STRUCT @ PKU
Spatial and Temporal Restoration, Understanding and Compression

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CVPR
VANCOUVER, CANADA

Actionlet-Dependent Contrastive Learning for Unsupervised Skeleton-Based Action Recognition

Wangxuan Institute of Computer Technology, Peking University

CVPR 2023 Highlight

Poster ID: TUE-AM-226

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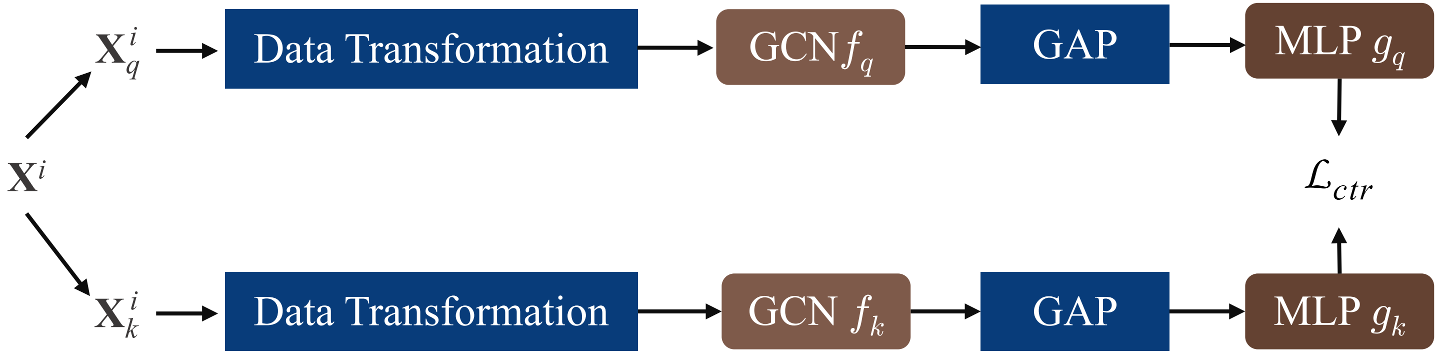
Challenges:

- Uniform data transformation → degrade the motion information
- Global average pooling → make feature space indistinguishable

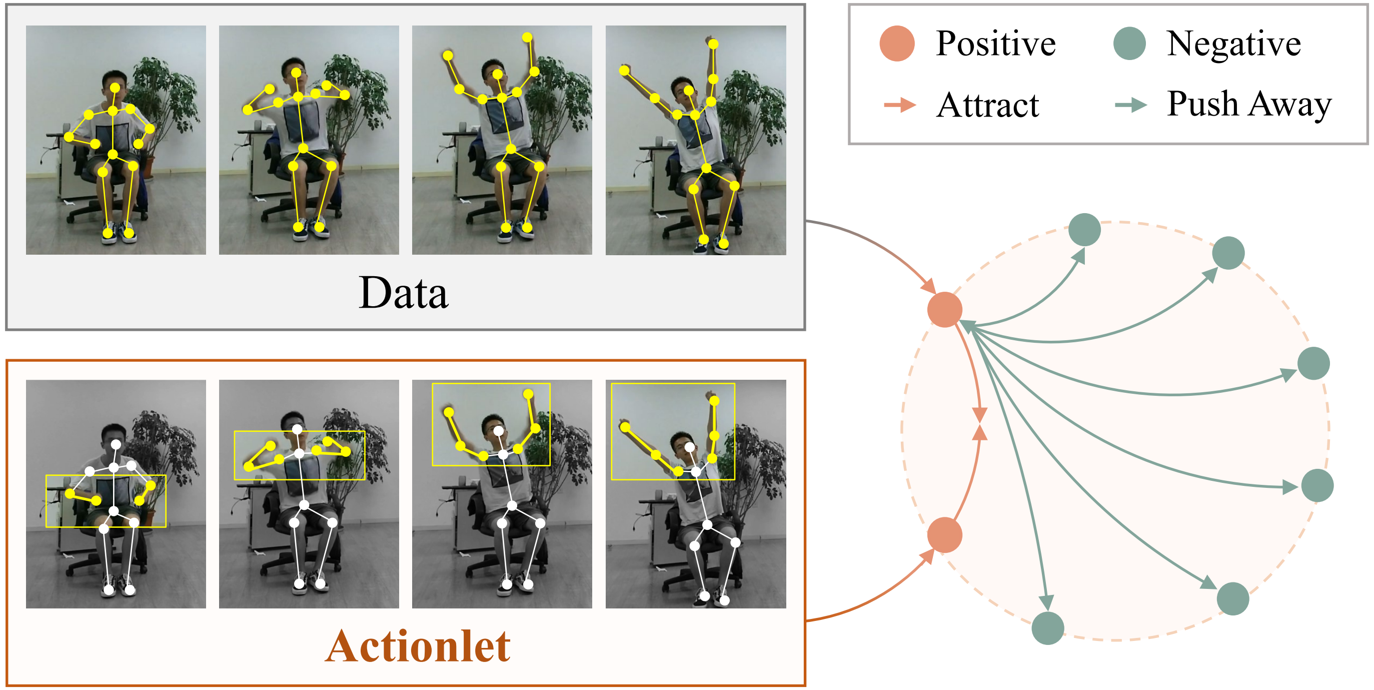


Challenges:

