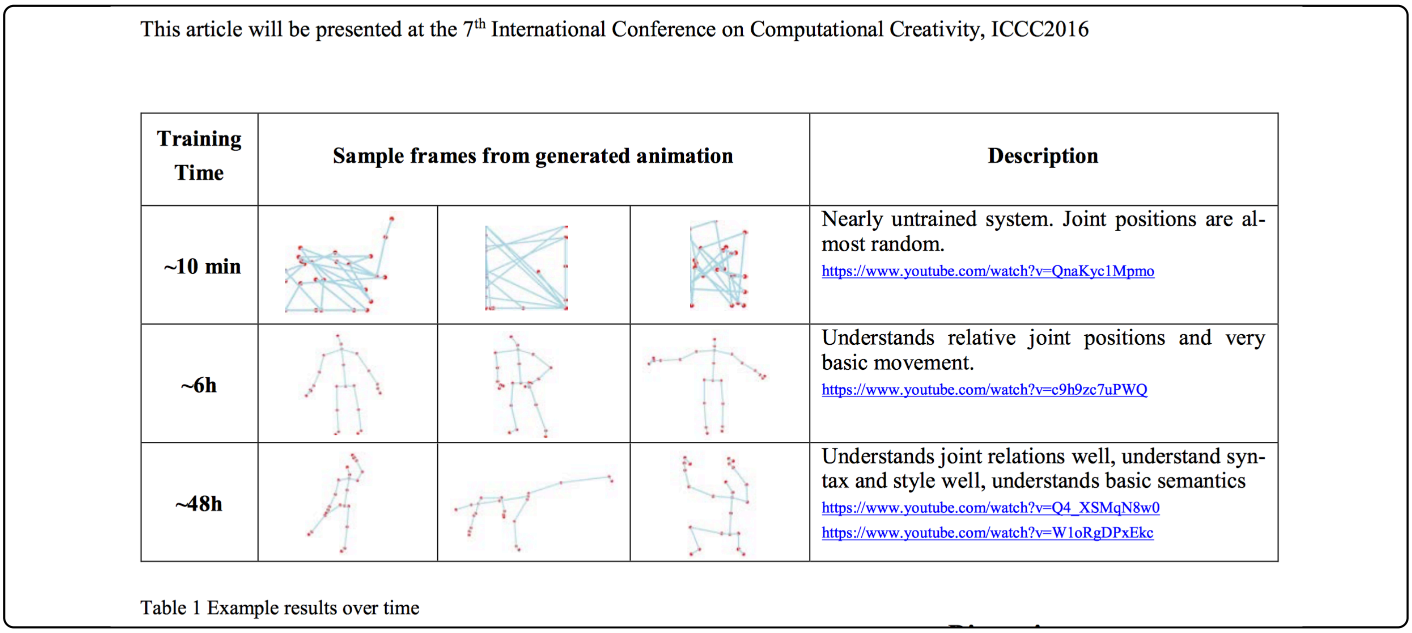
```
In [54]: %load_ext do_not_print_href
```

Motion Generation Example using RNN

- “Generative Choreography using Deep Learning”, Luka Crnkovic-Friis, Louise Crnkovic-Friis, 2016 (arXiv:1605.06921)



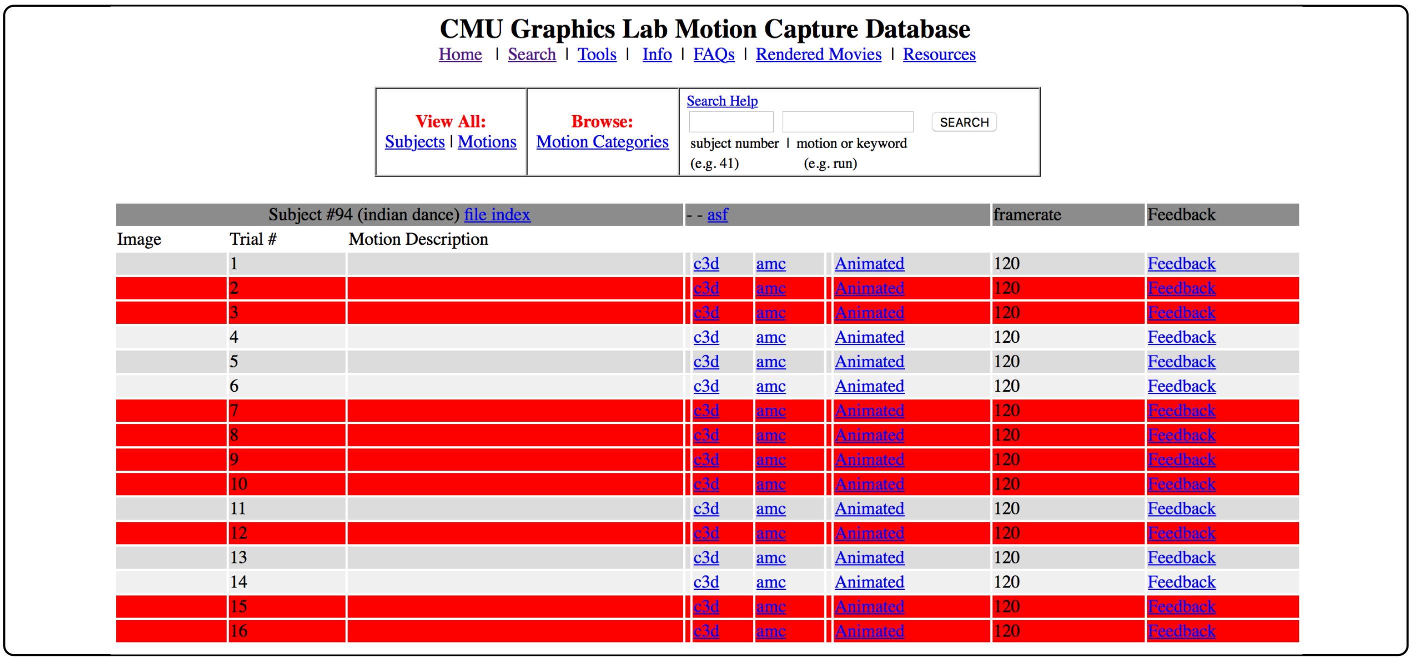
This article will be presented at the 7th International Conference on Computational Creativity, ICCC2016

Training Time	Sample frames from generated animation			Description
~10 min				Nearly untrained system. Joint positions are almost random. https://www.youtube.com/watch?v=QnaKyc1Mpmo
~6h				Understands relative joint positions and very basic movement. https://www.youtube.com/watch?v=c9h9zc7uPWQ
~48h				Understands joint relations well, understand syntax and style well, understands basic semantics https://www.youtube.com/watch?v=Q4_XSMqN8w0 https://www.youtube.com/watch?v=W1oRgDPxEkc

Table 1 Example results over time

motion capture data sample

- CMU motion caption data
  - http://mocap.cs.cmu.edu
  - "Subject #94 (indian dance)"



CMU Graphics Lab Motion Capture Database

Home | Search | Tools | Info | FAQs | Rendered Movies | Resources

View All: Subjects | Motions	Browse: Motion Categories	Search Help SEARCH subject number (e.g. 41) | motion or keyword (e.g. run)

Subject #94 (indian dance) file index			- - asf			framerate	Feedback
Image	Trial #	Motion Description					
	1		c3d	amc	Animated	120	Feedback
	2		c3d	amc	Animated	120	Feedback
	3		c3d	amc	Animated	120	Feedback
	4		c3d	amc	Animated	120	Feedback
	5		c3d	amc	Animated	120	Feedback
	6		c3d	amc	Animated	120	Feedback
	7		c3d	amc	Animated	120	Feedback
	8		c3d	amc	Animated	120	Feedback
	9		c3d	amc	Animated	120	Feedback
	10		c3d	amc	Animated	120	Feedback
	11		c3d	amc	Animated	120	Feedback
	12		c3d	amc	Animated	120	Feedback
	13		c3d	amc	Animated	120	Feedback
	14		c3d	amc	Animated	120	Feedback
	15		c3d	amc	Animated	120	Feedback
	16		c3d	amc	Animated	120	Feedback

