CSE527 Homework 6

Due date: 23:59 on Dec. 5, 2019 (Thursday)

In this semester, we will use Google Colab for the assignments, which allows us to utilize resources that some of us might not have in their local machines such as GPUs. You will need to use your Stony Brook (*.stonybrook.edu) account for coding and Google Drive to save your results.

Google Colab Tutorial

Go to https://colab.research.google.com/notebooks/ (https://colab.research.google.com/notebooks/), you will see a tutorial named "Welcome to Colaboratory" file, where you can learn the basics of using google colab.

Settings used for assignments: ***Edit -> Notebook Settings -> Runtime Type (Python 3)***.

Description

In this homework we are going to work on estimating the 3D pose of a person given their 2D pose. Turns out, just regressing the 3D pose coordinates using the 2D pose works pretty well [1] (you can find the paper here (https://arxiv.org/pdf/1705.03098.pdf)). In Part One, we are going to work on reproducing the results of the paper, in Part Two, we are going to try to find a way to handle noisy measurement.

Some Tutorials (PyTorch)

- You will be using PyTorch for deep learning toolbox (follow the link (http://pytorch.org) for installation).
- For PyTorch beginners, please read this tutorial (http://pytorch.org/tutorials/beginner/deep_learning_60min_blitz.html) before doing your homework.
- Feel free to study more tutorials at http://pytorch.org/tutorials/ (http://pytorch.org/tutorials/).
- Find cool visualization here at http://playground.tensorflow.org (http://playground.tensorflow.org).

Starter Code

In the starter code, you are provided with a function that loads data into minibatches for training and testing in PyTorch.

Benchmark

Train for a least 30 epochs to get a least 44mm avg error. The test result(mm error) should be in the following sequence **direct. discuss. eat. greet. phone photo pose purch. sit sitd. somke wait walkd. walk walkT avg**

Problem 1:

{60 points} Let us first start by trying to reproduce the testing accuracy obtained by in the paper ((https://arxiv.org/pdf/1705.03098.pdf) above using PyTorch. The 2D pose of a person is represented as a set of 2D coordinates for each of their $n = 32$ joints i.e P_i^{2D} = $\{(x_i^1, y_i^1), \ldots, (x_i^{32}, y_i^{32})\}$, where (x_i^j, y_i^j) are the 2D coordinates of the j'th joint of the i'th sample. Similarly, the 3D pose of a person is P_i^{3D} = { $(x_i^1, y_i^1, z_i^1), \ldots, (x_i^{32}, y_i^{32}, z_i^{32})\}$, where (x_i^j, y_i^j, z_i^j) are the 3D coordinates of the j'th joint of the i'th sample. The only data given to you is the ground truth 3D pose and the 2D pose calculated using the camera parameters. You are going to train a network $f_\theta : R^{2n} \rightarrow R^{3n}$ that takes as input the P_i^{2D} and tries to regress the ground truth 3D pose P_i^{3D}. The loss function to train this network would be the $L2$ loss between the ground truth and the predicted pose

$$L(\theta) = \sum_{i=1}^{M} (P_i^{3D} - f_\theta(P_i^{2D}))^2; \qquad \text{for a minibatch of size M} \qquad (2)$$

Download the Human3.6M Dataset here (https://www.dropbox.com/s/e35qv3n6zlkouki/h36m.zip).

Bonus: Every 1mm drop in test error from 44mm till 40mm gets you 2 extra points, and every 1mm drop below 40mm gets you 4 extra points.

In [1]:
```
# Mount your google drive where you've saved your assignment folder
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client
_id=947318989803-6bn6qk8qdgf4n4g3pfee6491hc0brc4i.apps.googleusercontent.com&
redirect_uri=urn%3aietf%3awg%3aoauth%3a2.0%3aoob&response_type=code&scope=ema
il%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdocs.test%20https%3a%2f%2fwww.
googleapis.com%2fauth%2fdrive%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdri
ve.photos.readonly%20https%3a%2f%2fwww.googleapis.com%2fauth%2fpeopleapi.read
only

Enter your authorization code:
..........
Mounted at /content/gdrive
```

In [3]:
```
pip install pykalman
```

```
Collecting pykalman
  Downloading https://files.pythonhosted.org/packages/2f/62/a4adc4516bd5974aa
5583090199dd4b78d1e87018d14e9279f72ccbf0b9b/pykalman-0.9.5.tar.gz (228kB)
     |████████████████████████████████| 235kB 6.3MB/s
Building wheels for collected packages: pykalman
  Building wheel for pykalman (setup.py) ... done
  Created wheel for pykalman: filename=pykalman-0.9.5-cp36-none-any.whl size=
48464 sha256=e8f4e21597f4f3f54c03d55d5b696eb469869345fbce8db09f77b9c9a121a9f5
  Stored in directory: /root/.cache/pip/wheels/d9/e8/6a/553d9832679cb74a8434f
a597c3abdb07313e40054a0adf9ac
Successfully built pykalman
Installing collected packages: pykalman
Successfully installed pykalman-0.9.5
```

In [0]:
```
from __future__ import print_function, absolute_import, division

import os
import sys
import time
from pprint import pprint
import numpy as np

import torch
import torch.nn as nn
import torch.optim
import torch.backends.cudnn as cudnn
from torch.utils.data import DataLoader
from torch.autograd import Variable

# Locate to the src folder to import the following functions.
from procrustes import get_transformation
import procrustes
import data_process as data_process
import data_utils
import progress.progress.bar as pBar
import utils as utils
import misc as misc
import log as log
import cameras

from pykalman import KalmanFilter
from sklearn.metrics import mean_squared_error
import matplotlib.pyplot as plt
```

In [0]:
```
# Feel free to use more cells if necessary.
```

In [0]:
```
# Define actions
actions = data_utils.define_actions("All")
```

In [0]:
```
# Load camera parameters
SUBJECT_IDS = [1,5,6,7,8,9,11]
cameras_path = '../data/h36m/cameras.h5'
rcams = cameras.load_cameras(cameras_path, SUBJECT_IDS)
```

