Motion Synthesis based on Motion Decomposition

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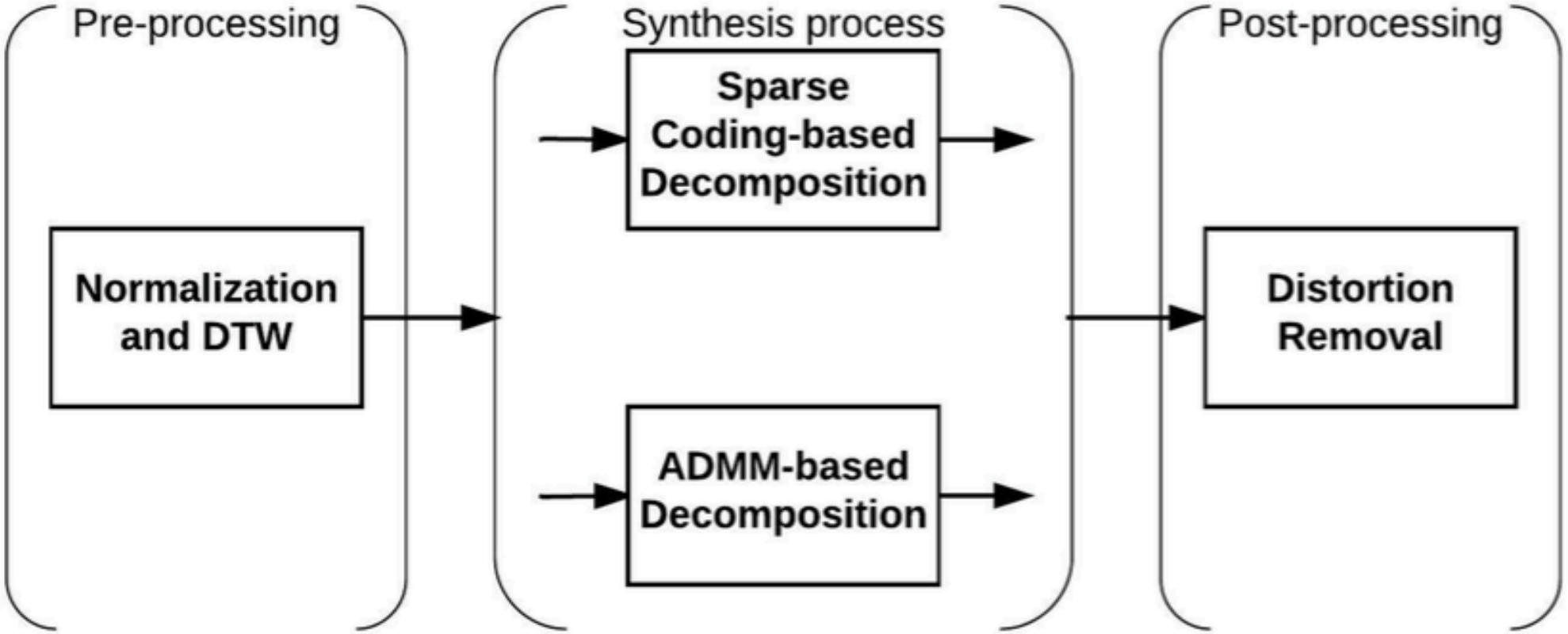
Outline