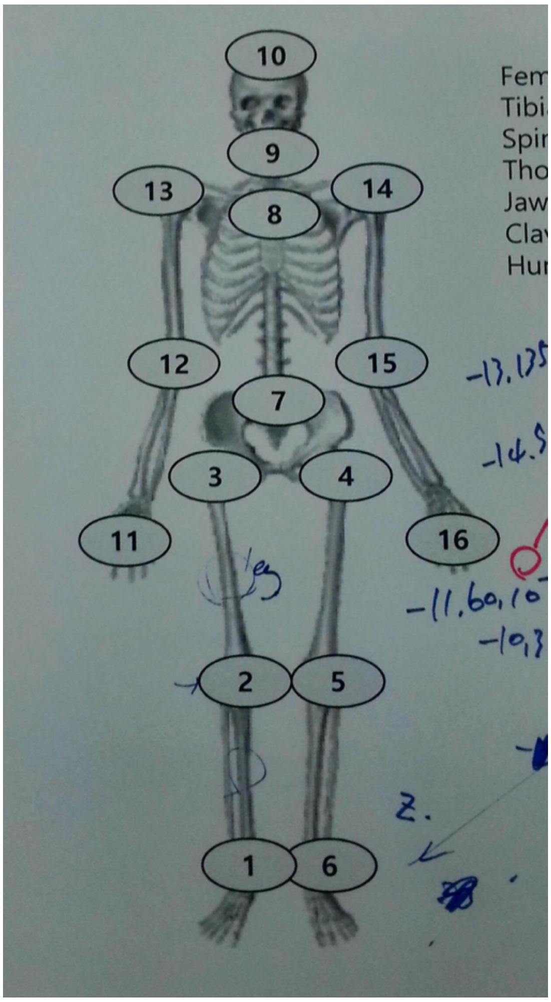
```
In [1]: %%bash
        rm -fr data/input
        rm -fr data/input2 data/input3
        rm -fr data/input4 data/tmp
        rm -fr save1 save2 save3 save4
```

```
In [2]: %matplotlib inline
        # coding: utf-8
        from __future__ import print_function
        from __future__ import division
        from __future__ import absolute_import
        import numpy as np
        import matplotlib.pyplot as plt
```

모션데이터를 전처리 하여 csv 포맷으로 변환

- 모션 캡춰 데이터의 한 프레임에서 주요 관절의 3차원 좌표값 추출하여 차례로 기록
- 모션 캡춰 데이터 모든 프레임에 대해서 위 과정을 반복
- 주요관절의 아래 그림과 같이 선택
- csv 데이터의 하나의 row 에는 16개 관절 좌표의 x,y,z 값을 차례대로 기록 (전체 48개 column)

$$[x_1, y_1, z_1, x_2, y_2, z_2, \ldots, x_{16}, y_{16}, z_{16}]$$



모션 데이터 예시

- data/mocap-thkim-3d/94_04_skeleton_3d.csv

```
In [3]: data = np.loadtxt(
            'data/mocap-thkim-3d/94_04_skeleton_3d.csv',
            delimiter=',')
        data.shape
```

```
Out[3]: (716, 48)
```

```
In [4]: import pandas as pd
        df = pd.DataFrame(data)
        colnames = [a+str(b)
                    for b in range(1,17)
                    for a in ['x_','y_','z_'] ]
        df.columns = colnames
        df
```

Out[4]:

	x_1	y_1	z_1	x_2	y_2	z_2	x_3
0	1.882192	756.66960	144.147340	-31.925642	697.06940	107.631160	2.9472
1	1.883342	756.67890	144.150670	-31.815847	697.03030	107.629860	2.9253
2	1.890642	756.70060	144.164610	-31.691278	696.98720	107.639490	2.8684
3	1.888782	756.71560	144.184250	-31.598267	696.93536	107.655106	2.7869
4	1.897167	756.73083	144.202870	-31.539127	696.90410	107.680260	2.6528
5	1.907214	756.74603	144.215380	-31.534208	696.90234	107.715510	2.4281
6	1.917874	756.75354	144.212880	-31.573100	696.93710	107.697930	2.1183
7	1.939046	756.76056	144.198700	-31.622274	697.04020	107.598000	1.6795
8	1.955456	756.77966	144.174730	-31.690561	697.20610	107.395930	1.0666
9	1.951021	756.83026	144.160140	-31.695585	697.41925	107.128660	0.3110
10	1.947459	756.90656	144.148560	-31.602858	697.62616	106.830560	-0.538
11	1.938678	756.97420	144.121980	-31.450668	697.77850	106.487724	-1.406
12	1.900310	757.03460	144.102630	-31.214990	697.88257	106.088980	-2.278
13	1.831522	757.10370	144.107040	-30.911634	697.96640	105.642820	-3.108
14	1.747009	757.16330	144.123520	-30.636566	698.02970	105.209900	-3.822
15	1.678542	757.20940	144.133700	-30.414112	698.08966	104.865600	-4.276
16	1.624095	757.26544	144.152500	-30.169820	698.15314	104.586464	-4.361
17	1.584209	757.31714	144.174930	-29.792175	698.18365	104.234184	-4.144
18	1.563949	757.34450	144.175740	-29.256231	698.18866	103.760130	-3.742

19	1.561036	757.33887	144.151430	-28.647322	698.15420	103.267140	-3.126
20	1.578463	757.29010	144.114550	-27.984106	698.06024	102.815880	-2.117
21	1.603456	757.17633	144.057170	-27.196768	697.86960	102.292830	-0.718
22	1.711625	757.04980	143.954640	-26.159270	697.53064	101.820490	0.8030
23	1.830794	756.87150	143.934130	-24.984285	696.89820	101.690500	2.4037
24	1.723435	756.22520	143.869340	-23.844180	695.75610	101.555810	4.2539
25	1.499542	754.62980	143.472550	-22.809896	694.18330	100.606636	6.2052
26	1.337029	752.14417	142.335740	-22.206560	692.32690	98.185200	7.9170
27	1.265661	749.50340	140.172490	-21.823687	690.36945	94.723820	9.195
28	1.366566	747.38696	136.877320	-21.139654	688.50165	90.791540	10.078
29	1.719596	746.15936	132.191200	-19.965536	686.71860	86.430275	10.606
...	...	...	...	...	...	...	...
686	-2.531506	753.10020	-57.438564	-26.558670	687.00610	-89.963440	-0.447
687	-3.804404	750.34160	-58.423798	-29.106009	685.63214	-93.178790	-0.815
688	-6.878615	744.68100	-61.351900	-34.576366	682.40560	-99.473340	-0.755
689	-12.088651	737.63190	-66.647080	-41.752422	677.45325	-107.078896	-0.516
690	-19.129330	732.52590	-74.027054	-48.510345	671.79090	-113.641106	-0.548
691	-28.785208	732.38710	-84.101470	-54.068897	666.73760	-117.944820	-1.176
692	-41.993830	737.06350	-97.422080	-57.927338	663.93560	-119.946670	-2.050
693	-57.686380	743.29016	-113.234940	-59.667873	665.05396	-120.329810	-3.482
694	-72.226555	747.91010	-128.932540	-59.542133	670.47420	-119.649230	-5.983
695	-80.439670	750.79320	-139.513460	-58.328766	677.88556	-118.601890	-9.668
696	-80.685425	754.60300	-142.215590	-56.419647	684.10376	-117.996150	-14.41
697	-80.060790	756.99896	-142.093700	-55.020363	687.61420	-116.862686	-19.43
698	-81.515100	757.58210	-141.709270	-56.411854	688.08276	-116.190020	-23.23
699	-82.678360	757.92520	-141.409030	-59.363533	687.25195	-116.942080	-25.08
700	-83.172844	757.79016	-141.864290	-61.196210	686.55426	-117.820310	-25.64
701	-83.001910	757.49840	-142.166170	-62.252880	685.72840	-118.972560	-25.70
702	-82.220085	757.17487	-142.034130	-64.465385	684.07180	-120.494100	-25.34
703	-80.345310	756.49603	-141.142720	-68.430830	681.03510	-122.637690	-24.74
704	-76.388920	755.01373	-137.853800	-72.429860	677.17554	-125.607925	-24.47
705	-68.397280	752.79550	-130.502910	-74.868576	674.10660	-128.878020	-24.90
706	-57.514492	749.99180	-120.290530	-74.909386	673.48010	-131.119840	-26.08