In [8]:
```
# Load data
data_dir = '../data/h36m/'
camera_frame = True
predict_14 = False
# Load 3d data and load (or create) 2d projections
train_set_3d, test_set_3d, data_mean_3d, data_std_3d, dim_to_ignore_3d, dim_to
_use_3d, train_root_positions, test_root_positions = data_utils.read_3d_data(
    actions, data_dir, camera_frame, rcams, predict_14 )
```

```
Reading subject 1, action Directions
../data/h36m/S1/MyPoses/3D_positions/Directions*.h5
../data/h36m/S1/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S1/MyPoses/3D_positions/Directions.h5
Reading subject 1, action Discussion
../data/h36m/S1/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S1/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S1/MyPoses/3D_positions/Discussion.h5
Reading subject 1, action Eating
../data/h36m/S1/MyPoses/3D_positions/Eating*.h5
../data/h36m/S1/MyPoses/3D_positions/Eating 2.h5
../data/h36m/S1/MyPoses/3D_positions/Eating.h5
Reading subject 1, action Greeting
../data/h36m/S1/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S1/MyPoses/3D_positions/Greeting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Greeting.h5
Reading subject 1, action Phoning
../data/h36m/S1/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S1/MyPoses/3D_positions/Phoning 1.h5
../data/h36m/S1/MyPoses/3D_positions/Phoning.h5
Reading subject 1, action Photo
../data/h36m/S1/MyPoses/3D_positions/Photo*.h5
../data/h36m/S1/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S1/MyPoses/3D_positions/Photo.h5
Reading subject 1, action Posing
../data/h36m/S1/MyPoses/3D_positions/Posing*.h5
../data/h36m/S1/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S1/MyPoses/3D_positions/Posing.h5
Reading subject 1, action Purchases
../data/h36m/S1/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S1/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S1/MyPoses/3D_positions/Purchases.h5
Reading subject 1, action Sitting
../data/h36m/S1/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S1/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Sitting 2.h5
Reading subject 1, action SittingDown
../data/h36m/S1/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S1/MyPoses/3D_positions/SittingDown 2.h5
../data/h36m/S1/MyPoses/3D_positions/SittingDown.h5
Reading subject 1, action Smoking
../data/h36m/S1/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S1/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S1/MyPoses/3D_positions/Smoking.h5
Reading subject 1, action Waiting
../data/h36m/S1/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S1/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Waiting.h5
Reading subject 1, action WalkDog
../data/h36m/S1/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S1/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S1/MyPoses/3D_positions/WalkDog.h5
Reading subject 1, action Walking
../data/h36m/S1/MyPoses/3D_positions/Walking*.h5
../data/h36m/S1/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S1/MyPoses/3D_positions/Walking.h5
Reading subject 1, action WalkTogether
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../data/h36m/S1/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S1/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S1/MyPoses/3D_positions/WalkTogether.h5
Reading subject 5, action Directions
../data/h36m/S5/MyPoses/3D_positions/Directions*.h5
../data/h36m/S5/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S5/MyPoses/3D_positions/Directions 2.h5
Reading subject 5, action Discussion
../data/h36m/S5/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S5/MyPoses/3D_positions/Discussion 2.h5
../data/h36m/S5/MyPoses/3D_positions/Discussion 3.h5
Reading subject 5, action Eating
../data/h36m/S5/MyPoses/3D_positions/Eating*.h5
../data/h36m/S5/MyPoses/3D_positions/Eating 1.h5
../data/h36m/S5/MyPoses/3D_positions/Eating.h5
Reading subject 5, action Greeting
../data/h36m/S5/MyPoses/3D_positions/Greeting*.h5
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../data/h36m/S5/MyPoses/3D_positions/Greeting 2.h5
Reading subject 5, action Phoning
../data/h36m/S5/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S5/MyPoses/3D_positions/Phoning 1.h5
../data/h36m/S5/MyPoses/3D_positions/Phoning.h5
Reading subject 5, action Photo
../data/h36m/S5/MyPoses/3D_positions/Photo*.h5
../data/h36m/S5/MyPoses/3D_positions/Photo 2.h5
../data/h36m/S5/MyPoses/3D_positions/Photo.h5
Reading subject 5, action Posing
../data/h36m/S5/MyPoses/3D_positions/Posing*.h5
../data/h36m/S5/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S5/MyPoses/3D_positions/Posing.h5
Reading subject 5, action Purchases
../data/h36m/S5/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S5/MyPoses/3D_positions/Purchases 1.h5
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Reading subject 5, action Sitting
../data/h36m/S5/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S5/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S5/MyPoses/3D_positions/Sitting.h5
Reading subject 5, action SittingDown
../data/h36m/S5/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S5/MyPoses/3D_positions/SittingDown 1.h5
../data/h36m/S5/MyPoses/3D_positions/SittingDown.h5
Reading subject 5, action Smoking
../data/h36m/S5/MyPoses/3D_positions/Smoking*.h5
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Reading subject 5, action Waiting
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../data/h36m/S5/MyPoses/3D_positions/Waiting 1.h5
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Reading subject 5, action WalkDog
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../data/h36m/S5/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S5/MyPoses/3D_positions/WalkDog.h5
Reading subject 5, action Walking
../data/h36m/S5/MyPoses/3D_positions/Walking*.h5
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Reading subject 5, action WalkTogether
../data/h36m/S5/MyPoses/3D_positions/WalkTogether*.h5
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Reading subject 6, action Greeting
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Reading subject 6, action Phoning
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../data/h36m/S6/MyPoses/3D_positions/Phoning.h5
Reading subject 6, action Photo
../data/h36m/S6/MyPoses/3D_positions/Photo*.h5
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../data/h36m/S6/MyPoses/3D_positions/Photo.h5
Reading subject 6, action Posing
../data/h36m/S6/MyPoses/3D_positions/Posing*.h5
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Reading subject 6, action Purchases
../data/h36m/S6/MyPoses/3D_positions/Purchases*.h5
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Reading subject 6, action Sitting
../data/h36m/S6/MyPoses/3D_positions/Sitting*.h5
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Reading subject 6, action SittingDown
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../data/h36m/S6/MyPoses/3D_positions/SittingDown.h5
Reading subject 6, action Smoking
../data/h36m/S6/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S6/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S6/MyPoses/3D_positions/Smoking.h5
Reading subject 6, action Waiting
../data/h36m/S6/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S6/MyPoses/3D_positions/Waiting 3.h5
../data/h36m/S6/MyPoses/3D_positions/Waiting.h5
Reading subject 6, action WalkDog
../data/h36m/S6/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S6/MyPoses/3D_positions/WalkDog 1.h5
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Reading subject 6, action Walking
../data/h36m/S6/MyPoses/3D_positions/Walking*.h5
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../data/h36m/S6/MyPoses/3D_positions/Walking.h5
Reading subject 6, action WalkTogether
../data/h36m/S6/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S6/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S6/MyPoses/3D_positions/WalkTogether.h5
Reading subject 7, action Directions
../data/h36m/S7/MyPoses/3D_positions/Directions*.h5
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../data/h36m/S7/MyPoses/3D_positions/Directions.h5
Reading subject 7, action Discussion
../data/h36m/S7/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S7/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S7/MyPoses/3D_positions/Discussion.h5
Reading subject 7, action Eating
../data/h36m/S7/MyPoses/3D_positions/Eating*.h5
../data/h36m/S7/MyPoses/3D_positions/Eating 1.h5
../data/h36m/S7/MyPoses/3D_positions/Eating.h5
Reading subject 7, action Greeting
../data/h36m/S7/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S7/MyPoses/3D_positions/Greeting 1.h5
../data/h36m/S7/MyPoses/3D_positions/Greeting.h5
Reading subject 7, action Phoning
../data/h36m/S7/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S7/MyPoses/3D_positions/Phoning 2.h5
../data/h36m/S7/MyPoses/3D_positions/Phoning.h5
Reading subject 7, action Photo
../data/h36m/S7/MyPoses/3D_positions/Photo*.h5
../data/h36m/S7/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S7/MyPoses/3D_positions/Photo.h5
Reading subject 7, action Posing
../data/h36m/S7/MyPoses/3D_positions/Posing*.h5
../data/h36m/S7/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S7/MyPoses/3D_positions/Posing.h5
Reading subject 7, action Purchases
../data/h36m/S7/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S7/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S7/MyPoses/3D_positions/Purchases.h5
Reading subject 7, action Sitting
../data/h36m/S7/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S7/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S7/MyPoses/3D_positions/Sitting.h5
Reading subject 7, action SittingDown
../data/h36m/S7/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S7/MyPoses/3D_positions/SittingDown 1.h5
../data/h36m/S7/MyPoses/3D_positions/SittingDown.h5
Reading subject 7, action Smoking
../data/h36m/S7/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S7/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S7/MyPoses/3D_positions/Smoking.h5
Reading subject 7, action Waiting
../data/h36m/S7/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S7/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S7/MyPoses/3D_positions/Waiting 2.h5
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```
Reading subject 7, action WalkDog
../data/h36m/S7/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S7/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S7/MyPoses/3D_positions/WalkDog.h5
Reading subject 7, action Walking
../data/h36m/S7/MyPoses/3D_positions/Walking*.h5
../data/h36m/S7/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S7/MyPoses/3D_positions/Walking 2.h5
Reading subject 7, action WalkTogether
../data/h36m/S7/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S7/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S7/MyPoses/3D_positions/WalkTogether.h5
Reading subject 8, action Directions
../data/h36m/S8/MyPoses/3D_positions/Directions*.h5
../data/h36m/S8/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S8/MyPoses/3D_positions/Directions.h5
Reading subject 8, action Discussion
../data/h36m/S8/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S8/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S8/MyPoses/3D_positions/Discussion.h5
Reading subject 8, action Eating
../data/h36m/S8/MyPoses/3D_positions/Eating*.h5
../data/h36m/S8/MyPoses/3D_positions/Eating 1.h5
../data/h36m/S8/MyPoses/3D_positions/Eating.h5
Reading subject 8, action Greeting
../data/h36m/S8/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S8/MyPoses/3D_positions/Greeting 1.h5
../data/h36m/S8/MyPoses/3D_positions/Greeting.h5
Reading subject 8, action Phoning
../data/h36m/S8/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S8/MyPoses/3D_positions/Phoning 1.h5
../data/h36m/S8/MyPoses/3D_positions/Phoning.h5
Reading subject 8, action Photo
../data/h36m/S8/MyPoses/3D_positions/Photo*.h5
../data/h36m/S8/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S8/MyPoses/3D_positions/Photo.h5
Reading subject 8, action Posing
../data/h36m/S8/MyPoses/3D_positions/Posing*.h5
../data/h36m/S8/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S8/MyPoses/3D_positions/Posing.h5
Reading subject 8, action Purchases
../data/h36m/S8/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S8/MyPoses/3D_positions/Purchases.h5
../data/h36m/S8/MyPoses/3D_positions/Purchases 1.h5
Reading subject 8, action Sitting
../data/h36m/S8/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S8/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S8/MyPoses/3D_positions/Sitting.h5
Reading subject 8, action SittingDown
../data/h36m/S8/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S8/MyPoses/3D_positions/SittingDown 1.h5
../data/h36m/S8/MyPoses/3D_positions/SittingDown.h5
Reading subject 8, action Smoking
../data/h36m/S8/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S8/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S8/MyPoses/3D_positions/Smoking.h5
Reading subject 8, action Waiting
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../data/h36m/S8/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S8/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S8/MyPoses/3D_positions/Waiting.h5
Reading subject 8, action WalkDog
../data/h36m/S8/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S8/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S8/MyPoses/3D_positions/WalkDog.h5
Reading subject 8, action Walking
../data/h36m/S8/MyPoses/3D_positions/Walking*.h5
../data/h36m/S8/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S8/MyPoses/3D_positions/Walking.h5
Reading subject 8, action WalkTogether
../data/h36m/S8/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S8/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S8/MyPoses/3D_positions/WalkTogether 2.h5
Reading subject 9, action Directions
../data/h36m/S9/MyPoses/3D_positions/Directions*.h5
../data/h36m/S9/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S9/MyPoses/3D_positions/Directions.h5
Reading subject 9, action Discussion
../data/h36m/S9/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S9/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S9/MyPoses/3D_positions/Discussion 2.h5
Reading subject 9, action Eating
../data/h36m/S9/MyPoses/3D_positions/Eating*.h5
../data/h36m/S9/MyPoses/3D_positions/Eating 1.h5
../data/h36m/S9/MyPoses/3D_positions/Eating.h5
Reading subject 9, action Greeting
../data/h36m/S9/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S9/MyPoses/3D_positions/Greeting 1.h5
../data/h36m/S9/MyPoses/3D_positions/Greeting.h5
Reading subject 9, action Phoning
../data/h36m/S9/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S9/MyPoses/3D_positions/Phoning 1.h5
../data/h36m/S9/MyPoses/3D_positions/Phoning.h5
Reading subject 9, action Photo
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../data/h36m/S9/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S9/MyPoses/3D_positions/Photo.h5
Reading subject 9, action Posing
../data/h36m/S9/MyPoses/3D_positions/Posing*.h5
../data/h36m/S9/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S9/MyPoses/3D_positions/Posing.h5
Reading subject 9, action Purchases
../data/h36m/S9/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S9/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S9/MyPoses/3D_positions/Purchases.h5
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../data/h36m/S9/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S9/MyPoses/3D_positions/Sitting.h5
Reading subject 9, action SittingDown
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../data/h36m/S9/MyPoses/3D_positions/SittingDown 1.h5
../data/h36m/S9/MyPoses/3D_positions/SittingDown.h5
Reading subject 9, action Smoking
../data/h36m/S9/MyPoses/3D_positions/Smoking*.h5
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../data/h36m/S9/MyPoses/3D_positions/Smoking.h5
Reading subject 9, action Waiting
../data/h36m/S9/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S9/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S9/MyPoses/3D_positions/Waiting.h5
Reading subject 9, action WalkDog
../data/h36m/S9/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S9/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S9/MyPoses/3D_positions/WalkDog.h5
Reading subject 9, action Walking
../data/h36m/S9/MyPoses/3D_positions/Walking*.h5
../data/h36m/S9/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S9/MyPoses/3D_positions/Walking.h5
Reading subject 9, action WalkTogether
../data/h36m/S9/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S9/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S9/MyPoses/3D_positions/WalkTogether.h5
Reading subject 11, action Directions
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../data/h36m/S11/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S11/MyPoses/3D_positions/Directions.h5
Reading subject 11, action Discussion
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../data/h36m/S11/MyPoses/3D_positions/Discussion 2.h5
Reading subject 11, action Eating
../data/h36m/S11/MyPoses/3D_positions/Eating*.h5
../data/h36m/S11/MyPoses/3D_positions/Eating 1.h5
../data/h36m/S11/MyPoses/3D_positions/Eating.h5
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../data/h36m/S11/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S11/MyPoses/3D_positions/Greeting 2.h5
../data/h36m/S11/MyPoses/3D_positions/Greeting.h5
Reading subject 11, action Phoning
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../data/h36m/S11/MyPoses/3D_positions/Phoning 3.h5
Reading subject 11, action Photo
../data/h36m/S11/MyPoses/3D_positions/Photo*.h5
../data/h36m/S11/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S11/MyPoses/3D_positions/Photo.h5
Reading subject 11, action Posing
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../data/h36m/S11/MyPoses/3D_positions/Posing.h5
Reading subject 11, action Purchases
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../data/h36m/S11/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S11/MyPoses/3D_positions/Purchases.h5
Reading subject 11, action Sitting
../data/h36m/S11/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S11/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S11/MyPoses/3D_positions/Sitting.h5
Reading subject 11, action SittingDown
../data/h36m/S11/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S11/MyPoses/3D_positions/SittingDown 1.h5
```

```
../data/h36m/S11/MyPoses/3D_positions/SittingDown.h5
Reading subject 11, action Smoking
../data/h36m/S11/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S11/MyPoses/3D_positions/Smoking 2.h5
../data/h36m/S11/MyPoses/3D_positions/Smoking.h5
Reading subject 11, action Waiting
../data/h36m/S11/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S11/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S11/MyPoses/3D_positions/Waiting.h5
Reading subject 11, action WalkDog
../data/h36m/S11/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S11/MyPoses/3D_positions/WalkDog.h5
../data/h36m/S11/MyPoses/3D_positions/WalkDog 1.h5
Reading subject 11, action Walking
../data/h36m/S11/MyPoses/3D_positions/Walking*.h5
../data/h36m/S11/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S11/MyPoses/3D_positions/Walking.h5
Reading subject 11, action WalkTogether
../data/h36m/S11/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S11/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S11/MyPoses/3D_positions/WalkTogether.h5

/content/gdrive/My Drive/CV assignments/Shah_Karan_112715555_hw6/src/data_uti
ls.py:462: FutureWarning: arrays to stack must be passed as a "sequence" type
such as list or tuple. Support for non-sequence iterables such as generators
is deprecated as of NumPy 1.16 and will raise an error in the future.
  complete_train = copy.deepcopy( np.vstack( train_set.values() ))
```

