**Human Motion Signatures: Analysis, Synthesis, Recognition**

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**Approach**

1. Human motion is modeled as the composite consequence of:
   - **Actions:** essence of an activity or movement encodes action invariances across different people
   - **Motion Signatures:** distinctive pattern or movement of a particular individual encodes person invariances across different actions

2. **Tensor decomposition of motion data**: spanning multiple subjects performing different actions to extract motion signatures, action parameters & eigenmotions

3. **Analysis**: Yields a multilinear generative motion model that can synthesize new motions in the distinctive styles of these individuals

4. **Synthesis**: Given motion capture samples of an individual’s walk, synthesize other motions - ascending, descending stairs - in their distinctive style

5. **Recognition**: Motion signatures are used to recognize people. Similarly, action signatures are used to recognize actions

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**Analysis: - Tensor Decomposition**

Joint Angles \rightarrow Actions

\[ \mathcal{D} = U_{\text{people}} \times_1 U_{\text{actions}} \times_2 U_{\text{joint angles}} \]

- **Tensor Decomposition**:
  \[ \mathcal{D} = U_1 \times_1 U_2 \times_2 U_3 \times_3 \ldots \times_n U_n \times N U_N \]

- **N-mode SVD algorithm**:
  1. For \( n = 1, \ldots, N \), compute matrix \( U_n \) by computing the SVD of the flattened matrix \( D_{(n)} \) and setting \( U_n \) to be the left matrix of the SVD.
  2. Solve for the core tensor as follows
  \[ Z = D_{(1)} U_1^T \times_1 U_2^T \times_2 \ldots \times_n U_n^T \times N U_N^T. \]

- **Mode-n Tensor Flattening**: \( \mathcal{D} \rightarrow \mathcal{D}_{(n)} \)

- **Mode-n Product** of a tensor \( A \in \mathbb{R}^{k_1 \times k_2 \times \ldots \times k_N} \) & matrix \( M \in \mathbb{R}^{k_1 \times k_2} \) is a tensor \( B \in \mathbb{R}^{k_1 \times k_2 \times \ldots \times k_N} \)

\[
B = A \times_M M \quad B_{(n)} = MA_{(n)}
\]

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**Recognition**

Set of basis matrices that map motions into the people parameter space:

\[ \mathcal{P} = Z_{\times_2} U_{\text{actions}} \times_3 U_{\text{joint angles}} \]

Set of basis matrices that map motions into the action parameter space:

\[ \mathcal{A} = Z_{\times_1} U_{\text{people}} \times_3 U_{\text{joint angles}} \]

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**Synthesis Examples**