707	-47.540966	747.37620	-109.833390	-72.263390	675.66470	-132.186690	-27.63
708	-40.426094	747.27680	-101.572260	-67.227165	679.96210	-132.474000	-29.29
709	-36.221110	751.35950	-97.827810	-60.754690	684.89710	-131.145570	-31.15
710	-33.827175	755.21124	-96.917410	-55.527416	687.78740	-129.189500	-32.89
711	-33.839127	755.76086	-97.059310	-53.661446	687.41223	-129.745060	-34.06
712	-34.591507	755.82430	-97.278010	-53.734493	686.72626	-130.451550	-34.88
713	-34.687830	756.16090	-97.028250	-54.017150	687.08520	-129.065670	-36.09
714	-34.806538	756.39764	-96.819695	-54.563060	687.28910	-127.727580	-37.77
715	-34.987312	756.55720	-96.684940	-55.357400	687.19183	-127.087610	-39.34

716 rows × 48 columns

In [5]:

```
df.describe()
```

Out[5]:

	x_1	**y_1**	**z_1**	**x_2**	**y_2**	**z_2**
count	716.000000	716.000000	716.000000	716.000000	716.000000	716.000000
mean	-3.518349	741.012391	60.978439	-19.462976	679.968872	32.958518
std	165.634351	26.224731	89.881845	156.700390	22.239540	82.227495
min	-247.948400	597.344400	-142.215590	-250.783620	573.122800	-132.474000
25%	-112.370794	738.313720	-4.724420	-122.785225	675.907575	-31.781075
50%	-2.874052	751.471200	81.822103	-27.833915	685.672270	44.818014
75%	10.579322	756.158225	118.554532	-8.219873	692.030925	100.865803
max	436.693760	759.918150	214.190540	420.481050	711.845030	176.197020

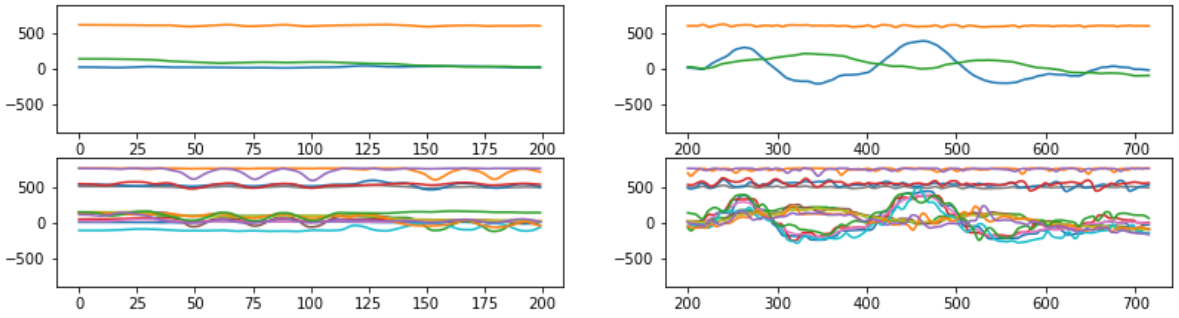
8 rows × 48 columns

모션데이터 시각화 - 주요 좌표들의 변화 plot

- 신체중심 (골반) x,y,z 좌표의 변화
- 기타 주요 단말 (손,발,정수리) x,y,z 좌표의 변화
- 200 스텝까지의 변화와, 그 이후 데이터 전체의 변화를 관찰

In [6]:
```
def plot_motion(data, vlim=5.5):
    if type(data) is str or type(data) is unicode:
        data = np.loadtxt(data,delimiter=',')

    cols0 = [18,19,20] # 골반 = (7)

    cols = np.concatenate([
        [0,1,2],        # 오른쪽 발 = (0)
        [15,16,17],     # 왼쪽 발    = (6)
        [27,28,29],     # 정수리     = (10)
        [30,31,32],     # 오른손     = (11)
        [45,46,47],     # 왼손        = (16)
    ])

    plt.figure(figsize=(13.5, 3.5))

    # 앞에서부터 500 스텝만 plot
    plt.subplot(2,2,1)
    plt.ylim(-vlim, vlim)
    plt.plot(range(200),data[:200,cols0])

    plt.subplot(2,2,3)
    plt.ylim(-vlim, vlim)
    plt.plot(range(200),data[:200,cols])

    # 나머지 스텝 plot
    plt.subplot(2,2,2)
    plt.ylim(-vlim, vlim)
    plt.plot(range(200,len(data)),data[200:,cols0])

    plt.subplot(2,2,4)
    plt.ylim(-vlim, vlim)
    plt.plot(range(200,len(data)),data[200:,cols])
```

In [7]:
```
plot_motion('data/mocap-thkim-3d/94_04_skeleton_3d.csv',
            vlim=900)
```



모션 데이터 시각화 - 애니메이션

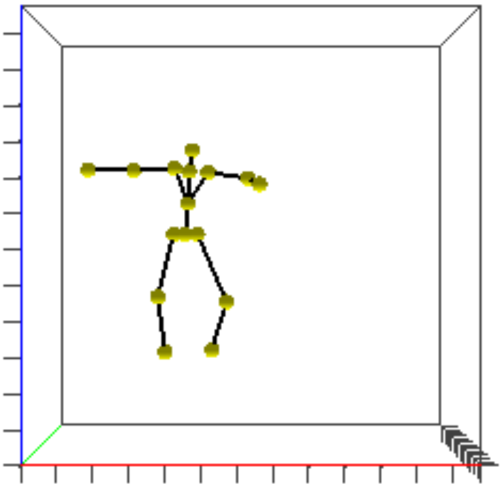
- Javascript + Processing.js 기반의 간단한 3D 애니메이션 뷰어
- Jupyter Notebook 의 HTML 렌더링 기능을 이용

In [8]:

```
def show_motion(filename):
    from IPython.core.display import HTML, display
    html="""
<iframe
    style="width:440px;height:440px;border:0"
    src="BodyViewerJs/index.html#../{filename:s}">
</iframe>
"""
    display(HTML(html.format(filename=filename)))
```

In [9]:

```
show_motion('data/mocap-thkim-3d/94_04_skeleton_3d.csv')
```



In [10]:

```
!ls data/mocap-thkim-3d/
```

```
94_01_skeleton_3d.csv  94_05_skeleton_3d.csv  94_09_skeleton_3d.cs
v
94_02_skeleton_3d.csv  94_06_skeleton_3d.csv  94_10_skeleton_3d.cs
v
94_03_skeleton_3d.csv  94_07_skeleton_3d.csv  94_11_skeleton_3d.cs
v
94_04_skeleton_3d.csv  94_08_skeleton_3d.csv  94_12_skeleton_3d.cs
v
```

In [11]:

```
%%html
<a href="catalog.html" target="_">
click me!
</a>
```

click me!

학습을 위해서 학습 데이터를 정규화 하고, data/input 에 저장

- step #1: get means & standard deviations for (multiple) input files
  - 입력파일(들) 에 포함된 좌표값들의 평균, 표준편차 계산 (관절별로 따로)
- step #2:
  - 위에서 구한 평균 분산을 이용해서 입력파일의 좌표를 변환
  - (좌표값 - 평균값) / 표준편차

In [12]:

```
# %pycat csv_stats.py
```

In [13]:

```
%%bash -e
# step #1: get means & standard deviations
python csv_stats.py \
    data/mocap-thkim-3d/94_04_skeleton_3d.csv \
    --mean_file data/input/mean.txt \
    --std_file data/input/std.txt
```

```
{'var_file': None, 'verbose': False, 'std_file': 'data/input/std.t
xt', 'mean_file': 'data/input/mean.txt', 'input_files': ['data/moc
ap-thkim-3d/94_04_skeleton_3d.csv']}
input: data/mocap-thkim-3d/94_04_skeleton_3d.csv
wrote: data/input/mean.txt
wrote: data/input/std.txt
```

