180305-1_all.deb ...
Unpacking texlive (2017.20180305-1) ...
Selecting previously unselected package texlive-pictures.
Preparing to unpack .../43-texlive-pictures_2017.20180305-1_all.deb ...
Unpacking texlive-pictures (2017.20180305-1) ...
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack .../44-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 .../45-texlive-plain-generic_2017.20180305-2_all.deb ...
Unpacking texlive-plain-generic (2017.20180305-2) ...
Selecting previously unselected package tipa.
Preparing to unpack .../46-tipa_2%3a1.3-20_all.deb ...
Unpacking tipa (2:1.3-20) ...
Selecting previously unselected package texlive-xetex.
Preparing to unpack .../47-texlive-xetex_2017.20180305-1_all.deb ...
Unpacking texlive-xetex (2017.20180305-1) ...
Setting up libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.12) ...
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 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 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 libcups2:amd64 (2.2.7-1ubuntu2.8) ...
Setting up libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) ...
Setting up libcupsimage2:amd64 (2.2.7-1ubuntu2.8) ...
Setting up libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.12) ...
Setting up lmodern (2.004.5-3) ...
Setting up texlive-binaries (2017.20170613.44572-8ubuntu0.1) ...
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) 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-paper.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/pdftexconfig.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 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 (2.5.1-1ubuntu1.6) ...
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 (2.5.1-1ubuntu1.6) ...
Processing triggers for mime-support (3.60ubuntu1) ...
Processing triggers for libc-bin (2.27-3ubuntu1) ...
/sbin/ldconfig.real: /usr/local/lib/python3.6/dist-
packages/ideep4py/lib/libmkldnn.so.0 is not a symbolic link

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.
Requirement already satisfied: pypandoc in /usr/local/lib/python3.6/dist-
packages (1.5)
Requirement already satisfied: setuptools in /usr/local/lib/python3.6/dist-
packages (from pypandoc) (46.1.3)
Requirement already satisfied: wheel>=0.25.0 in /usr/local/lib/python3.6/dist-
packages (from pypandoc) (0.34.2)
Requirement already satisfied: pip>=8.1.0 in /usr/local/lib/python3.6/dist-
packages (from pypandoc) (19.3.1)
```

[161]:
```
# Export the notebook as pdf
!sudo apt-get update
```

```
Get:1 https://cloud.r-project.org/bin/linux/ubuntu bionic-cran35/ InRelease
[3,626 B]
Ign:2 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
InRelease
Get:3 https://cloud.r-project.org/bin/linux/ubuntu bionic-cran35/ Packages [91.7
kB]
Ign:4 https://developer.download.nvidia.com/compute/machine-
learning/repos/ubuntu1804/x86_64  InRelease
Hit:5 https://developer.download.nvidia.com/compute/cuda/repos/ubuntu1804/x86_64
```

```
Release
Hit:6 https://developer.download.nvidia.com/compute/machine-
learning/repos/ubuntu1804/x86_64  Release
Get:8 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu bionic InRelease
[21.3 kB]
Get:10 http://security.ubuntu.com/ubuntu bionic-security InRelease [88.7 kB]
Hit:11 http://archive.ubuntu.com/ubuntu bionic InRelease
Get:12 http://archive.ubuntu.com/ubuntu bionic-updates InRelease [88.7 kB]
Get:13 http://ppa.launchpad.net/marutter/c2d4u3.5/ubuntu bionic InRelease [15.4
kB]
Get:14 http://security.ubuntu.com/ubuntu bionic-security/main amd64 Packages
[908 kB]
Get:15 http://ppa.launchpad.net/graphics-drivers/ppa/ubuntu bionic/main amd64
Packages [37.4 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic-backports InRelease [74.6 kB]
Get:17 http://security.ubuntu.com/ubuntu bionic-security/restricted amd64
Packages [52.4 kB]
Get:18 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 Packages
[844 kB]
Get:19 http://security.ubuntu.com/ubuntu bionic-security/multiverse amd64
Packages [8,505 B]
Get:20 http://archive.ubuntu.com/ubuntu bionic-updates/restricted amd64 Packages
[66.8 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic-updates/universe amd64 Packages
[1,376 kB]
Get:22 http://ppa.launchpad.net/marutter/c2d4u3.5/ubuntu bionic/main Sources
[1,813 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 Packages
[1,205 kB]
Get:24 http://archive.ubuntu.com/ubuntu bionic-updates/multiverse amd64 Packages
[19.8 kB]
Get:25 http://archive.ubuntu.com/ubuntu bionic-backports/main amd64 Packages
[8,286 B]
Get:26 http://archive.ubuntu.com/ubuntu bionic-backports/universe amd64 Packages
[8,158 B]
Get:27 http://ppa.launchpad.net/marutter/c2d4u3.5/ubuntu bionic/main amd64
Packages [875 kB]
Fetched 7,606 kB in 7s (1,114 kB/s)
Reading package lists... Done
[NbConvertApp] Converting notebook ./gdrive/My Drive/Colab
Notebooks/MAEG5735-2020-Assignment4/FinalAssignment_S1155135359.ipynb to PDF
[NbConvertApp] Support files will be in FinalAssignment_S1155135359_files/
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Writing 164317 bytes to ./notebook.tex
```