In [9]:
```
# Read stacked hourglass 2D predictions if use_sh, otherwise use groundtruth 2
D projections
use_sh = False
if use_sh:
    train_set_2d, test_set_2d, data_mean_2d, data_std_2d, dim_to_ignore_2d, di
m_to_use_2d = data_utils.read_2d_predictions(actions, data_dir)
else:
    train_set_2d, test_set_2d, data_mean_2d, data_std_2d, dim_to_ignore_2d, di
m_to_use_2d = data_utils.create_2d_data( actions, data_dir, rcams )
print( "done reading and normalizing data." )

stat_3d = {}
stat_3d['mean'] = data_mean_3d
stat_3d['std'] = data_std_3d
stat_3d['dim_use'] = dim_to_use_3d
```

```
Reading subject 1, action Directions
../data/h36m/S1/MyPoses/3D_positions/Directions*.h5
../data/h36m/S1/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S1/MyPoses/3D_positions/Directions.h5
Reading subject 1, action Discussion
../data/h36m/S1/MyPoses/3D_positions/Discussion*.h5
../data/h36m/S1/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S1/MyPoses/3D_positions/Discussion.h5
Reading subject 1, action Eating
../data/h36m/S1/MyPoses/3D_positions/Eating*.h5
../data/h36m/S1/MyPoses/3D_positions/Eating 2.h5
../data/h36m/S1/MyPoses/3D_positions/Eating.h5
Reading subject 1, action Greeting
../data/h36m/S1/MyPoses/3D_positions/Greeting*.h5
../data/h36m/S1/MyPoses/3D_positions/Greeting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Greeting.h5
Reading subject 1, action Phoning
../data/h36m/S1/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S1/MyPoses/3D_positions/Phoning 1.h5
../data/h36m/S1/MyPoses/3D_positions/Phoning.h5
Reading subject 1, action Photo
../data/h36m/S1/MyPoses/3D_positions/Photo*.h5
../data/h36m/S1/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S1/MyPoses/3D_positions/Photo.h5
Reading subject 1, action Posing
../data/h36m/S1/MyPoses/3D_positions/Posing*.h5
../data/h36m/S1/MyPoses/3D_positions/Posing 1.h5
../data/h36m/S1/MyPoses/3D_positions/Posing.h5
Reading subject 1, action Purchases
../data/h36m/S1/MyPoses/3D_positions/Purchases*.h5
../data/h36m/S1/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S1/MyPoses/3D_positions/Purchases.h5
Reading subject 1, action Sitting
../data/h36m/S1/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S1/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Sitting 2.h5
Reading subject 1, action SittingDown
../data/h36m/S1/MyPoses/3D_positions/SittingDown*.h5
../data/h36m/S1/MyPoses/3D_positions/SittingDown 2.h5
../data/h36m/S1/MyPoses/3D_positions/SittingDown.h5
Reading subject 1, action Smoking
../data/h36m/S1/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S1/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S1/MyPoses/3D_positions/Smoking.h5
Reading subject 1, action Waiting
../data/h36m/S1/MyPoses/3D_positions/Waiting*.h5
../data/h36m/S1/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S1/MyPoses/3D_positions/Waiting.h5
Reading subject 1, action WalkDog
../data/h36m/S1/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S1/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S1/MyPoses/3D_positions/WalkDog.h5
Reading subject 1, action Walking
../data/h36m/S1/MyPoses/3D_positions/Walking*.h5
../data/h36m/S1/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S1/MyPoses/3D_positions/Walking.h5
Reading subject 1, action WalkTogether
```