In [14]:

```
# %pycat csv_normalize.py
```

In [15]:

```
%%bash -e
# step #2: normalize
#   (1) subtract with mean value
#   (2) divide by std value
python csv_normalize.py \
    --mean_file data/input/mean.txt \
    --std_file data/input/std.txt \
    data/mocap-thkim-3d/94_04_skeleton_3d.csv \
    data/input/04.csv
```

```
{'scale': 1.0, 'std_file': 'data/input/std.txt', 'reverse': False,
'input_file': 'data/mocap-thkim-3d/94_04_skeleton_3d.csv', 'output
_file': 'data/input/04.csv', 'mean_file': 'data/input/mean.txt', '
verbose': False}
normalize: data/mocap-thkim-3d/94_04_skeleton_3d.csv data/input/04
.csv
```

역정규화 un-normalize

- normalize step
  - (좌표값 - 평균값) / 표준편차
- un-normalize step (reverse normalize)
  - 변환좌표값 * 표준편차 + 평균값

In [16]:
```
%%bash -e
# un-normalize step (reverse normalize)
# (1) multiply by std value
# (2) add mean value
python csv_normalize.py -r \
    --mean_file data/input/mean.txt \
    --std_file  data/input/std.txt \
    data/input/04.csv \
    data/tmp/rev-04.csv
```

```
{'scale': 1.0, 'std_file': 'data/input/std.txt', 'reverse': True,
'input_file': 'data/input/04.csv', 'output_file': 'data/tmp/rev-04
.csv', 'mean_file': 'data/input/mean.txt', 'verbose': False}
un-normalize: data/input/04.csv data/tmp/rev-04.csv
```

변환 + 역변환 결과가 원본과 같은지 검사

In [17]:
```
%%bash -e
# compare original data with un-normalized data
python csv_compare.py \
    data/mocap-thkim-3d/94_04_skeleton_3d.csv \
    data/tmp/rev-04.csv
```

```
{'input2': 'data/tmp/rev-04.csv', 'input1': 'data/mocap-thkim-3d/9
4_04_skeleton_3d.csv'}
max square error: 6.72400000334e-09
```

훈련데이터의 구성

In [18]:
```
# %pycat dataloader.py
```

prepare training data - `DataLoader` (`dataloader.py`)

```
    for dirname, _, filelist in os.walk(data_dir):
        for filename in filelist:
            filepath = join(dirname,filename)
            if filename.endswith('.csv'):
                logger.info(('loadtxt',filepath))

                data = np.loadtxt(filepath, delimiter=',')

                if augment_data > 1:
                    # mirror augment * xN augment
                    data = np.vstack([data, data[::-1]] * augment_data)
                    logger.info(('augment > 1','shape',data.shape))

                self.data.append(data)

    self.data_len  = [len(d) for d in self.data]
    self.data_prob = np.array(self.data_len, dtype=np.float32) / \
        np.sum(self.data_len, dtype=np.float32)
```

prepare training data batch - `DataLoader` (`dataloader.py`)

```
    for _ in range(batch_size):
        data_choice = np.random.choice(range(len(self.data)),p=self.dat
a_prob)
        data        = self.data[data_choice]
        index       = np.random.randint(0,len(data)-(seq_length+1))
        x           = data[index:index+seq_length,:]
        y           = data[index+1:index+1+seq_length,:]
        x_batch.append(x)
        y_batch.append(y)

        data_id     = self.data_id[data_choice]
        id_batch.append(data_id)
```

생성모형 정의

In [19]:

```
# %pycat model.py
```

placeholders

```
input_data = tf.placeholder(
    dtype=tf.float32,
    shape=[None, seq_length, NUM_OUTPUTS],
    name='input_data')
target_data = tf.placeholder(
    dtype=tf.float32,
    shape=[None, seq_length, NUM_OUTPUTS],
    name='target_data')
seq_length  = tf.placeholder(
    dtype=tf.int64,
    shape=[None],
    name='seq_length')
motion_id   = tf.placeholder(
        dtype=tf.float32,
        shape=[None, ID_SIZE],
        name='mot_id')
batch_size = tf.shape(seq_length)[0]
```

RNN

```
cell_list = \
    [new_cell(args, NUM_OUTPUTS, infer)] + \
    [new_cell(args, rnn_size, infer)] * (num_layers-1)
cell = tf.contrib.rnn.MultiRNNCell(cell_list)

motion_state = tf.layers.dense(motion_id,
                    rnn_size * 2 * num_layers)
initial_state = tuple([
    tf.contrib.rnn.LSTMStateTuple(*tf.split(x, 2, axis=1))
    for x in tf.split(motion_state, num_layers, axis=1)])

outputs, last_state = tf.nn.dynamic_rnn(
    cell,
    input_data,
    sequence_length=seq_length,
    initial_state = initial_state,
    dtype=tf.float32
)
output = tf.layers.dense(outputs, NUM_OUTPUTS)
```

Loss & Optimize

```
# loss A MSE on relative coords
loss = tf.losses.mean_squared_error(
            target_data,
            output)
```

Sampling

```
 def sample(model, sess, num):



    prev_state   = sess.run(model.initial_state,{model.motion_id:[motio
n_id]})
    prev_vec     = np.zeros((1, 1, NUM_OUTPUTS), dtype=np.float32)
    strokes      = np.zeros((num, NUM_OUTPUTS), dtype=np.float32)
    output       = np.zeros(NUM_OUTPUTS, dtype=np.float32)

    for i in tqdm(range(num)):
        feed                = {
            model.input_data:    prev_vec,
            model.initial_state: prev_state,
            model.seq_length:    [1],
        }
        o_rest, next_state  = sess.run(
            [model.output, model.last_state],
            feed)
        strokes[i, :]       = o_rest[0]
        prev_vec[0, 0, :]   = o_rest[0, 0, :]
        prev_state          = next_state

    return strokes
```

</code>

학습 시작

In [20]:

```
# "Last executed 2017-10-10 22:06:10 in 10m 40s"
!python -u train.py \
    --rnn_type lstm \
    --data_dir data/input \
    --save_dir save1
```

```
INFO:dataloader:('checking:', 'data/input')
INFO:dataloader:('loadtxt', 'data/input/04.csv')
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 10
0)
epoch 1, step 200, loss = 0.21686, elapsed = 0.119
epoch 1, step 400, loss = 0.07980, elapsed = 0.107
model saved to save1/model.ckpt-500
epoch 1, step 600, loss = 0.03650, elapsed = 0.109
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 10
0)
epoch 2, step 800, loss = 0.02491, elapsed = 0.200
epoch 2, step 1000, loss = 0.01285, elapsed = 0.102
model saved to save1/model.ckpt-1000
epoch 2, step 1200, loss = 0.01183, elapsed = 0.205
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 10
0)
epoch 3, step 1400, loss = 0.00697, elapsed = 0.099
model saved to save1/model.ckpt-1500
epoch 3, step 1600, loss = 0.00684, elapsed = 0.102
epoch 3, step 1800, loss = 0.00568, elapsed = 0.111
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 10
0)
epoch 4, step 2000, loss = 0.00395, elapsed = 0.103
model saved to save1/model.ckpt-2000
epoch 4, step 2200, loss = 0.00320, elapsed = 0.100
epoch 4, step 2400, loss = 0.00270, elapsed = 0.102
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 10
0)
model saved to save1/model.ckpt-2500
epoch 5, step 2600, loss = 0.00237, elapsed = 0.098
epoch 5, step 2800, loss = 0.00278, elapsed = 0.106
epoch 5, step 3000, loss = 0.00190, elapsed = 0.098
model saved to save1/model.ckpt-3000
model saved to save1/model.ckpt-3080
```

In [21]:

```
#!python -mtensorboard.main --port 5000 --logdir save1:save1,save2:save2,
save3:save3
```

학습된 네트워을 이용해서 동작 생성

In [22]:

```
!python sample.py \
    --save_dir save1 \
    --motion_id 0,0,0,0,1 \
    --output_file data/tmp/sample_04.csv
```

```
loading model:  save1/model.ckpt-3080
100%|██████████████████████████████████████| 1000/1000 [00:01<00:00, 906.9
4it/s]
```