- Uniform data transformation → degrade the motion information
- Global average pooling → make feature space indistinguishable

Solution:

- Decouple **motion** and **static regions** in the data sequences



Aim and Challenge

Video in Big Data Era

- **Videos in Internet**
  - Over a billion users on YouTube
  - A billion hours of videos each day
- **Surveillance Videos**
  - 176 million in China in 2017
  - Expected 626 million by 2020

Huge number of videos contains **Human Action**

→ **Video Action Analytics**

05 Aim and Challenge

Various Applications

Surveillance

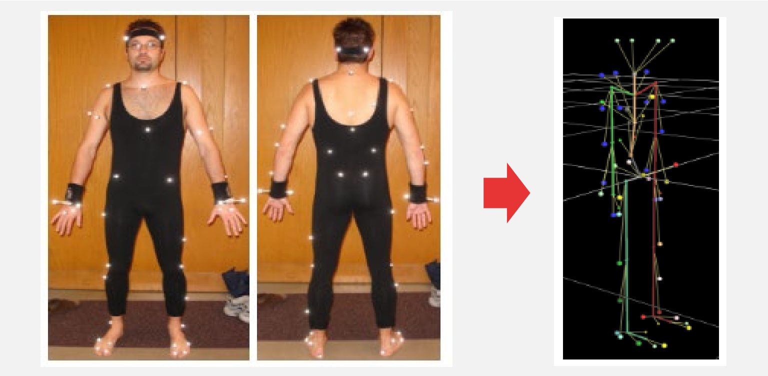
Retrieval

HCI

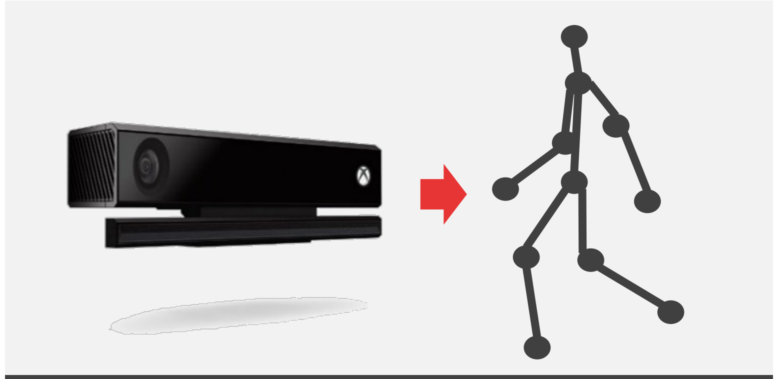
Home Care

Skeleton Data

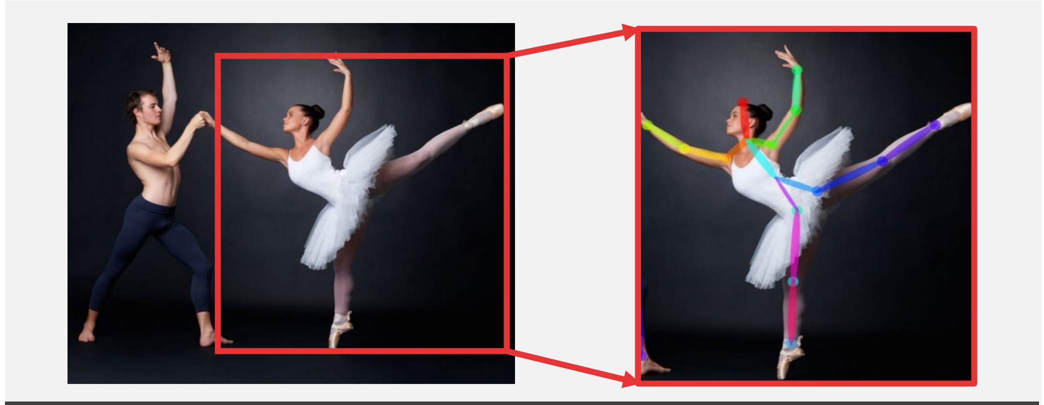
Data Access



Motion Capture System



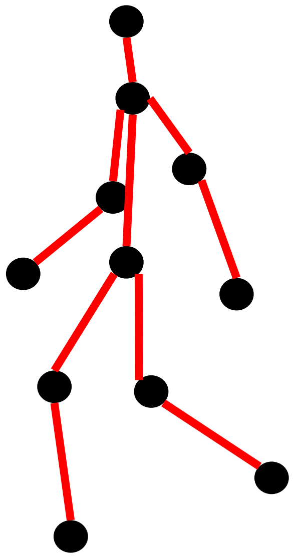
Microsoft Kinect



Pose Estimation

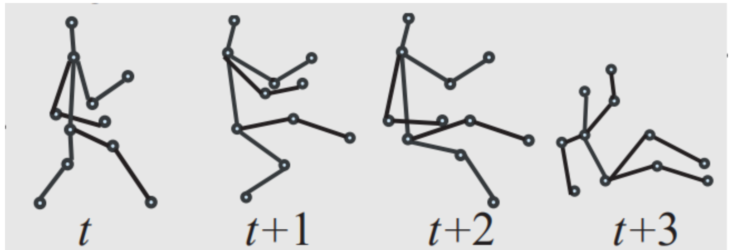
Skeleton Data

- **Pros**
  - High-level human representation
  - Robust to illumination and clustered background
  - Additional depth information
  - Real-time online performance
- **Cons**
  - Missing visual information
  - Not reliable due to noise and occlusion