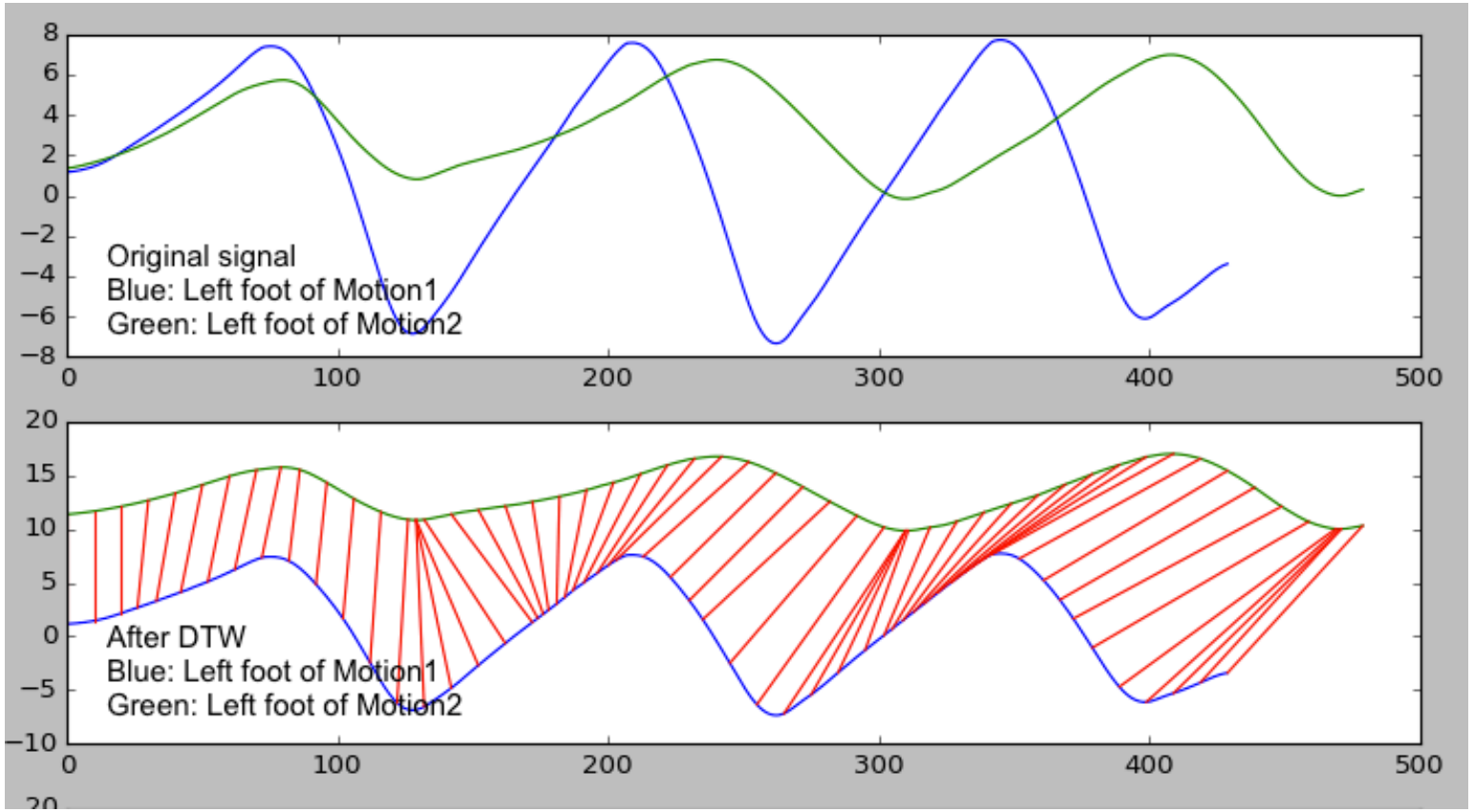
- System overview
- Dynamic Time Warping for Motion
- Motion Decomposition
  - Sparse representation of basic motion
  - Motion synthesis
- Motion Distortion Clean-up
- Experimental results

1. System overview



2. DTW for motion

- Synchronize two motions by warping their foot signals.



3. Motion Decomposition

3.1 Sparse Representation of basic motion

- Given motion $\mathbf{X} = \begin{bmatrix} (v_1^{(1)})^\top & (v_2^{(1)})^\top & \cdots & (v_N^{(1)})^\top \\ (v_1^{(2)})^\top & (v_2^{(2)})^\top & \cdots & (v_N^{(2)})^\top \\ \vdots & \vdots & \ddots & \vdots \\ (v_1^{(F)})^\top & (v_2^{(F)})^\top & \cdots & (v_N^{(F)})^\top \end{bmatrix}$
- Suppose that X can be decomposed by

$$X_{F\times N} = W_{F\times K} C_{K\times N} \quad (*)$$

3.1 Sparse Representation of basic motion

- Extracting a basic motion from X by
  - Set sparsity coefficient fi ~ % of non-zero weight in sparse coding.
  - Update components C_{fi} using decomposition (*): $X_{fi} = W fi C_{fi}$
  - Update residual motion: $X \leftarrow X - X_{fi}$
- The idea is representing motion X by a chain of m basic motions iteratively.

$$X = \sum_{i=1}^{m} X_{fi} = \sum_{i=1}^{m} W_{fi} C_{fi}$$

3.1 One basic motion decomposition

- Give motion X_{FxN}, we want to decompose into $W_{Fxk}C_{kxN}$.
- Step 1: Initialization
  - Initialize weights and components
- Step 2: Optimizing weight W
  - Fixing the initial component C, optimize W.
- Step 3: Optimizing component C
  - Fix optimized W above, using sparse coding to find sparse components.