정규화된 입력을 학습했기 때문에, 사용하기 전에는 다시 역-정규화

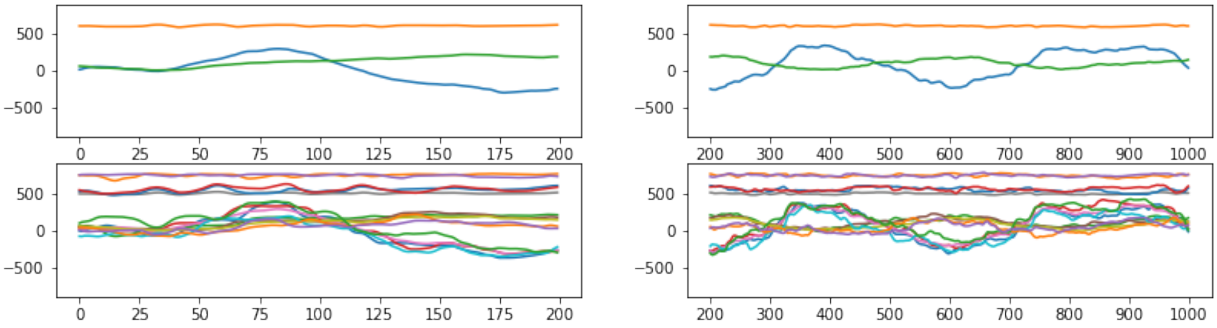
In [23]:

```
!python csv_normalize.py -r \
    --mean_file data/input/mean.txt \
    --std_file data/input/std.txt \
    data/tmp/sample_04.csv \
    save1/sample_04.csv
```

```
{'scale': 1.0, 'std_file': 'data/input/std.txt', 'reverse': True, 'input_f
ile': 'data/tmp/sample_04.csv', 'output_file': 'save1/sample_04.csv', 'mea
n_file': 'data/input/mean.txt', 'verbose': False}
un-normalize: data/tmp/sample_04.csv save1/sample_04.csv
```

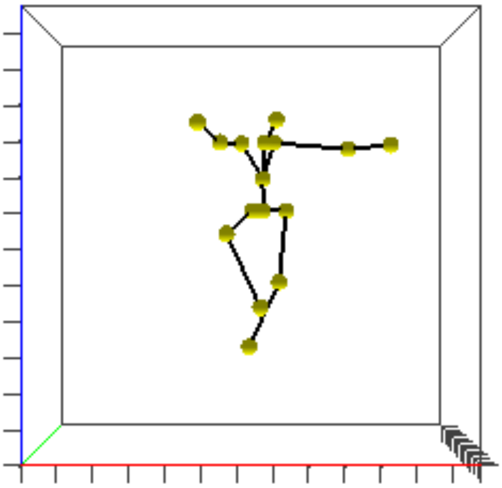
In [24]:

```
plot_motion('save1/sample_04.csv',
            vlim=900.0)
```



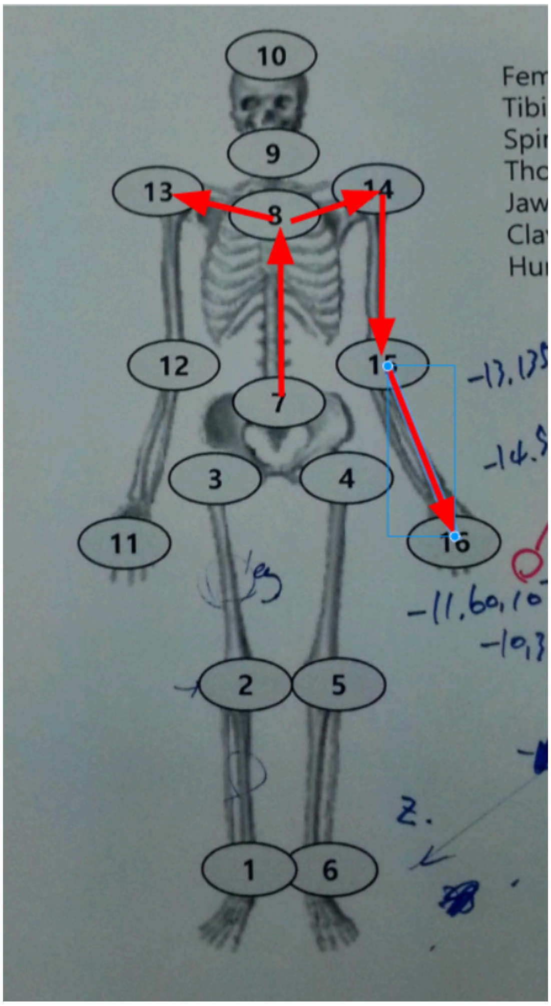
In [25]:

```
show_motion('save1/sample_04.csv')
```



데이터 포맷의 변경

- 인체 중심을 골반 (7번) 관절 기준으로
- 연결된 두 개 관절에서 중심 방향에 있는 관절을 기준으로
- 바깥 방향에 있는 관절은 중심방향에 있는 관절에 대한 상대좌표
- 중심좌표는 절대값을 그대로 사용



In [26]:

```
# %pycat csv_motion_to_jrel2.py
```

```
 LINKS = (
     (7, 3), (3, 2), (2, 1), # 골반에서 우측 발까지
     (7, 4), (4, 5), (5, 6), # 골반에서 좌측 발까지
     (7, 8), (8, 9), (9, 10), # 골반에서 정수리까지
     (8, 13), (13, 12), (12, 11), # 명치에서 우측 손 끝 까지
     (8, 14), (14, 15), (15, 16), # 명치에서 좌측 손 끝 까지
 )



def motion_to_jrel2_row(row):
    row = row[:3*N_JOINTS].reshape([-1,3])
    row_rel = np.zeros_like(row)
    j1, j2 = LINKS[0]
    row_rel[j1-1] = row[j1-1]
    for j1, j2 in LINKS:
        row_rel[j2-1] = row[j2-1] - row[j1-1]
    row = row_rel.reshape([-1])
    return row

def jrel2_to_motion_row(row):
    row = row[:3*N_JOINTS].reshape([-1,3])
    for j1, j2 in LINKS:
        row[j2-1] = row[j2-1] + row[j1-1]
    row = row.reshape([-1])
    return row
```

</code>

상대좌표로 변환하고, 정규화

In [27]:

```
%%bash -e
python csv_motion_to_jrel2.py \
    data/mocap-thkim-3d/94_04_skeleton_3d.csv \
    data/tmp/__rel__.csv

python csv_stats.py \
    --mean_file /data/input2/mean.txt \
    --std_file /data/input2/std.txt \
    data/tmp/__rel__.csv

python csv_normalize.py \
    --mean_file /data/input2/mean.txt \
    --std_file /data/input2/std.txt \
    data/tmp/__rel__.csv \
    data/input2/04.csv
```

```
{'output_file': 'data/tmp/__rel__.csv', 'reverse': False, 'input_file': 'data/mocap-thkim
-3d/94_04_skeleton_3d.csv'}
{'var_file': None, 'verbose': False, 'std_file': '/data/input2/std.txt', 'mean_file': '/d
ata/input2/mean.txt', 'input_files': ['data/tmp/__rel__.csv']}
input: data/tmp/__rel__.csv
wrote: /data/input2/mean.txt
wrote: /data/input2/std.txt
{'scale': 1.0, 'std_file': '/data/input2/std.txt', 'reverse': False, 'input_file': 'data/
tmp/__rel__.csv', 'output_file': 'data/input2/04.csv', 'mean_file': '/data/input2/mean.tx
t', 'verbose': False}
normalize: data/tmp/__rel__.csv data/input2/04.csv
```

학습시작

In [28]:

```
!python -u train.py \
    --save_dir save2 \
    --rnn_type lstm \
    --data_dir data/input2
```

```
INFO:dataloader:('checking:', 'data/input2')
INFO:dataloader:('loadtxt', 'data/input2/04.csv')
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 1, step 200, loss = 0.32935, elapsed = 0.136
epoch 1, step 400, loss = 0.17336, elapsed = 0.117
model saved to save2/model.ckpt-500
epoch 1, step 600, loss = 0.08954, elapsed = 0.133
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 2, step 800, loss = 0.05468, elapsed = 0.167
epoch 2, step 1000, loss = 0.03993, elapsed = 0.111
model saved to save2/model.ckpt-1000
epoch 2, step 1200, loss = 0.02360, elapsed = 0.107
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 3, step 1400, loss = 0.01700, elapsed = 0.113
model saved to save2/model.ckpt-1500
epoch 3, step 1600, loss = 0.01324, elapsed = 0.111
epoch 3, step 1800, loss = 0.01074, elapsed = 0.110
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 4, step 2000, loss = 0.00888, elapsed = 0.115
model saved to save2/model.ckpt-2000
epoch 4, step 2200, loss = 0.00966, elapsed = 0.109
epoch 4, step 2400, loss = 0.00636, elapsed = 0.113
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
model saved to save2/model.ckpt-2500
epoch 5, step 2600, loss = 0.00664, elapsed = 0.106
epoch 5, step 2800, loss = 0.00697, elapsed = 0.110
epoch 5, step 3000, loss = 0.00829, elapsed = 0.117
model saved to save2/model.ckpt-3000
model saved to save2/model.ckpt-3080
```