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Reading subject 5, action Directions
../data/h36m/S5/MyPoses/3D_positions/Directions*.h5
../data/h36m/S5/MyPoses/3D_positions/Directions 1.h5
../data/h36m/S5/MyPoses/3D_positions/Directions 2.h5
Reading subject 5, action Discussion
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../data/h36m/S5/MyPoses/3D_positions/Discussion 3.h5
Reading subject 5, action Eating
../data/h36m/S5/MyPoses/3D_positions/Eating*.h5
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Reading subject 5, action Phoning
../data/h36m/S5/MyPoses/3D_positions/Phoning*.h5
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Reading subject 5, action Photo
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Reading subject 5, action Posing
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Reading subject 5, action Purchases
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../data/h36m/S5/MyPoses/3D_positions/Purchases 1.h5
../data/h36m/S5/MyPoses/3D_positions/Purchases.h5
Reading subject 5, action Sitting
../data/h36m/S5/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S5/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S5/MyPoses/3D_positions/Sitting.h5
Reading subject 5, action SittingDown
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../data/h36m/S5/MyPoses/3D_positions/SittingDown 1.h5
../data/h36m/S5/MyPoses/3D_positions/SittingDown.h5
Reading subject 5, action Smoking
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../data/h36m/S5/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S5/MyPoses/3D_positions/Smoking.h5
Reading subject 5, action Waiting
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../data/h36m/S5/MyPoses/3D_positions/Waiting 1.h5
../data/h36m/S5/MyPoses/3D_positions/Waiting 2.h5
Reading subject 5, action WalkDog
../data/h36m/S5/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S5/MyPoses/3D_positions/WalkDog 1.h5
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Reading subject 5, action Walking
../data/h36m/S5/MyPoses/3D_positions/Walking*.h5
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Reading subject 5, action WalkTogether
../data/h36m/S5/MyPoses/3D_positions/WalkTogether*.h5
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../data/h36m/S5/MyPoses/3D_positions/WalkTogether.h5
Reading subject 6, action Directions
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Reading subject 6, action Discussion
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Reading subject 6, action Eating
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Reading subject 6, action Greeting
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Reading subject 6, action Photo
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Reading subject 6, action Posing
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Reading subject 6, action SittingDown
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../data/h36m/S6/MyPoses/3D_positions/SittingDown.h5
Reading subject 6, action Smoking
../data/h36m/S6/MyPoses/3D_positions/Smoking*.h5
../data/h36m/S6/MyPoses/3D_positions/Smoking 1.h5
../data/h36m/S6/MyPoses/3D_positions/Smoking.h5
Reading subject 6, action Waiting
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../data/h36m/S6/MyPoses/3D_positions/Waiting 3.h5
../data/h36m/S6/MyPoses/3D_positions/Waiting.h5
Reading subject 6, action WalkDog
../data/h36m/S6/MyPoses/3D_positions/WalkDog*.h5
../data/h36m/S6/MyPoses/3D_positions/WalkDog 1.h5
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Reading subject 6, action Walking
../data/h36m/S6/MyPoses/3D_positions/Walking*.h5
../data/h36m/S6/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S6/MyPoses/3D_positions/Walking.h5
Reading subject 6, action WalkTogether
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Reading subject 7, action Directions
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Reading subject 7, action Discussion
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../data/h36m/S7/MyPoses/3D_positions/Discussion.h5
Reading subject 7, action Eating
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../data/h36m/S7/MyPoses/3D_positions/Eating.h5
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../data/h36m/S7/MyPoses/3D_positions/Greeting 1.h5
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Reading subject 7, action Phoning
../data/h36m/S7/MyPoses/3D_positions/Phoning*.h5
../data/h36m/S7/MyPoses/3D_positions/Phoning 2.h5
../data/h36m/S7/MyPoses/3D_positions/Phoning.h5
Reading subject 7, action Photo
../data/h36m/S7/MyPoses/3D_positions/Photo*.h5
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Reading subject 7, action Posing
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Reading subject 7, action Purchases
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Reading subject 7, action Sitting
../data/h36m/S7/MyPoses/3D_positions/Sitting*.h5
../data/h36m/S7/MyPoses/3D_positions/Sitting 1.h5
../data/h36m/S7/MyPoses/3D_positions/Sitting.h5
Reading subject 7, action SittingDown
../data/h36m/S7/MyPoses/3D_positions/SittingDown*.h5
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../data/h36m/S7/MyPoses/3D_positions/SittingDown.h5
Reading subject 7, action Smoking
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../data/h36m/S7/MyPoses/3D_positions/Smoking.h5
Reading subject 7, action Waiting
../data/h36m/S7/MyPoses/3D_positions/Waiting*.h5
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../data/h36m/S7/MyPoses/3D_positions/Waiting 2.h5
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../data/h36m/S7/MyPoses/3D_positions/WalkDog 1.h5
../data/h36m/S7/MyPoses/3D_positions/WalkDog.h5
Reading subject 7, action Walking
../data/h36m/S7/MyPoses/3D_positions/Walking*.h5
../data/h36m/S7/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S7/MyPoses/3D_positions/Walking 2.h5
Reading subject 7, action WalkTogether
../data/h36m/S7/MyPoses/3D_positions/WalkTogether*.h5
../data/h36m/S7/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S7/MyPoses/3D_positions/WalkTogether.h5
Reading subject 8, action Directions
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../data/h36m/S8/MyPoses/3D_positions/Directions.h5
Reading subject 8, action Discussion
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../data/h36m/S8/MyPoses/3D_positions/Discussion 1.h5
../data/h36m/S8/MyPoses/3D_positions/Discussion.h5
Reading subject 8, action Eating
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../data/h36m/S8/MyPoses/3D_positions/Purchases 1.h5
Reading subject 8, action Sitting
../data/h36m/S8/MyPoses/3D_positions/Sitting*.h5
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Reading subject 8, action SittingDown
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Reading subject 8, action Waiting
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../data/h36m/S8/MyPoses/3D_positions/WalkDog.h5
Reading subject 8, action Walking
../data/h36m/S8/MyPoses/3D_positions/Walking*.h5
../data/h36m/S8/MyPoses/3D_positions/Walking 1.h5
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Reading subject 8, action WalkTogether
../data/h36m/S8/MyPoses/3D_positions/WalkTogether*.h5
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../data/h36m/S8/MyPoses/3D_positions/WalkTogether 2.h5
Reading subject 9, action Directions
../data/h36m/S9/MyPoses/3D_positions/Directions*.h5
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Reading subject 9, action Discussion
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../data/h36m/S9/MyPoses/3D_positions/Discussion 2.h5
Reading subject 9, action Eating
../data/h36m/S9/MyPoses/3D_positions/Eating*.h5
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../data/h36m/S9/MyPoses/3D_positions/Photo 1.h5
../data/h36m/S9/MyPoses/3D_positions/Photo.h5
Reading subject 9, action Posing
../data/h36m/S9/MyPoses/3D_positions/Posing*.h5
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Reading subject 9, action Walking
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../data/h36m/S9/MyPoses/3D_positions/Walking 1.h5
../data/h36m/S9/MyPoses/3D_positions/Walking.h5
Reading subject 9, action WalkTogether
../data/h36m/S9/MyPoses/3D_positions/WalkTogether*.h5
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Reading subject 11, action Directions
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Reading subject 11, action Eating
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Reading subject 11, action Photo
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Reading subject 11, action Posing
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Reading subject 11, action Purchases
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Reading subject 11, action Sitting
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Reading subject 11, action SittingDown
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Reading subject 11, action Waiting
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Reading subject 11, action Walking
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../data/h36m/S11/MyPoses/3D_positions/Walking 1.h5
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Reading subject 11, action WalkTogether
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../data/h36m/S11/MyPoses/3D_positions/WalkTogether 1.h5
../data/h36m/S11/MyPoses/3D_positions/WalkTogether.h5