```
[NbConvertApp] Building PDF
Traceback (most recent call last):
  File "/usr/local/bin/jupyter-nbconvert", line 8, in <module>
    sys.exit(main())
  File "/usr/local/lib/python2.7/dist-packages/jupyter_core/application.py",
line 267, in launch_instance
    return super(JupyterApp, cls).launch_instance(argv=argv, **kwargs)
  File "/usr/local/lib/python2.7/dist-packages/traitlets/config/application.py",
line 658, in launch_instance
    app.start()
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/nbconvertapp.py", line
338, in start
    self.convert_notebooks()
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/nbconvertapp.py", line
508, in convert_notebooks
    self.convert_single_notebook(notebook_filename)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/nbconvertapp.py", line
479, in convert_single_notebook
    output, resources = self.export_single_notebook(notebook_filename,
resources, input_buffer=input_buffer)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/nbconvertapp.py", line
408, in export_single_notebook
    output, resources = self.exporter.from_filename(notebook_filename,
resources=resources)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/exporters/exporter.py",
line 179, in from_filename
    return self.from_file(f, resources=resources, **kw)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/exporters/exporter.py",
line 197, in from_file
    return self.from_notebook_node(nbformat.read(file_stream, as_version=4),
resources=resources, **kw)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/exporters/pdf.py", line
178, in from_notebook_node
    rc = self.run_latex(tex_file)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/exporters/pdf.py", line
149, in run_latex
    self.latex_count, log_error)
  File "/usr/local/lib/python2.7/dist-packages/nbconvert/exporters/pdf.py", line
111, in run_command
    "at {link}.".format(formatter=command_list[0], link=link))
OSError: xelatex not found on PATH, if you have not installed xelatex you may
need to do so. Find further instructions at
https://nbconvert.readthedocs.io/en/latest/install.html#installing-tex.
```

[163]:
```
!jupyter nbconvert --to PDF "./gdrive/My Drive/Colab Notebooks/
↪MAEG5735-2020-Assignment4/FinalAssignment_S1155135359.ipynb"
```

```
[NbConvertApp] Converting notebook ./gdrive/My Drive/Colab
```

```
Notebooks/MAEG5735-2020-Assignment4/FinalAssignment_S1155135359.ipynb to PDF
[NbConvertApp] Support files will be in FinalAssignment_S1155135359_files/
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Making directory ./FinalAssignment_S1155135359_files
[NbConvertApp] Writing 164317 bytes to ./notebook.tex
[NbConvertApp] Building PDF
[NbConvertApp] Running xelatex 3 times: [u'xelatex', u'./notebook.tex',
'-quiet']
[NbConvertApp] Running bibtex 1 time: [u'bibtex', u'./notebook']
[NbConvertApp] WARNING | bibtex had problems, most likely because there were no
citations
[NbConvertApp] PDF successfully created
[NbConvertApp] Writing 203548 bytes to ./gdrive/My Drive/Colab
Notebooks/MAEG5735-2020-Assignment4/FinalAssignment_S1155135359.pdf
```