In [29]:

```
#!python -mtensorboard.main --port 5000 --logdir save1:save1,save2:save2,save3:save3,save
4:save4
```

학습된 모델을 이용하여 동작 생성

In [30]:

```
!python sample.py \
    --save_dir save2 \
    --motion_id 0,0,0,0,1 \
    --output_file data/tmp/sample_04-2.csv
```

```
loading model:  save2/model.ckpt-3080
100%|██████████████████████████████████████| 1000/1000 [00:01<00:00, 691.42it/s]
```

역 정규화 (un-normalization)

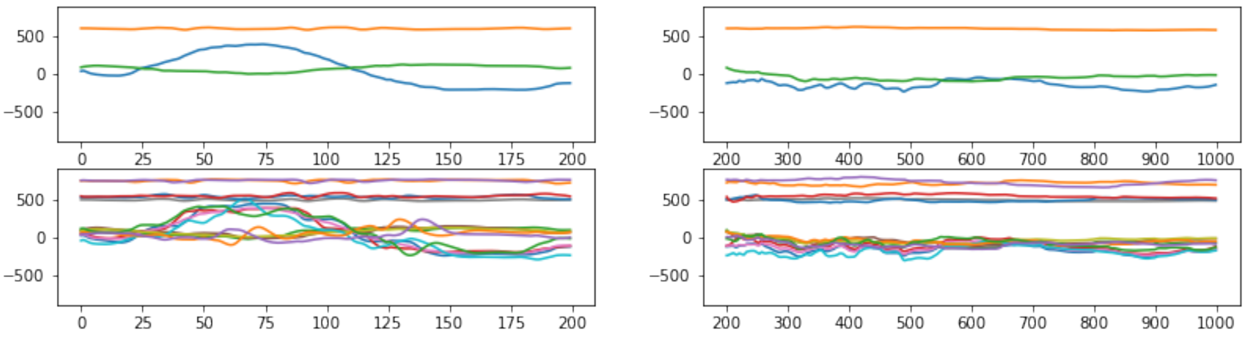
In [31]:

```
%%bash -e
python csv_normalize.py -r \
    --mean_file /data/input2/mean.txt \
    --std_file /data/input2/std.txt \
    data/tmp/sample_04-2.csv \
    data/tmp/__rel__.csv

python csv_motion_to_jrel2.py -r \
    data/tmp/__rel__.csv \
    save2/sample_04-2.csv
```

```
{'scale': 1.0, 'std_file': '/data/input2/std.txt', 'reverse': True, 'input_file': 'data/t
mp/sample_04-2.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': '/data/input2/me
an.txt', 'verbose': False}
un-normalize: data/tmp/sample_04-2.csv data/tmp/__rel__.csv
{'output_file': 'save2/sample_04-2.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__
.csv'}
```

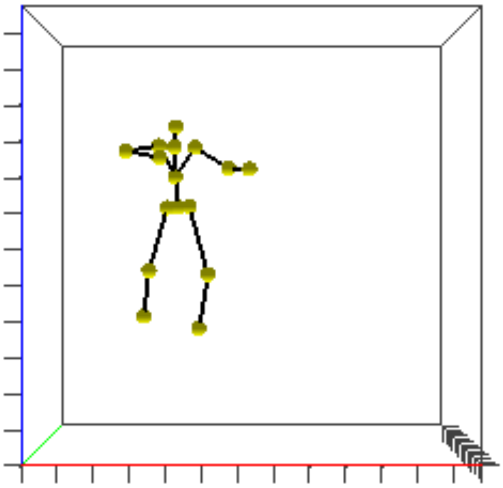
In [32]:

```
plot_motion('save2/sample_04-2.csv',
            vlim=900.0)
```



In [33]:

```
show_motion('save2/sample_04-2.csv')
```



Layer-normalized LSTM

In [34]:

```
!python -u train.py \
    --save_dir save3 \
    --data_dir data/input2 \
    --rnn_type lnlstm
```

```
INFO:dataloader:('checking:', 'data/input2')
INFO:dataloader:('loadtxt', 'data/input2/04.csv')
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 1, step 200, loss = 0.00843, elapsed = 0.682
epoch 1, step 400, loss = 0.00246, elapsed = 0.720
model saved to save3/model.ckpt-500
epoch 1, step 600, loss = 0.00154, elapsed = 0.686
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 2, step 800, loss = 0.00099, elapsed = 0.697
epoch 2, step 1000, loss = 0.00107, elapsed = 0.676
model saved to save3/model.ckpt-1000
epoch 2, step 1200, loss = 0.00076, elapsed = 0.674
INFO:dataloader:('num_batches:', 616, 'batch_size:', 50, 'seq_length:', 100)
epoch 3, step 1400, loss = 0.00162, elapsed = 0.690
model saved to save3/model.ckpt-1500
epoch 3, step 1600, loss = 0.00037, elapsed = 0.700
epoch 3, step 1800, loss = 0.00037, elapsed = 0.682
^C
Traceback (most recent call last):
  File "train.py", line 154, in <module>
    train(args)
  File "train.py", line 110, in train
    feed)
  File "/opt/conda/envs/airi400/lib/python2.7/site-packages/tensorflow/python/client/sess
ion.py", line 895, in run
    run_metadata_ptr)
  File "/opt/conda/envs/airi400/lib/python2.7/site-packages/tensorflow/python/client/sess
ion.py", line 1124, in _run
    feed_dict_tensor, options, run_metadata)
  File "/opt/conda/envs/airi400/lib/python2.7/site-packages/tensorflow/python/client/sess
ion.py", line 1321, in _do_run
    options, run_metadata)
  File "/opt/conda/envs/airi400/lib/python2.7/site-packages/tensorflow/python/client/sess
ion.py", line 1327, in _do_call
    return fn(*args)
  File "/opt/conda/envs/airi400/lib/python2.7/site-packages/tensorflow/python/client/sess
ion.py", line 1306, in _run_fn
    status, run_metadata)
KeyboardInterrupt
```

```
In [38]:
!python sample.py \
    --save_dir save3 \
    --motion_id 0,0,0,0,1 \
    --output_file data/tmp/sample_04-3.csv
```

```
loading model:  save3/model.ckpt-1500
100%|██████████████████████████████████████| 1000/1000 [00:01<00:00, 520.94it/s]
```

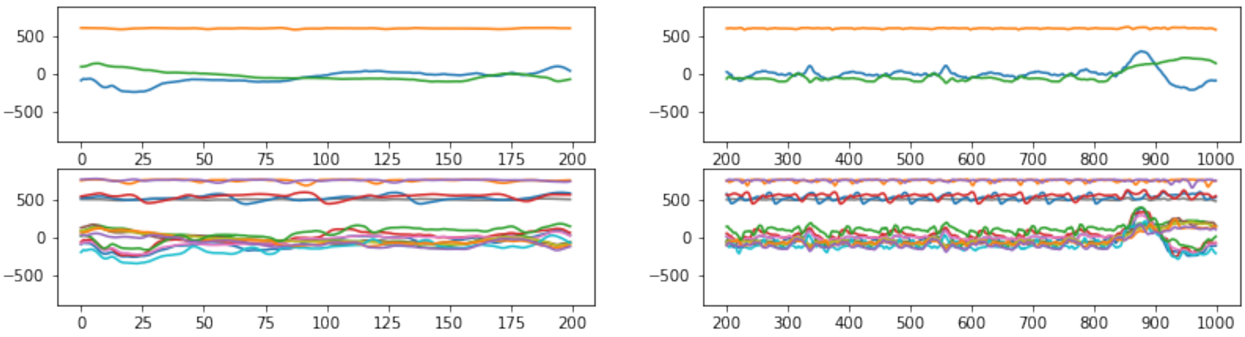
In [39]:

```
%%bash -e
python csv_normalize.py -r \
    --mean_file /data/input2/mean.txt \
    --std_file /data/input2/std.txt \
    data/tmp/sample_04-3.csv \
    data/tmp/__rel__.csv

python csv_motion_to_jrel2.py -r \
    data/tmp/__rel__.csv \
    save3/sample_04-3.csv
```

```
{'scale': 1.0, 'std_file': '/data/input2/std.txt', 'reverse': True, 'input_file': 'data/t
mp/sample_04-3.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': '/data/input2/me
an.txt', 'verbose': False}
un-normalize: data/tmp/sample_04-3.csv data/tmp/__rel__.csv
{'output_file': 'save3/sample_04-3.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__
.csv'}
```