/content/gdrive/My Drive/CV assignments/Shah_Karan_112715555_hw6/src/data_uti
ls.py:419: FutureWarning: arrays to stack must be passed as a "sequence" type
such as list or tuple. Support for non-sequence iterables such as generators
is deprecated as of NumPy 1.16 and will raise an error in the future.
  complete_train = copy.deepcopy( np.vstack( train_set.values() ))

done reading and normalizing data.
```

In [0]:
```
# ============================
#   Define Train/Test Methods
# ============================
def train(train_loader, model, criterion, optimizer,
          lr_init=None, lr_now=None, glob_step=None, lr_decay=None, gamma=None
,
          max_norm=True):

    # Write you code here
    losses = utils.AverageMeter()
    model.train()
    all_dist = []

    for i, (inps, tars) in enumerate(train_loader):

        if glob_step == 1:
            lr_now = utils.lr_decay(optimizer, glob_step, lr_init, lr_decay, g
amma)
        glob_step += 1

        inputs = Variable(inps.cuda())
        targets = Variable(tars.cuda(async=True))

        outputs = model(inputs)
        outputs_coord = outputs

        optimizer.zero_grad()
        loss = criterion(outputs, targets)
        losses.update(loss.item(), inputs.size(0))
        loss.backward()

        if max_norm:
            nn.utils.clip_grad_norm_(model.parameters(), max_norm=1) # clippin
g gradients if >1
        optimizer.step()

        tars = targets
        targets_unnorm = data_process.unNormalizeData(tars.data.cpu().numpy(),
stat_3d['mean'], stat_3d['std'], stat_3d['dim_use'])
        outputs_unnorm = data_process.unNormalizeData(outputs.data.cpu().numpy
(), stat_3d['mean'], stat_3d['std'], stat_3d['dim_use'])

        dim_use = np.hstack((np.arange(3), stat_3d['dim_use']))

        outputs_use = outputs_unnorm[:, dim_use]
        targets_use = targets_unnorm[:, dim_use]

        if procrustes:
            for ba in range(inps.size(0)):
                gt = targets_use[ba].reshape(-1, 3)
                out = outputs_use[ba].reshape(-1, 3)
                _, Z, T, b, c = get_transformation(gt, out, True)
                out = (b * out.dot(T)) + c
                outputs_use[ba, :] = out.reshape(1, 51)

        sqerr = (outputs_use - targets_use) ** 2
```

```
        distance = np.zeros((sqerr.shape[0], 17))
        dist_idx = 0
        for k in np.arange(0, 17 * 3, 3):
            distance[:, dist_idx] = np.sqrt(np.sum(sqerr[:, k:k + 3], axis=1))
            dist_idx += 1
        all_dist.append(distance)


    all_dist = np.vstack(all_dist)
    joint_err = np.mean(all_dist, axis=0)
    ttl_err = np.mean(all_dist)

    return glob_step, lr_now, losses.avg, ttl_err


def test(test_loader, model, criterion, stat_3d, procrustes=False):
    losses = utils.AverageMeter()

    model.eval()

    all_dist = []
    start = time.time()
    batch_time = 0
    bar = pBar.Bar('>>>', fill='>', max=len(test_loader))

    for i, (inps, tars) in enumerate(test_loader):
        inputs = Variable(inps.cuda())
        # inputs = Variable()

        targets = Variable(tars.cuda(async=True))
        # targets = Variable()

        outputs = model(inputs)

        # calculate loss
        outputs_coord = outputs
        loss = criterion(outputs_coord, targets)

        losses.update(loss.item(), inputs.size(0))

        tars = targets

        # calculate erruracy
        targets_unnorm = data_process.unNormalizeData(tars.data.cpu().numpy(),
stat_3d['mean'], stat_3d['std'], stat_3d['dim_use'])
        outputs_unnorm = data_process.unNormalizeData(outputs.data.cpu().numpy
(), stat_3d['mean'], stat_3d['std'], stat_3d['dim_use'])

        # remove dim ignored
        dim_use = np.hstack((np.arange(3), stat_3d['dim_use']))

        outputs_use = outputs_unnorm[:, dim_use]
        targets_use = targets_unnorm[:, dim_use]

        if procrustes:
            for ba in range(inps.size(0)):
```

```
                gt = targets_use[ba].reshape(-1, 3)
                out = outputs_use[ba].reshape(-1, 3)
                _, Z, T, b, c = get_transformation(gt, out, True)
                out = (b * out.dot(T)) + c
                outputs_use[ba, :] = out.reshape(1, 51)

        sqerr = (outputs_use - targets_use) ** 2

        distance = np.zeros((sqerr.shape[0], 17))
        dist_idx = 0
        for k in np.arange(0, 17 * 3, 3):
            distance[:, dist_idx] = np.sqrt(np.sum(sqerr[:, k:k + 3], axis=1))
            dist_idx += 1
        all_dist.append(distance)

        # update summary
        if (i + 1) % 100 == 0:
            batch_time = time.time() - start
            start = time.time()

        bar.suffix = '({batch}/{size}) | batch: {batchtime:.4}ms | Total: {tt
l} | ETA: {eta:} | loss: {loss:.6f}' \
            .format(batch=i + 1,
                    size=len(test_loader),
                    batchtime=batch_time * 10.0,
                    ttl=bar.elapsed_td,
                    eta=bar.eta_td,
                    loss=losses.avg)
        bar.next()

    all_dist = np.vstack(all_dist)
    joint_err = np.mean(all_dist, axis=0)
    ttl_err = np.mean(all_dist)
    bar.finish()
    print (">>> error: {} <<<".format(ttl_err))
    return losses.avg, ttl_err
```

In [0]:
```
# ==================
#   Dataset class
# ==================
from torch.utils.data import Dataset
TRAIN_SUBJECTS = [1, 5, 6, 7, 8]
TEST_SUBJECTS = [9, 11]

class Human36M(Dataset):
    def __init__(self, actions, data_path, use_hg=True, is_train=True):
        """
        :param actions: list of actions to use
        :param data_path: path to dataset
        :param use_hg: use stacked hourglass detections
        :param is_train: load train/test dataset
        """

        # Write you code here

        self.train_inp, self.train_out, self.test_inp, self.test_out = [], [],
[], []

        # Write you code here
        self.is_train = is_train
        self.actions = actions

        if self.is_train:
            self.train_3d = train_set_3d
            self.train_2d = train_set_2d
            for key in self.train_2d.keys():
                if key[0] in TRAIN_SUBJECTS:
                  for i in range(len(self.train_2d[key])):
                      self.train_inp.append(self.train_2d[key][i])
                      self.train_out.append(self.train_3d[key][i])
                else:
                  print("ignoring", key)

        else:
            self.test_3d = test_set_3d
            self.test_2d = test_set_2d
            for key in self.test_2d.keys():
                if key[1] not in self.actions:
                    continue
                if key[0] in TEST_SUBJECTS:
                  for i in range(len(self.test_2d[key])):
                      self.test_inp.append(self.test_2d[key][i])
                      self.test_out.append(self.test_3d[key][i])
                else:
                  print("ignoring", key)

    def __getitem__(self, index):
        if self.is_train:
            inputs = torch.from_numpy(self.train_inp[index])
            outputs = torch.from_numpy(self.train_out[index])
        else:
            inputs = torch.from_numpy(self.test_inp[index])
            outputs = torch.from_numpy(self.test_out[index])
```

```
        return inputs.float(), outputs.float()

    def __len__(self):
      return len(self.train_inp) if self.is_train else len(self.test_inp)
```

In [0]:
```
# ========================================
#       Define Network Architecture
# ========================================
def weight_init(m):
    if isinstance(m, nn.Linear):
        nn.init.kaiming_normal_(m.weight)