3.1 Sparse Representation of basic motion

- Step 1:
- Calculate Variation matrix

$$Var(X) = \underset{axis=1}{Sum}(X^2)$$

- Choose best vertex, then update residual motion

$$X' = W_i C_i$$

$$X \leftarrow X - X'.$$

- Continues until we obtain K pairs of components and weights.
- Not optimal solution, but the components were initialized sparsely.

3.1 Sparse Representation of basic motion

- Step 2:

$$\underset{W_{:,k} \in V}{\arg\min} \|X - WC\|_F^2 = P_v\left(\frac{(R + W_{:,k}C_k)C_k}{C_k{}^{\top} C_k}\right)$$

$$R = X - WC$$

3.1 Sparse Representation of basic motion

- Step 3:
- Set sparsity coefficient (% non-zero)
- Fix optimized W, using sparse coding to estimate C sparsely.

3.2 Motion Synthesis

- Given a basic motion, we firstly apply SVD on a component as below,

$$X_{fi} = W_{fi}C_{fi} = W_{fi}(U_{fi}\Sigma_{fi}V_{fi}^{\top})$$
$$= W_{fi}(U_{fi}\Sigma_{fi})V_{fi}^{\top} = W_{fi}K_{fi}V_{fi}^{\top}$$

where $K_{fi} = U_{fi}\Sigma_{fi}$

We called K_{fi} core component.

3.2 Motion Synthesis

- The idea of emotion synthesis is **replacing core component K_{fi}** of one motion to another as below,

$$X^1 = \sum_{i=1}^{m} W_{fi}^1 K_{fi}^1 V_{fi}^{1\top}$$

$$X^2 = \sum_{i=1}^{m} W_{fi}^2 K_{fi}^2 V_{fi}^{2\top}$$

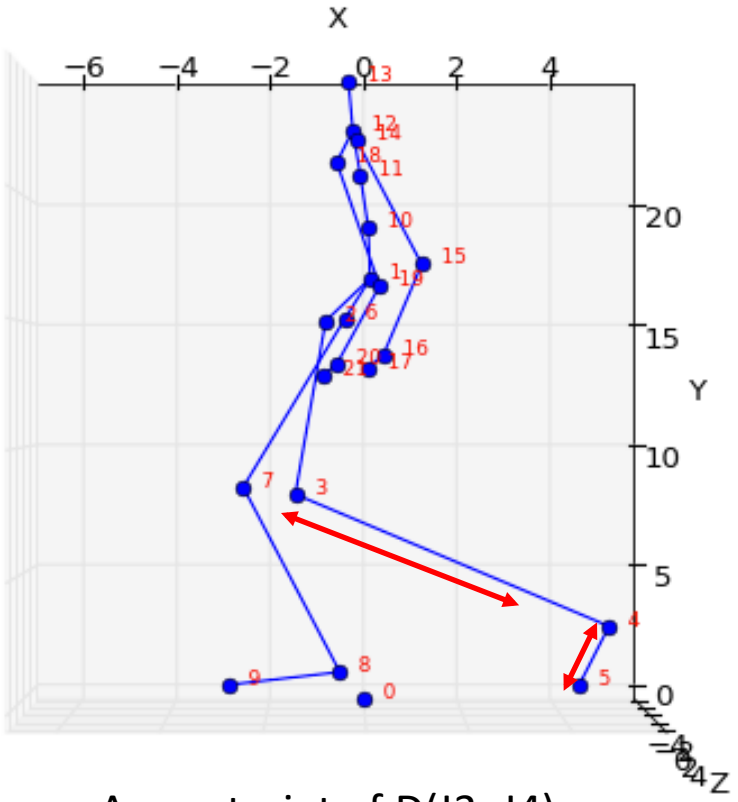
$$X_{syn} = W_{f1}^1 K_{f1}^1 V_{f1}^{1\top} + \ldots + W_{fi}^1 \mathbf{K_{fi}^2} V_{fi}^{1\top} + \ldots + W_{fm}^1 K_{fm}^1 V_{fm}^{1\top}$$