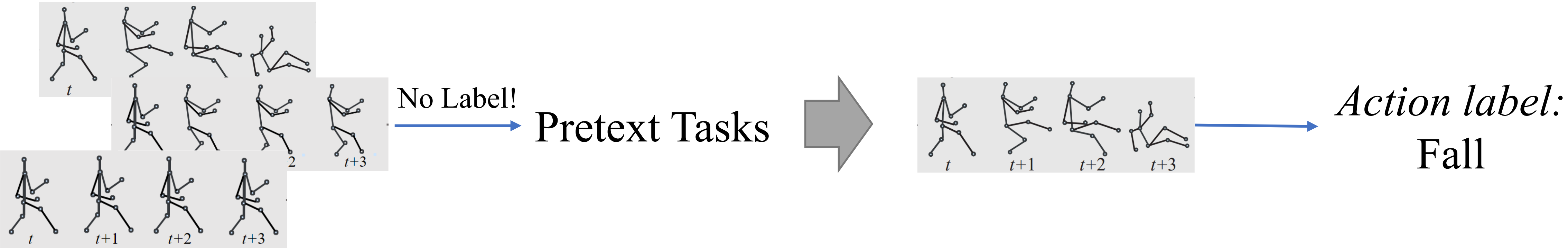
Aim and Challenge

Skeleton-Based Action Recognition:



Action label:
Fall

Self-Supervised Learning:



No Label!

Pretext Tasks

Action label:
Fall

Self-Supervised Pretrain

Supervised Finetune

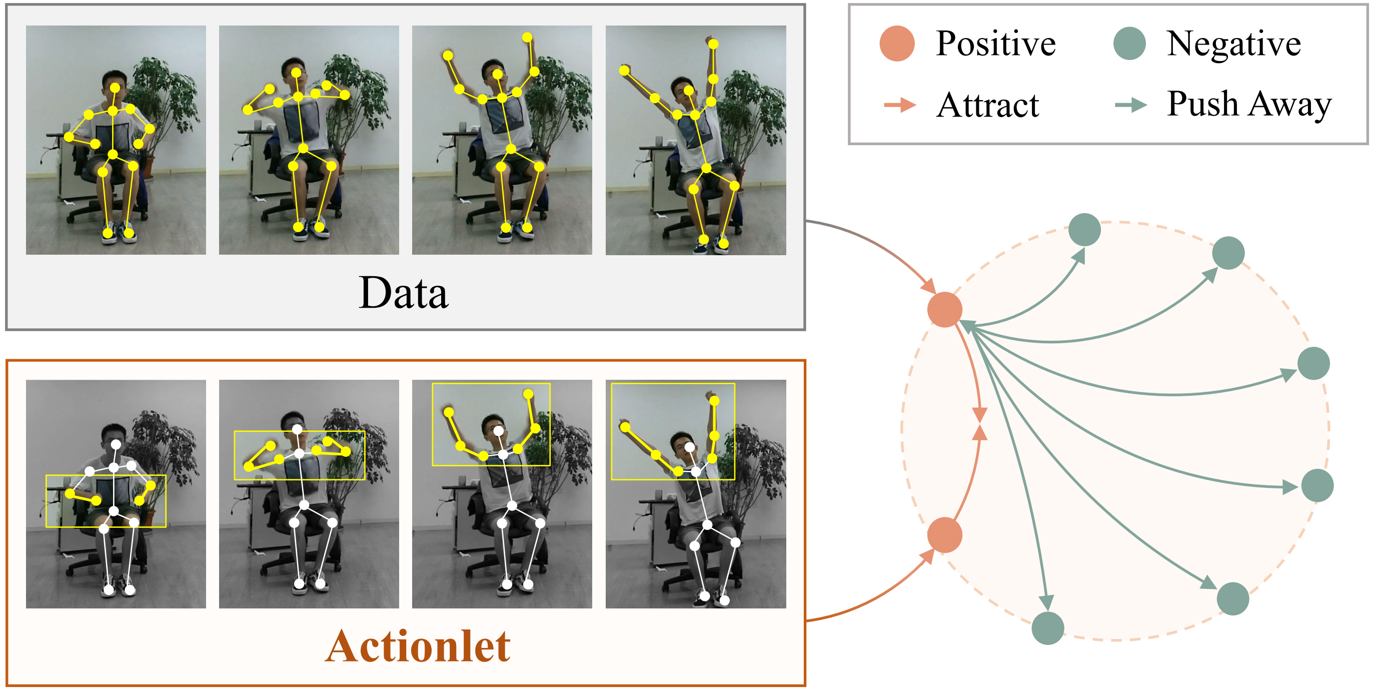
Aim and Challenge

Challenges:

- Uniform data transformation → degrade the motion information
- Global average pooling → make feature space indistinguishable

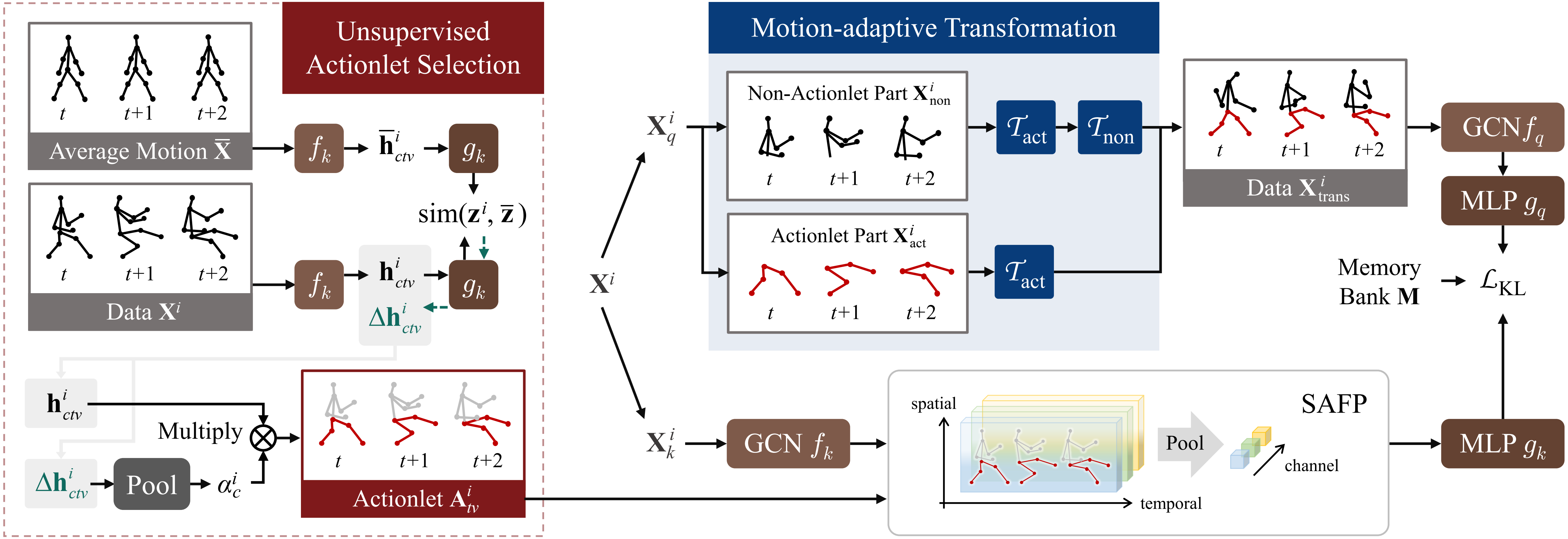
Solution:

- Decouple **motion** and **static regions** in the data sequences



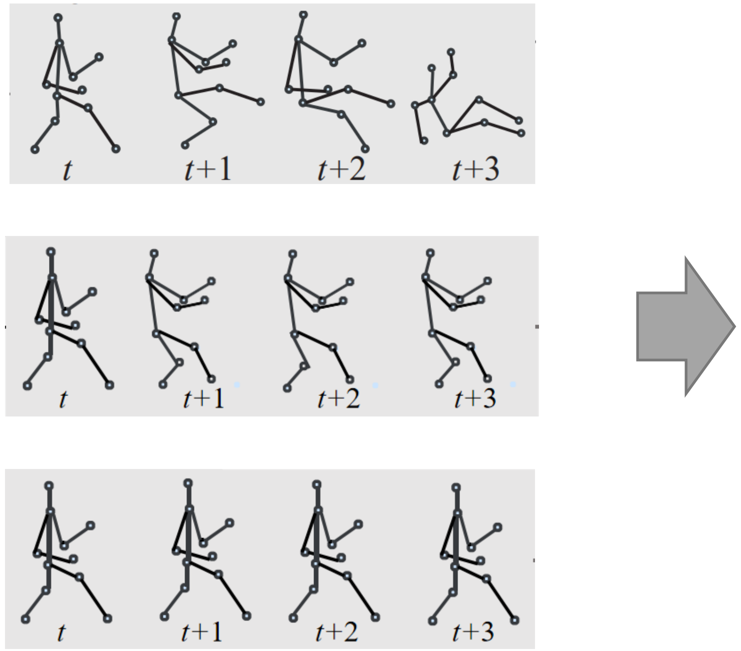
■ Overall Network Architecture

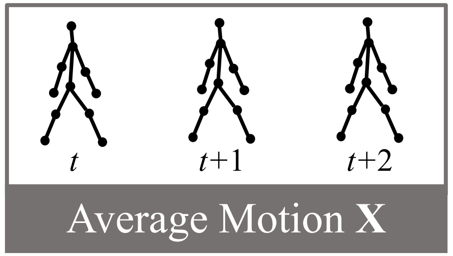
- Unsupervised Actionlet Selection
- Actionlet-Guided Contrastive Learning