# Write you code here
class network(nn.Module):
    def __init__(self):
        super(network, self).__init__()

        self.input_size =  32
        self.output_size = 48

        self.first = nn.Linear(self.input_size, 1024)
        self.batch_norm = nn.BatchNorm1d(1024)
        self.mid1 = nn.Linear(1024, 1024)
        self.batch_norm1 = nn.BatchNorm1d(1024)
        self.mid2 = nn.Linear(1024, 1024)
        self.batch_norm2 = nn.BatchNorm1d(1024)
        self.mid3 = nn.Linear(1024, 1024)
        self.batch_norm3 = nn.BatchNorm1d(1024)
        self.mid4 = nn.Linear(1024, 1024)
        self.batch_norm4 = nn.BatchNorm1d(1024)
        self.last = nn.Linear(1024, self.output_size)

        self.relu = nn.ReLU(inplace=True)
        self.dropout = nn.Dropout(0.5)

    def forward(self, x): # architecture as mentioned in paper
        #initial
        y = self.first(x)
        y1 = self.dropout(self.relu(self.batch_norm(y)))

        #block1
        y = self.mid1(y1)
        y = self.dropout(self.relu(self.batch_norm1(y)))

        y = self.mid2(y)
        y = self.dropout(self.relu(self.batch_norm2(y)))

        y1 = y + y1

        #block2
        y = self.mid3(y1)
        y = self.dropout(self.relu(self.batch_norm3(y)))

        y = self.mid4(y)
        y = self.dropout(self.relu(self.batch_norm4(y)))

        y1 = y + y1

        #last
        y = self.last(y1)
        return y
```

In [25]:
```
# ========================================
#         load dadasets for training
# ========================================
job = 8
use_hg = False
batch_size = 64
train_loader = DataLoader(dataset=Human36M(actions=actions, data_path=None, us
e_hg=use_hg, is_train=True), batch_size=batch_size, shuffle=True, num_workers=
job, pin_memory=True)
test_loader = DataLoader(dataset=Human36M(actions=actions, data_path=None, use
_hg=use_hg, is_train=False), batch_size=batch_size, shuffle=False, num_workers
=job, pin_memory=True)

print(">>> data loaded !")
```

```
>>> data loaded !
```

In [0]:
```
# ========================================
#         Optimize/Train Network
# ========================================

# Write you code here
epochs = 33
lr = 1e-3
lr_now = lr
glob_step = 1
lr_decay = 1e+5 # decay_steps
gamma = 1 # decay_rate
max_norm=True # grad clip
procrustes = True
model = network().cuda()
model.apply(weight_init)
criterion = nn.MSELoss().cuda()
optimizer = torch.optim.Adam(model.parameters(), lr=lr)

print("Training Started!")
minerr = 45
for epoch in range(epochs):
  glob_step, lr_now, loss_train, err_train = train(train_loader, model, criter
ion, optimizer, lr_init=lr, lr_now=lr_now, glob_step=glob_step, lr_decay=lr_de
cay, gamma=gamma, max_norm=max_norm)
  loss_test, err_test = test(test_loader, model, criterion, stat_3d, procruste
s=procrustes)
  if err_test < minerr:
    torch.save({'state_dict': model.state_dict()}, 'model_' + str(err_test)[:5
]+ '.pth')
    minerr = err_test
  print("epoch=>", epoch+1, "train loss=>", loss_train, 'train err=>', err_tra
in, "test loss=>", loss_test, 'test err=>', err_test)
```

```
Training Started!
>>> error: 43.621140677966395 <<<
epoch=> 1 train loss=> 0.14857783601524796 train err=> 63.5091663485707 test
loss=> 0.06039729385394094 test err=> 43.621140677966395
>>> error: 42.180654098510296 <<<
epoch=> 2 train loss=> 0.08838798123088872 train err=> 54.096579669017345 tes
t loss=> 0.053470068064951304 test err=> 42.180654098510296
>>> error: 40.18234031262952 <<<
epoch=> 3 train loss=> 0.07891043309433368 train err=> 51.724752043416245 tes
t loss=> 0.04866748149032261 test err=> 40.18234031262952
>>> error: 39.770933041002706 <<<
epoch=> 4 train loss=> 0.07357698309408638 train err=> 50.23462907393977 test
loss=> 0.047437847736694426 test err=> 39.770933041002706
>>> error: 38.851327343536795 <<<
epoch=> 5 train loss=> 0.0700178521905287 train err=> 49.20557405868452 test
loss=> 0.04553114627111095 test err=> 38.851327343536795
>>> error: 37.973789048489344 <<<
epoch=> 6 train loss=> 0.06737875683351156 train err=> 48.39474640272409 test
loss=> 0.04401948659594438 test err=> 37.973789048489344
>>> error: 38.589545235921705 <<<
epoch=> 7 train loss=> 0.06518134682333764 train err=> 47.72895542815677 test
loss=> 0.044183931438742316 test err=> 38.589545235921705
>>> error: 37.31133051362759 <<<
epoch=> 8 train loss=> 0.06351478237568305 train err=> 47.18862100197925 test
loss=> 0.04271303998937559 test err=> 37.31133051362759
>>> error: 37.62186042055349 <<<
epoch=> 9 train loss=> 0.062031888213986336 train err=> 46.7275544973826 test
loss=> 0.043561393016363185 test err=> 37.62186042055349
>>> error: 37.40909117437141 <<<
epoch=> 10 train loss=> 0.06074309289392437 train err=> 46.306983510355465 te
st loss=> 0.0428757334999113 test err=> 37.40909117437141
>>> error: 37.07965265828307 <<<
epoch=> 11 train loss=> 0.05969554087656865 train err=> 45.96160990216594 tes
t loss=> 0.04311892680902741 test err=> 37.07965265828307
>>> error: 36.40697613347255 <<<
epoch=> 12 train loss=> 0.058902773636654505 train err=> 45.68418028630166 te
st loss=> 0.04138261260957074 test err=> 36.40697613347255
>>> error: 36.92361210583902 <<<
epoch=> 13 train loss=> 0.05811427716664839 train err=> 45.422471767917564 te
st loss=> 0.04276394107225115 test err=> 36.92361210583902
>>> error: 36.979769049890216 <<<
epoch=> 14 train loss=> 0.05734240349212357 train err=> 45.17159896944368 tes
t loss=> 0.04315361294693885 test err=> 36.979769049890216
>>> error: 36.85994780586125 <<<
epoch=> 15 train loss=> 0.05681664623175921 train err=> 44.96166833633186 tes
t loss=> 0.04307227682281753 test err=> 36.85994780586125
>>> error: 36.566519469700324 <<<
epoch=> 16 train loss=> 0.056245278102639684 train err=> 44.76796257882894 te
st loss=> 0.04203211659301084 test err=> 36.566519469700324
>>> error: 36.32262982076761 <<<
epoch=> 17 train loss=> 0.055822317558055674 train err=> 44.62037545509418 te
st loss=> 0.04085919032143323 test err=> 36.32262982076761
>>> error: 35.96910319707578 <<<
epoch=> 18 train loss=> 0.05541479579254811 train err=> 44.4713749398782 test
loss=> 0.041257366868141944 test err=> 35.96910319707578
>>> error: 36.6621535558623 <<<
epoch=> 19 train loss=> 0.05502047829243183 train err=> 44.326995236247136 te
```