3.3. Decomposition Algorithm

ID	Method (DTW. Distortion Removal are used in all methods)	Result
1	SPLOC decomposition X = WC; Combine SVD(C) with alpha coefficient [0,1].	If we use DTW as pre-processing, output motion is **normal**. Otherwise, it's foot-skating.
3	SPLOC decomposition X = WC; Consider each row of C as one Simple motion. Do SVD, then combine Simple motion.	Each simple motion is abnormal. Combined motion is **abnormal**, too.
2	Only combine first Simple motion (contain almost information)	**Abnormal**
4	Using Sparse coding to decompose a motion as a chain of Basic motion. $X \quad = \sum_{k=0}^{m} X \quad (f_k)$. Then synthesize.	Synthesized motion looks ok
5	Similar to fouth method. Instead of using Sparse coding, we ADMM to optimize first row of C and first column to find the best basic motion(= W_1C_1). Then synthesize.	Most result look fine, using DTW doesn't lead distinct change.

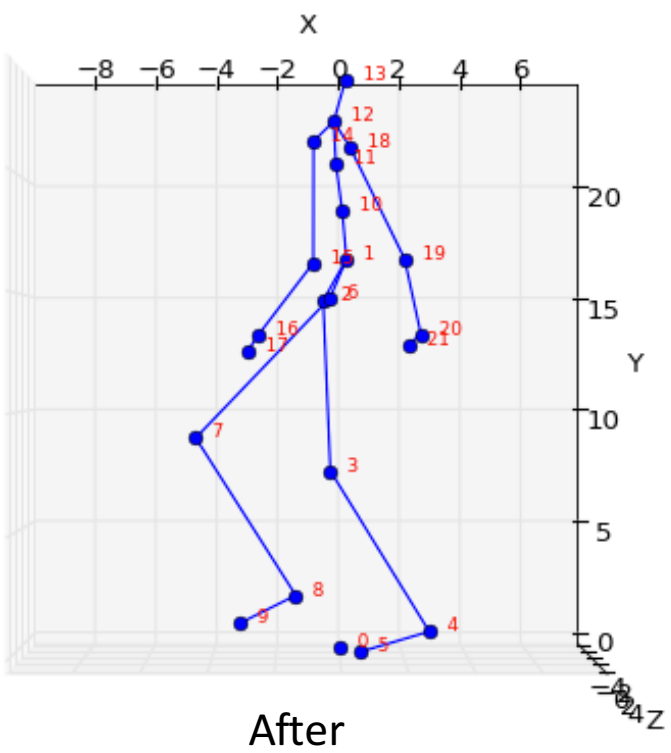
4. Motion distortion clean-up

- Pre-calculate limb lengths
- Apply pre-calculate limbs constraints into synthesized motion

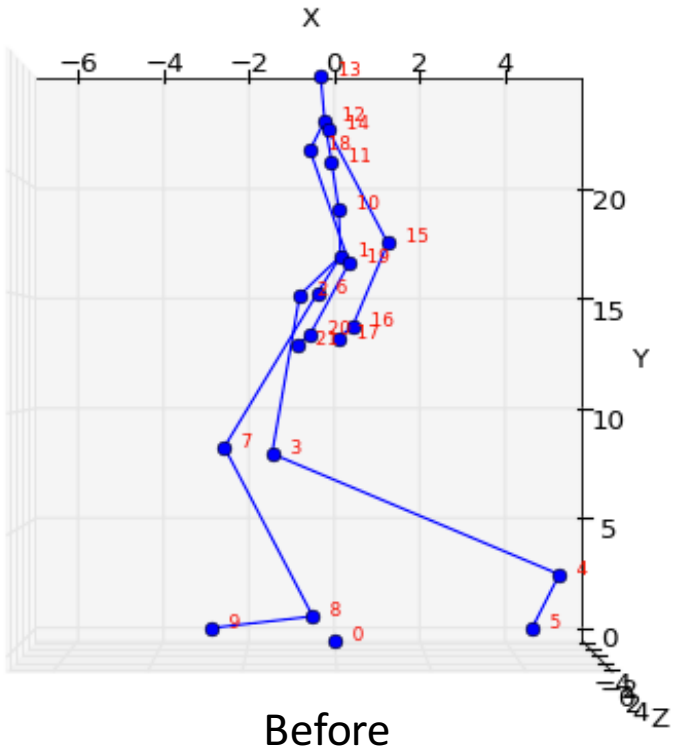


A constraint of D(J3, J4)

4. Motion distortion clean-up



After



Before

5. Results

- Show some demo videos.

Thanks for listening

Q&A