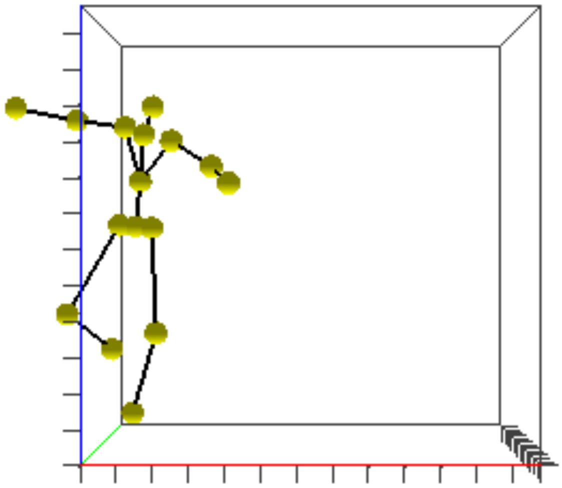
In [40]:

```
plot_motion('save3/sample_04-3.csv',
            vlim=900.0)
```



In [41]:

```
show_motion('save3/sample_04-3.csv')
```



여러개 안무 동시 학습

In [42]:

```
!ls data/mocap-thkim-3d/
```

```
94_01_skeleton_3d.csv  94_05_skeleton_3d.csv  94_09_skeleton_3d.csv
94_02_skeleton_3d.csv  94_06_skeleton_3d.csv  94_10_skeleton_3d.csv
94_03_skeleton_3d.csv  94_07_skeleton_3d.csv  94_11_skeleton_3d.csv
94_04_skeleton_3d.csv  94_08_skeleton_3d.csv  94_12_skeleton_3d.csv
```

In [43]:

```
%%bash
for n in 01 02 03 04       # 05 06 07 08 09 10 11 12
do
    python csv_motion_to_jrel2.py \
        data/mocap-thkim-3d/94_${n}_skeleton_3d.csv \
        data/tmp/${n}-4.csv
done

python csv_stats.py \
    --mean_file data/input4/mean.txt \
    --std_file data/input4/std.txt \
    data/tmp/*-4.csv

for n in 01 02 03 04       # 05 06 07 08 09 10 11 12
do
    python csv_normalize.py \
        --mean_file data/input4/mean.txt \
        --std_file data/input4/std.txt \
        data/tmp/${n}-4.csv \
        data/input4/${n}.csv
done
```

```
{'output_file': 'data/tmp/01-4.csv', 'reverse': False, 'input_file': 'data/mocap-thkim-3d
/94_01_skeleton_3d.csv'}
{'output_file': 'data/tmp/02-4.csv', 'reverse': False, 'input_file': 'data/mocap-thkim-3d
/94_02_skeleton_3d.csv'}
{'output_file': 'data/tmp/03-4.csv', 'reverse': False, 'input_file': 'data/mocap-thkim-3d
/94_03_skeleton_3d.csv'}
{'output_file': 'data/tmp/04-4.csv', 'reverse': False, 'input_file': 'data/mocap-thkim-3d
/94_04_skeleton_3d.csv'}
{'var_file': None, 'verbose': False, 'std_file': 'data/input4/std.txt', 'mean_file': 'dat
a/input4/mean.txt', 'input_files': ['data/tmp/01-4.csv', 'data/tmp/02-4.csv', 'data/tmp/0
3-4.csv', 'data/tmp/04-4.csv']}
input: data/tmp/01-4.csv
input: data/tmp/02-4.csv
input: data/tmp/03-4.csv
input: data/tmp/04-4.csv
wrote: data/input4/mean.txt
wrote: data/input4/std.txt
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': False, 'input_file': 'data/t
mp/01-4.csv', 'output_file': 'data/input4/01.csv', 'mean_file': 'data/input4/mean.txt', '
verbose': False}
normalize: data/tmp/01-4.csv data/input4/01.csv
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': False, 'input_file': 'data/t
mp/02-4.csv', 'output_file': 'data/input4/02.csv', 'mean_file': 'data/input4/mean.txt', '
verbose': False}
normalize: data/tmp/02-4.csv data/input4/02.csv
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': False, 'input_file': 'data/t
mp/03-4.csv', 'output_file': 'data/input4/03.csv', 'mean_file': 'data/input4/mean.txt', '
verbose': False}
normalize: data/tmp/03-4.csv data/input4/03.csv
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': False, 'input_file': 'data/t
mp/04-4.csv', 'output_file': 'data/input4/04.csv', 'mean_file': 'data/input4/mean.txt', '
verbose': False}
normalize: data/tmp/04-4.csv data/input4/04.csv
```

In [44]:

```
!python -u train.py \
    --save_dir save4 \
    --data_dir data/input4 \
    --rnn_type lnlstm \
    --keep_prob 0.2 \
    --num_epochs 20
```

1 ~ 4 번 동작 생성

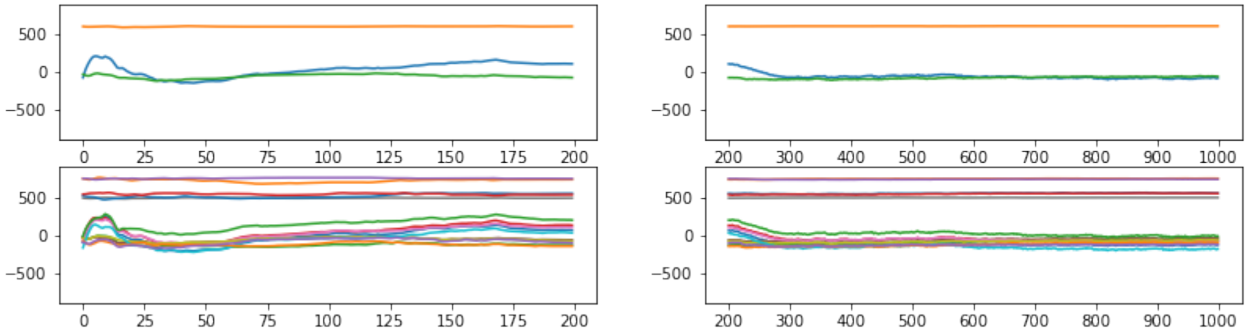
In [45]:

```
%%bash
set -e

for n in 1 2 3 4
do
    python sample.py \
        --save_dir save4 \
        --motion_id $n \
        --output_file data/tmp/samples-$n.csv

    python csv_normalize.py -r \
        --mean_file data/input4/mean.txt \
        --std_file data/input4/std.txt \
        data/tmp/samples-$n.csv \
        data/tmp/__rel__.csv

    python csv_motion_to_jrel2.py -r \
        data/tmp/__rel__.csv \
        save4/samples-$n.csv
done
```

```
loading model:  save4/model.ckpt-1000
100%|##########| 1000/1000 [00:02<00:00, 402.35it/s]
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': True, 'input_file': 'data/tm
p/samples-1.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': 'data/input4/mean.t
xt', 'verbose': False}
un-normalize: data/tmp/samples-1.csv data/tmp/__rel__.csv
{'output_file': 'save4/samples-1.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__.c
sv'}
loading model:  save4/model.ckpt-1000
100%|##########| 1000/1000 [00:02<00:00, 415.02it/s]
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': True, 'input_file': 'data/tm
p/samples-2.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': 'data/input4/mean.t
xt', 'verbose': False}
un-normalize: data/tmp/samples-2.csv data/tmp/__rel__.csv
{'output_file': 'save4/samples-2.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__.c
sv'}
loading model:  save4/model.ckpt-1000
100%|##########| 1000/1000 [00:02<00:00, 408.66it/s]
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': True, 'input_file': 'data/tm
p/samples-3.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': 'data/input4/mean.t
xt', 'verbose': False}
un-normalize: data/tmp/samples-3.csv data/tmp/__rel__.csv
{'output_file': 'save4/samples-3.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__.c
sv'}
loading model:  save4/model.ckpt-1000
100%|##########| 1000/1000 [00:02<00:00, 392.94it/s]
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': True, 'input_file': 'data/tm
p/samples-4.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': 'data/input4/mean.t
xt', 'verbose': False}
un-normalize: data/tmp/samples-4.csv data/tmp/__rel__.csv
{'output_file': 'save4/samples-4.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__.c
sv'}
```