Unsupervised Actionlet Selection
t
t+1
t+2
Average Motion $\bar{\mathbf{X}}$
f_k
$\bar{\mathbf{h}}^i_{ctv}$
g_k
sim($\mathbf{z}^i$, $\bar{\mathbf{z}}$)
Data $\mathbf{X}^i$
$\mathbf{h}^i_{ctv}$
$\Delta\mathbf{h}^i_{ctv}$
Multiply
Pool
α^i_c
Actionlet $\mathbf{A}^i_{tv}$
$\mathbf{X}^i$
$\mathbf{X}^i_q$
$\mathbf{X}^i_k$
Motion-adaptive Transformation
Non-Actionlet Part $\mathbf{X}^i_{\text{non}}$
Actionlet Part $\mathbf{X}^i_{\text{act}}$
$\mathcal{T}_{\text{act}}$
$\mathcal{T}_{\text{non}}$
Data $\mathbf{X}^i_{\text{trans}}$
GCN f_q
MLP g_q
Memory Bank $\mathbf{M}$
$\mathcal{L}_{\text{KL}}$
GCN f_k
SAFP
spatial
temporal
channel
MLP g_k

Overall Network Architecture

- Unsupervised Actionlet Selection
  - Average Motion as Static Anchor



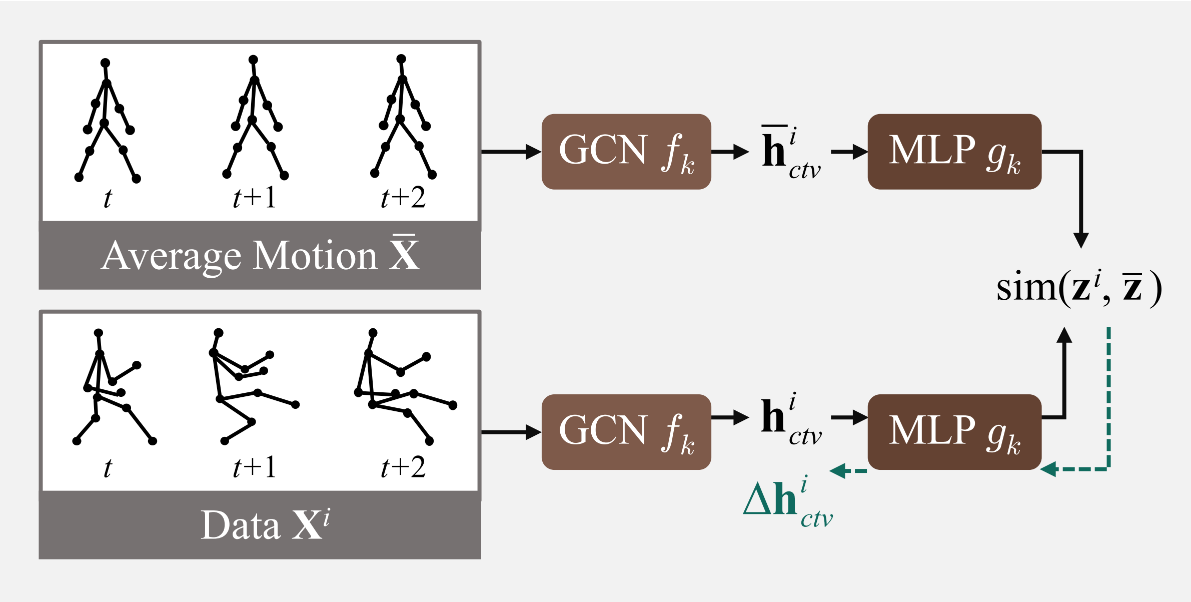


$$\bar{\mathbf{X}} = \frac{1}{N}\sum_{i=1}^{N}(\mathbf{X}^{i})$$

Overall Network Architecture