```
st loss=> 0.042561623001119674 test err=> 36.6621535558623
>>> error: 36.06553015381839 <<<
epoch=> 20 train loss=> 0.05468901474787205 train err=> 44.2146842701275 test
loss=> 0.04048459096381064 test err=> 36.06553015381839
>>> error: 36.008001826257264 <<<
epoch=> 21 train loss=> 0.054333591119363436 train err=> 44.08956197050218 te
st loss=> 0.041127225440072246 test err=> 36.008001826257264
>>> error: 36.719686916177025 <<<
epoch=> 22 train loss=> 0.05409847791609928 train err=> 44.01659387089851 tes
t loss=> 0.04176141658241871 test err=> 36.719686916177025
>>> error: 35.898149844722404 <<<
epoch=> 23 train loss=> 0.053821352991049363 train err=> 43.89689566596262 te
st loss=> 0.04076342353264334 test err=> 35.898149844722404
>>> error: 35.671552756482946 <<<
epoch=> 24 train loss=> 0.05355094720348497 train err=> 43.83302117478348 tes
t loss=> 0.04017110175450914 test err=> 35.671552756482946
>>> error: 35.619824606820934 <<<
epoch=> 25 train loss=> 0.053405526875183934 train err=> 43.770519234537 test
loss=> 0.0401069489073046 test err=> 35.619824606820934
>>> error: 35.88132870398785 <<<
epoch=> 26 train loss=> 0.05322563563908109 train err=> 43.70551586318289 tes
t loss=> 0.040734814312951596 test err=> 35.88132870398785
>>> error: 36.59013788132852 <<<
epoch=> 27 train loss=> 0.05305887585919674 train err=> 43.64258984696296 tes
t loss=> 0.04336916493938019 test err=> 36.59013788132852
>>> error: 36.82485837758229 <<<
epoch=> 28 train loss=> 0.052875478082841446 train err=> 43.588589877864806 t
est loss=> 0.042916167041774214 test err=> 36.82485837758229
>>> error: 35.574652556052904 <<<
epoch=> 29 train loss=> 0.05277607940089886 train err=> 43.540136093919735 te
st loss=> 0.03985584531763199 test err=> 35.574652556052904
>>> error: 36.001284260252746 <<<
epoch=> 30 train loss=> 0.0525636594501577 train err=> 43.479862313118105 tes
t loss=> 0.04138762588001481 test err=> 36.001284260252746
>>> error: 36.29210871869267 <<<
epoch=> 31 train loss=> 0.05254528378793907 train err=> 43.44849954866651 tes
t loss=> 0.04163091286974572 test err=> 36.29210871869267
>>> error: 35.64194610882941 <<<
epoch=> 32 train loss=> 0.05245966062898435 train err=> 43.41767437698581 tes
t loss=> 0.04013559883964352 test err=> 35.64194610882941
>>> error: 35.67522217632983 <<<
epoch=> 33 train loss=> 0.052445732875909826 train err=> 43.42120279334235 te
st loss=> 0.04020390706009973 test err=> 35.67522217632983
```

In [18]:
```
model = network().cuda()
model.load_state_dict(torch.load('model_35.57.pth')['state_dict'])
model.eval()
```

Out[18]:
```
network(
  (first): Linear(in_features=32, out_features=1024, bias=True)
  (batch_norm): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, track
_running_stats=True)
  (mid1): Linear(in_features=1024, out_features=1024, bias=True)
  (batch_norm1): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, trac
k_running_stats=True)
  (mid2): Linear(in_features=1024, out_features=1024, bias=True)
  (batch_norm2): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, trac
k_running_stats=True)
  (mid3): Linear(in_features=1024, out_features=1024, bias=True)
  (batch_norm3): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, trac
k_running_stats=True)
  (mid4): Linear(in_features=1024, out_features=1024, bias=True)
  (batch_norm4): BatchNorm1d(1024, eps=1e-05, momentum=0.1, affine=True, trac
k_running_stats=True)
  (last): Linear(in_features=1024, out_features=48, bias=True)
  (relu): ReLU(inplace=True)
  (dropout): Dropout(p=0.5, inplace=False)
)
```

In [32]:
```
# ========================================
#            Evaluating Network
# ========================================

err_set = []
for action in actions:
    print (">>> TEST on _{}_".format(action))
    test_loader = DataLoader(
                  dataset=Human36M(actions=action, data_path=data_dir, use_hg=us
e_hg, is_train=False),
                  batch_size=batch_size,
                  shuffle=False,
                  num_workers=job,
                  pin_memory=True)
    _, err_test = test(test_loader, model, criterion, stat_3d, procrustes=proc
rustes)
    err_set.append(err_test)

print (">>>>>> TEST results:")
for action in actions:
    print ("{}".format(action), end='\t')
print ("\n")
for err in err_set:
    print ("{:.4f}".format(err), end='\t')
print (">>>\nERRORS: {}".format(np.array(err_set).mean()))
```

```
>>> TEST on _Directions_
>>> error: 29.431925032316958 <<<
>>> TEST on _Discussion_
>>> error: 33.343995623113535 <<<
>>> TEST on _Eating_
>>> error: 31.75132871025416 <<<
>>> TEST on _Greeting_
>>> error: 34.425913797112266 <<<
>>> TEST on _Phoning_
>>> error: 35.80718585140732 <<<
>>> TEST on _Photo_
>>> error: 41.04975678720734 <<<
>>> TEST on _Posing_
>>> error: 34.73772762003982 <<<
>>> TEST on _Purchases_
>>> error: 30.88072093357265 <<<
>>> TEST on _Sitting_
>>> error: 40.968463251932334 <<<
>>> TEST on _SittingDown_
>>> error: 43.78295176432944 <<<
>>> TEST on _Smoking_
>>> error: 37.036448305489245 <<<
>>> TEST on _Waiting_
>>> error: 35.563704986073766 <<<
>>> TEST on _WalkDog_
>>> error: 37.49565340731514 <<<
>>> TEST on _Walking_
>>> error: 30.033912927260978 <<<
>>> TEST on _WalkTogether_
>>> error: 31.69926405292038 <<<
>>>>>> TEST results:
Directions      Discussion      Eating  Greeting        Phoning Photo   Posin
g       Purchases       Sitting SittingDown     Smoking Waiting WalkDog Walki
ng      WalkTogether

29.4319 33.3440 31.7513 34.4259 35.8072 41.0498 34.7377 30.8807 40.9685 43.78
30      37.0364 35.5637 37.4957 30.0339 31.6993 >>>
ERRORS: 35.20059687002303
```

Report the test result(mm error) in the following sequence **direct. discuss. eat. greet. phone photo pose purch. sit sitd. somke wait walkd. walk walkT avg**

Problem 2:

{40 points} In this task, we're going to tackle the situation of having a faulty 3D sensor. Since the sensor is quite old it's joint detections are quite noisy:

$$\hat{x} = x_{GT} + \epsilon_x$$
$$\hat{y} = y_{GT} + \epsilon_y$$
$$\hat{z} = z_{GT} + \epsilon_z$$

Where, (x_{GT}, y_{GT}, z_{GT}) are the ground truth joint locations, $(\hat{x}, \hat{y}, \hat{z})$ are the noisy measurements detected by our sensor and $(\epsilon_x, \epsilon_y, \epsilon_z)$ are the noise values. Being grad students, we'd much rather the department spend money for free coffee and doughnuts than on a new 3D sensor. Therefore, you're going to denoise the noisy data using a linear Kalman filter.

Modelling the state using velocity and acceleration: We assume a simple, if unrealistic model, of our system - we're only going to use the position, velocity and acceleration of the joints to denoise the data. The underlying equations representing our assumptions are:

$$x_{t+1} = x_t + \frac{\partial x_t}{\partial t}\delta t + 0.5 * \frac{\partial^2 x_t}{\partial t^2}\delta t^2 \qquad (1)$$
$$y_{t+1} = y_t + \frac{\partial y_t}{\partial t}\delta t + 0.5 * \frac{\partial^2 y_t}{\partial t^2}\delta t^2 \qquad (2)$$
$$z_{t+1} = z_t + \frac{\partial z_t}{\partial t}\delta t + 0.5 * \frac{\partial^2 z_t}{\partial t^2}\delta t^2 \qquad (3)$$

The only measurements/observations we have (i.e our 'observation space') are the noisy joint locations as recorded by the 3D sensors $o_t = (\hat{x}_t, \hat{y}_t, \hat{z}_t)$. The corresponding state-space would be $z_t = (x_t, y_t, z_t, \frac{\partial x_t}{\partial t}, \frac{\partial y_t}{\partial t}, \frac{\partial z_t}{\partial t}, \frac{\partial^2 x_t}{\partial t^2}, \frac{\partial^2 y_t}{\partial t^2}, \frac{\partial^2 z_t}{\partial t^2})$.

Formallly, a linear Kalman filter assumes the underlying dynamics of the system to be a linear Gaussian model i.e.

$$z_0 \sim N(\mu_0, \Sigma_0)$$
$$z_{t+1} = Az_t + b + \epsilon_t^1$$
$$o_t = Cz_t + d + \epsilon_t^2$$
$$\epsilon_t^1 \sim N(0, Q)$$
$$\epsilon_t^2 \sim N(0, R)$$

where, A and C are the `transition_matrix` and `observation_matrix` respectively, that you are going to define based on equations (1), (2) and (3). The intitial estimates of other parameters can be assumed as:

$$\texttt{initial\_state\_mean} := \mu_0 = mean(given\ data)$$
$$\texttt{initial\_state\_covariance} := \Sigma_0 = Cov(given\ data)$$
$$\texttt{transition\_offset} := b = 0$$
$$\texttt{observation\_offset} := d = 0$$
$$\texttt{transition\_covariance} := Q = I$$
$$\texttt{observation\_covariance} := R = I$$

The covariance matrices Q and R are hyperparameters that we initalize as identity matrices. In the code below, you must define A and C and use pykalman (https://pykalman.github.io/), a dedicated library for kalman filtering in python, to filter out the noise in the data.

(**Hint:** \ Gradients could be calculated using `np.gradient` or manually using finite differences \ You can assume the frame rate to be 50Hz)

For more detailed resources related to Kalman filtering, please refer to: \
http://web.mit.edu/kirtley/kirtley/binlustuff/literature/control/Kalman%20filter.pdf (http://web.mit.edu/kirtley/kirtley/binlustuff/literature/control/Kalman%20filter.pdf) \ https://www.bzarg.com/p/how-a-kalman-filter-works-in-pictures/ (https://www.bzarg.com/p/how-a-kalman-filter-works-in-pictures/) \ https://stanford.edu/class/ee363/lectures/kf.pdf (https://stanford.edu/class/ee363/lectures/kf.pdf)

In [0]:
```
'''================Function definition of the Kalman filter, which will retur
n the filtered 3D world coordinates=========================='''
'''================Students need to fill this part=============================
====='''
def KF_filter(full_data):