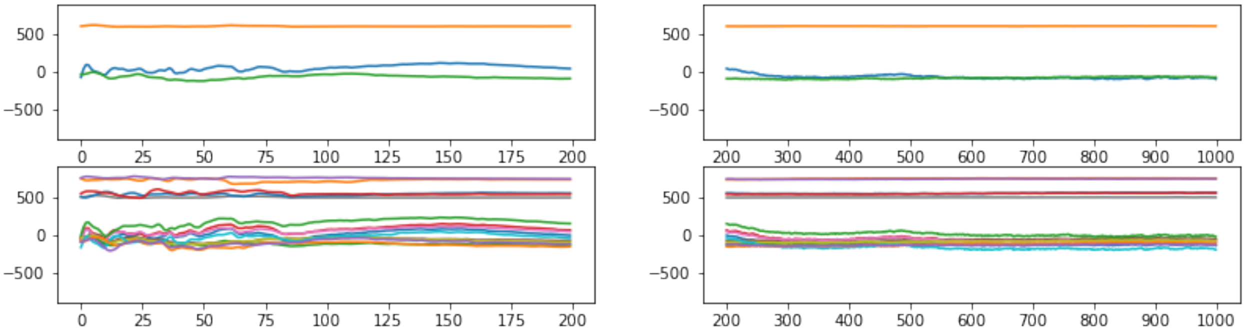
In [46]:

```
plot_motion('save4/samples-1.csv', vlim=900.0)
```



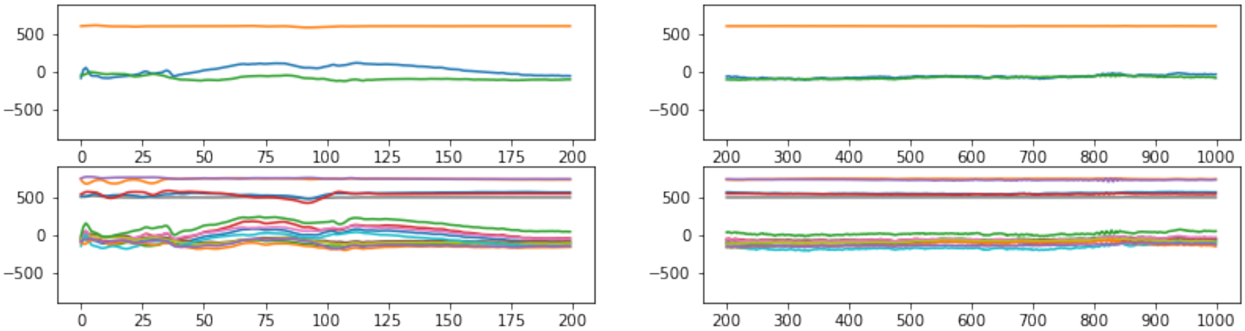
In [47]:

```
plot_motion('save4/samples-2.csv', vlim=900.0)
```



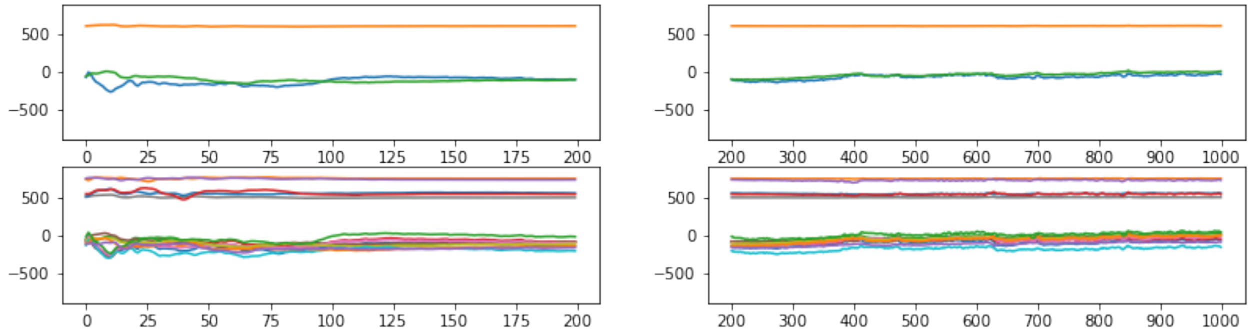
In [48]:

```
plot_motion('save4/samples-3.csv', vlim=900.0)
```



In [49]:

```
plot_motion('save4/samples-4.csv', vlim=900.0)
```



새로운 동작 테스트

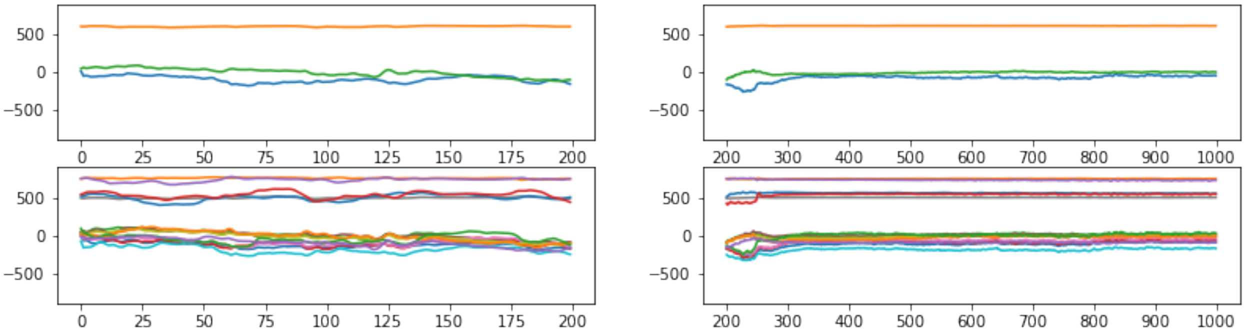
In [50]:

```
%%bash -e
python sample.py \
    --save_dir save4 \
    --motion_id 0,0,0,1,1 \
    --output_file data/tmp/samples-3_4.csv

python csv_normalize.py -r \
    --mean_file data/input4/mean.txt \
    --std_file data/input4/std.txt \
    data/tmp/samples-3_4.csv \
    data/tmp/__rel__.csv

python csv_motion_to_jrel2.py -r \
    data/tmp/__rel__.csv \
    save4/samples-3_4.csv
```

```
loading model:  save4/model.ckpt-1000
100%|##########| 1000/1000 [00:02<00:00, 401.47it/s]
{'scale': 1.0, 'std_file': 'data/input4/std.txt', 'reverse': True, 'input_file': 'data/tm
p/samples-3_4.csv', 'output_file': 'data/tmp/__rel__.csv', 'mean_file': 'data/input4/mean
.txt', 'verbose': False}
un-normalize: data/tmp/samples-3_4.csv data/tmp/__rel__.csv
{'output_file': 'save4/samples-3_4.csv', 'reverse': True, 'input_file': 'data/tmp/__rel__
.csv'}
```

In [51]:

```
plot_motion('save4/samples-3_4.csv',
            vlim=900.0)
```



In [52]:

```
%%html
<a href="catalog-before-after.html" target="_">
click me!
</a>
```

click me!

참고문헌

- “Generating Sequences With Recurrent Neural Networks”, Alex Graves, 2013 (arXiv:1308.0850)

- “Generative Choreography using Deep Learning”, Luka Crnkovic-Friis, Louise Crnkovic-Friis, 2016 (arXiv:1605.06921)

- https://github.com/hardmaru/write-rnn-tensorflow (blog.otoro.net)