Unsupervised Actionlet Selection

Difference Activation Mapping for Actionlet Localization

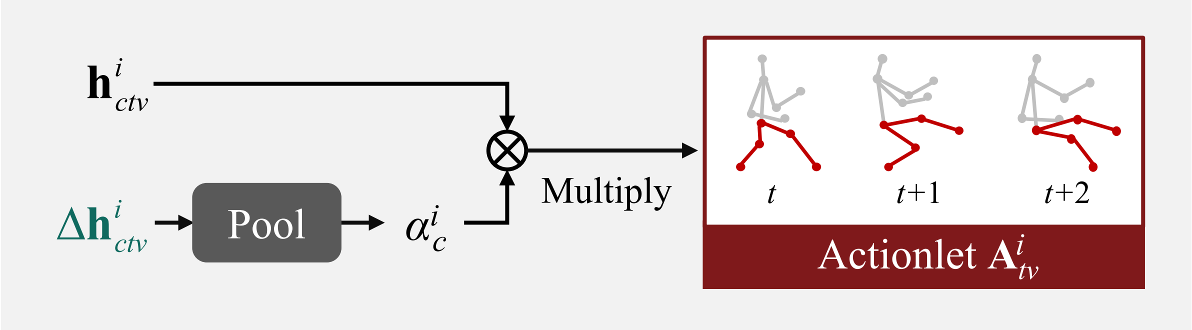

t
t+1
t+2
Average Motion $\bar{\mathbf{X}}$
GCN f_k
$\bar{\mathbf{h}}^i_{ctv}$
MLP g_k
$\mathrm{sim}(\mathbf{z}^i, \bar{\mathbf{z}})$
t
t+1
t+2
Data $\mathbf{X}^i$
GCN f_k
$\mathbf{h}^i_{ctv}$
MLP g_k
$\Delta\mathbf{h}^i_{ctv}$

$$\Delta \mathbf{h}^i_{ctv} = \frac{\partial(-\mathrm{sim}(\mathbf{z}^i, \bar{\mathbf{z}}))}{\partial \mathbf{h}^i_{ctv}},$$

$$\alpha^i_c = \frac{1}{T \times V} \sum_{t=1}^{T} \sum_{v=1}^{V} \sigma(\Delta \mathbf{h}^i_{ctv}),$$

Overall Network Architecture

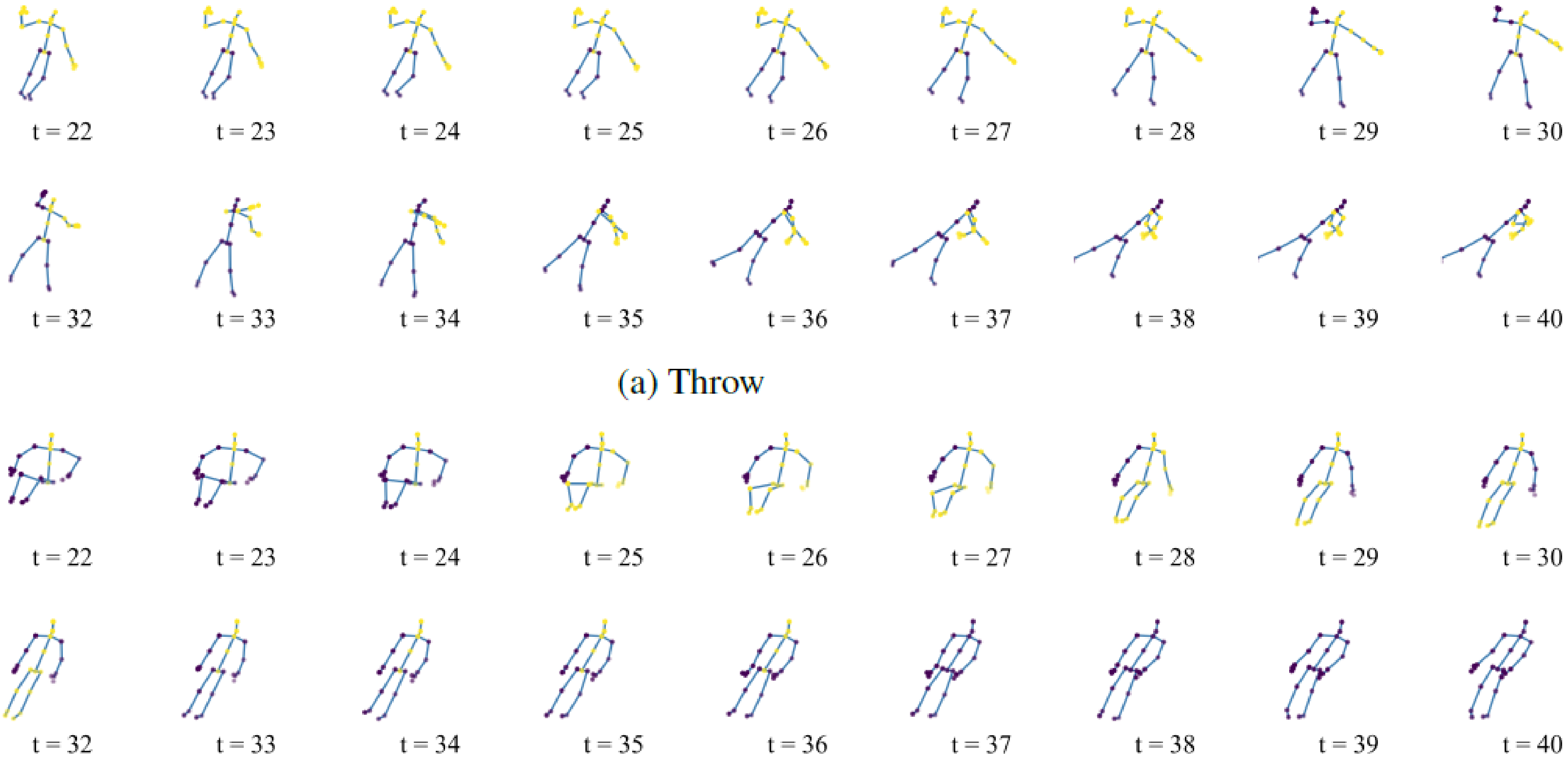
- Unsupervised Actionlet Selection
  - Difference Activation Mapping for Actionlet Localization



$$\mathbf{A}^i_{tv} = \sigma\left(\sum_{c=1}^{C} \alpha^i_c \mathbf{h}^i_{ctv}\right)\mathbf{G}_{vv}$$