    '''------------------TO DO-------------------
    '''
    '''--------Define the Kalman filter and filter the noisy signal-----------
-'''
    filtered_data = list()

    # iterating for each joint
    for i in range(0, full_data.shape[-1], 3):
      loc_data = full_data[...,i:i+3]
      vel_data = np.gradient(loc_data, axis=-1)
      acc_data = np.gradient(vel_data, axis=-1)
      data = np.concatenate([loc_data, vel_data, acc_data], axis=-1)

      dt = 1/50

      transition_matrix = np.array([[1, 0,  0,  dt,  0,   0, 0.5*dt**2,
0,         0    ],
                                    [0, 1,  0,  0,   dt,  0,    0,        0.5*
dt**2,     0,   ],
                                    [0, 0,  1,  0,   0,   dt,   0,
0,     0.5*dt**2],
                                    [0, 0,  0,  1,   0,   0,    dt,
0,         0    ],
                                    [0, 0,  0,  0,   1,   0,    0,
dt,        0    ],
                                    [0, 0,  0,  0,   0,   1,    0,
0,         dt   ],
                                    [0, 0,  0,  0,   0,   0,    1,
0,         0    ],
                                    [0, 0,  0,  0,   0,   0,    0,
1,         0    ],
                                    [0, 0,  0,  0,   0,   0,    0,
0,         1    ]
                                    ])
      observation_matrix = np.zeros((3,9))
      observation_matrix[0,0] = 1
      observation_matrix[1,1] = 1
      observation_matrix[2,2] = 1

      transition_covariance = np.identity(9, dtype=int)
      observation_covariance = np.identity(3, dtype=int)
      transition_offsets = np.zeros(9)
      observation_offsets = np.zeros(3)
      initial_state_mean = np.mean(data, axis=0)
      initial_state_covariance = np.cov(data.T)
      random_state = 42
      n_dim_state = 9
      n_dim_obs = 3
```

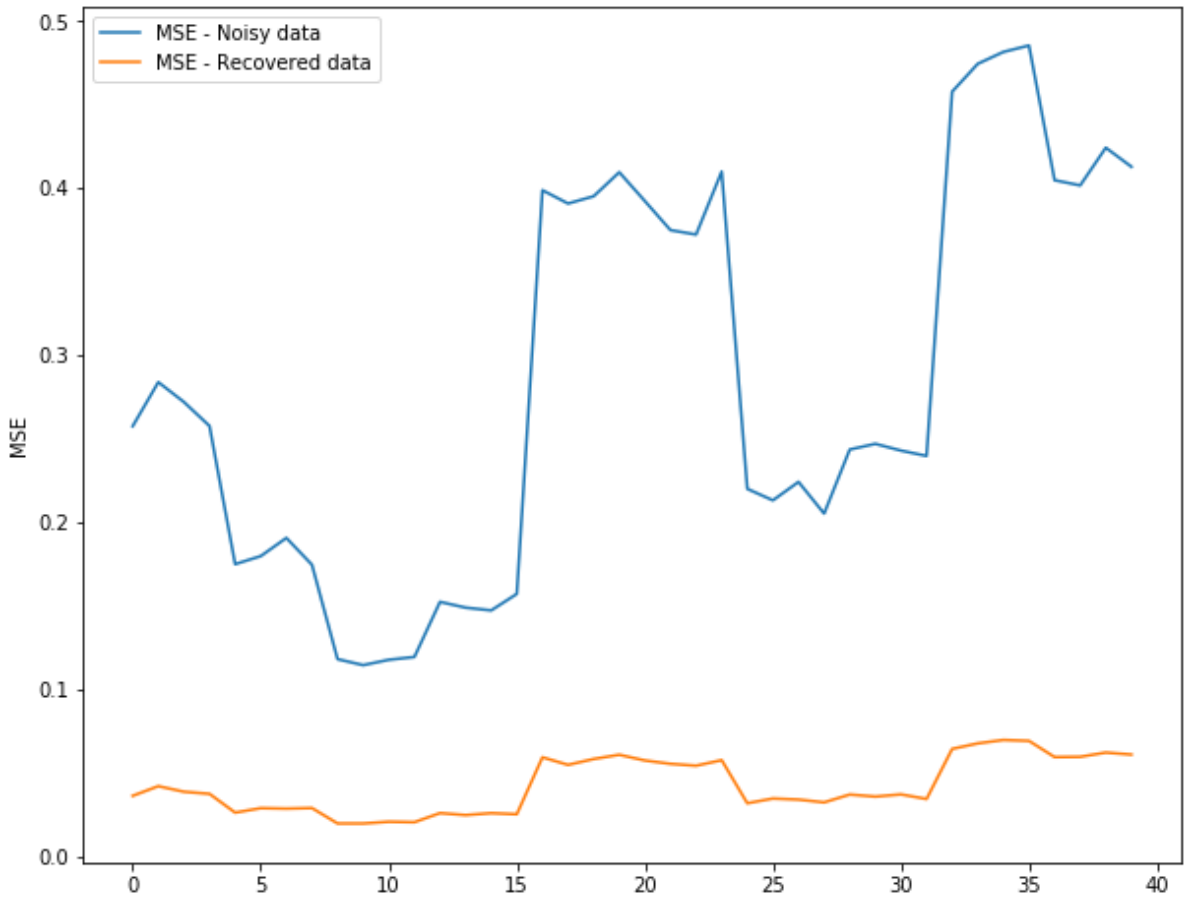
```
      kf = KalmanFilter(transition_matrices = transition_matrix,
                  observation_matrices = observation_matrix,
                  transition_covariance = transition_covariance,
                  observation_covariance = observation_covariance,
                  transition_offsets = transition_offsets,
                  observation_offsets = observation_offsets,
                  initial_state_mean = initial_state_mean,
                  initial_state_covariance = initial_state_covariance,
                  random_state = random_state,
                  n_dim_state = n_dim_state,
                  n_dim_obs = n_dim_obs
                  )

      [smoothed_state_means , smoothed_state_covariances  ] = kf.em(loc_data).
smooth(loc_data)
      filtered_data.append(smoothed_state_means[...,:3])

    filtered_data = np.concatenate(filtered_data, axis=-1)
    return filtered_data
```

In [0]:

```
noisy_stat = []
recovered_stat = []

for keys in list(train_set_3d.keys())[:40]:

    true_state = train_set_3d[keys]
    cov = np.cov(true_state.T)

    noise = np.random.multivariate_normal(mean = np.zeros(true_state.shape[1
]), cov = cov, size = true_state.shape[0])
    noisy_observation = true_state + noise

    filtered_onservation = KF_filter(noisy_observation)
    noisy_stat.append(mean_squared_error(true_state, noisy_observation))
    recovered_stat.append(mean_squared_error(true_state, filtered_onservation
))
```

In [0]:
```
## Plotting the results (tentetive)
# complete this
fig = plt.figure(figsize=(10,8))
plt.plot(noisy_stat, label = 'MSE - Noisy data')
plt.plot(recovered_stat, label = 'MSE - Recovered data')
plt.ylabel('MSE')
plt.legend()
```

Out[0]: <matplotlib.legend.Legend at 0x7fee4400d080>



References

[1] J. Martinez, R. Hossain, J. Romero, and J. J. Little, “A simple yet effective baseline for 3d human pose estimation,” in ICCV, 2017.