Overall Network Architecture

- Unsupervised Actionlet Selection
  - Visualization of Actionlet

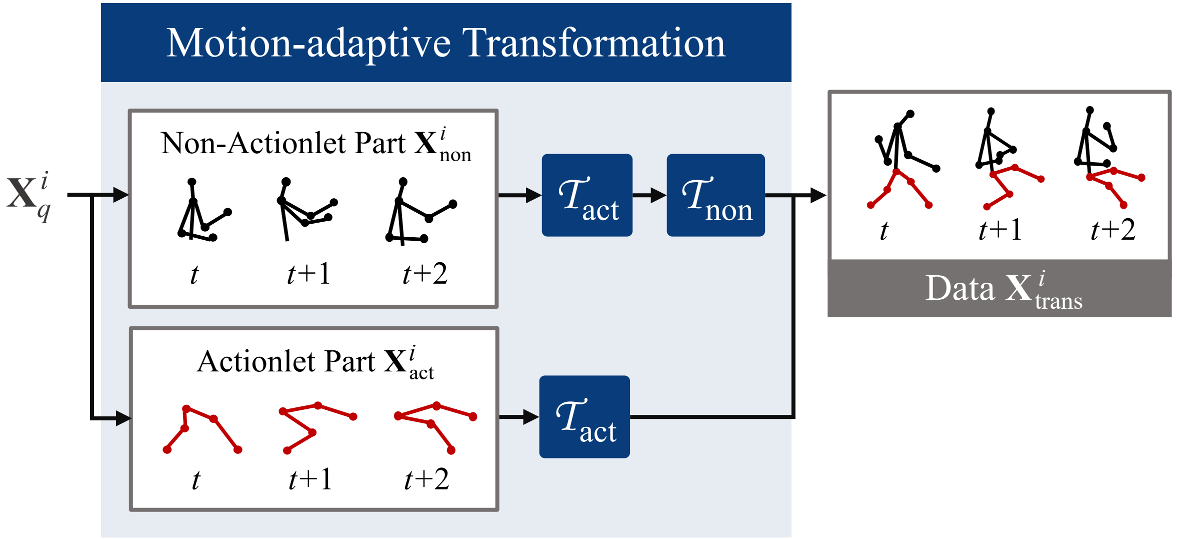


(a) Throw

(b) Standup

Overall Network Architecture

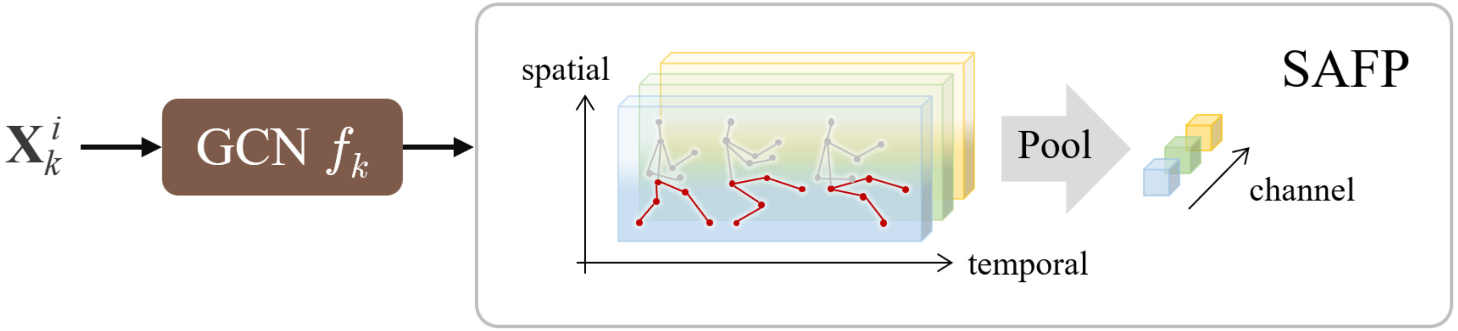
- Actionlet-Guided Contrastive Learning
  - Motion-Adaptive Transformation Strategy


Motion-adaptive Transformation
$\mathbf{X}_q^i$
Non-Actionlet Part $\mathbf{X}_{\text{non}}^i$
t
t+1
t+2
Actionlet Part $\mathbf{X}_{\text{act}}^i$
t
t+1
t+2
$\mathcal{T}_{\text{act}}$
$\mathcal{T}_{\text{non}}$
$\mathcal{T}_{\text{act}}$
t
t+1
t+2
Data $\mathbf{X}_{\text{trans}}^i$

- Actionlet Transformation
  - *Shear, Spatial Flip, Rotate, Axis Mask*
  - *Crop, Temporal Flip*
  - *Gaussian Noise, Gaussian Blur*
  - *Skeleton AdaIN*
- Non-Actionlet Transformation
  - *Random Noise, Skeleton Mix*

Overall Network Architecture

- Actionlet-Guided Contrastive Learning
  - Semantic-Aware Feature Pooling

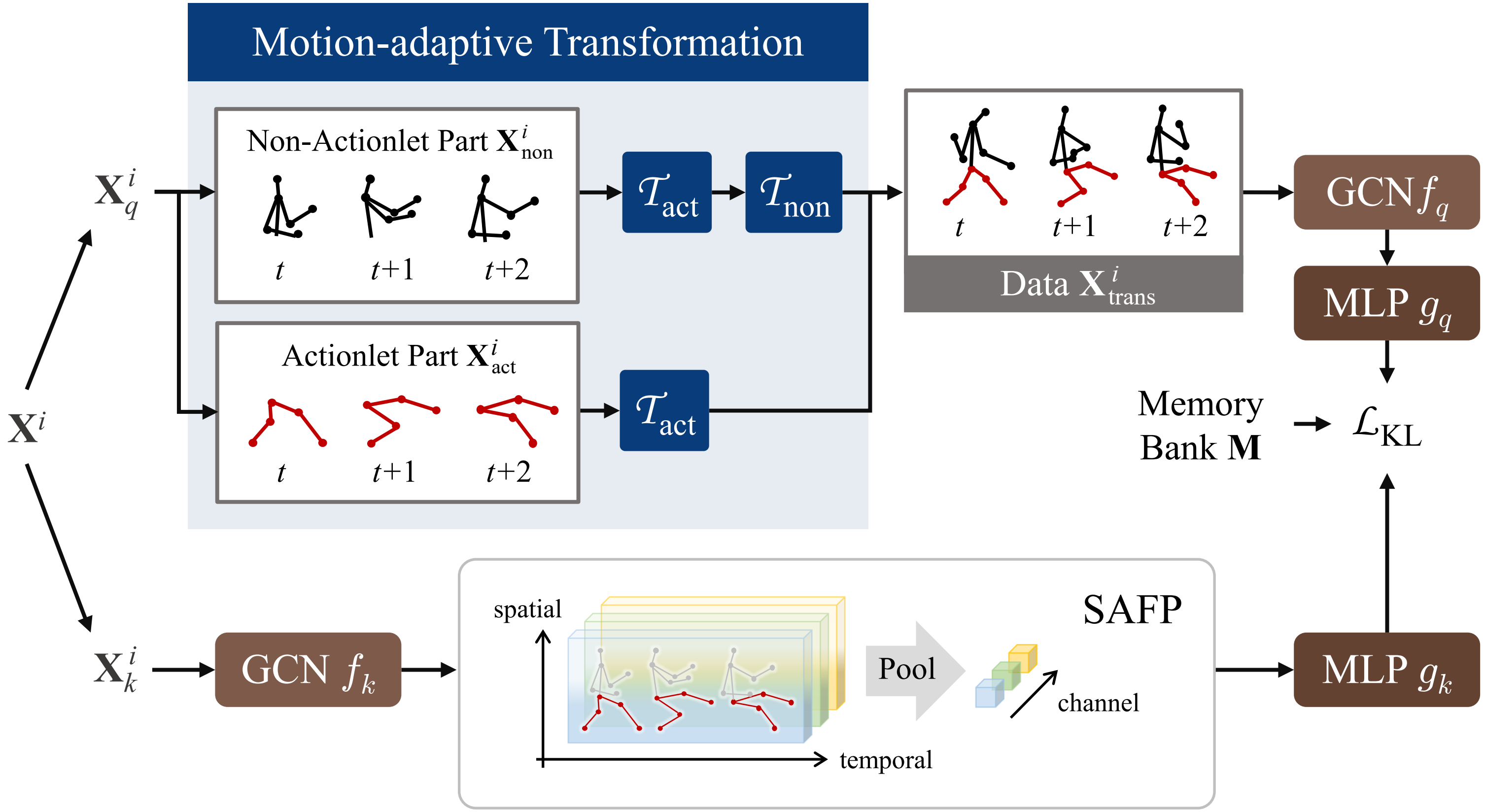


$$\mathrm{SAFP}(\mathbf{h}_{ctv}^i) = \sum_{t=1}^{T}\sum_{v=1}^{V}\mathbf{h}_{ctv}^i\left(\frac{\mathbf{A}_{tv}^i}{\sum_{t=1}^{T}\sum_{v=1}^{V}\mathbf{A}_{tv}^i}\right)$$

Overall Network Architecture

Actionlet-Guided Contrastive Learning

- Training Overview


Motion-adaptive Transformation
$\mathbf{X}^i_q$
$\mathbf{X}^i$
$\mathbf{X}^i_k$
Non-Actionlet Part $\mathbf{X}^i_{\text{non}}$
t
t+1
t+2
Actionlet Part $\mathbf{X}^i_{\text{act}}$
t
t+1
t+2
$\mathcal{T}_{\text{act}}$
$\mathcal{T}_{\text{non}}$
$\mathcal{T}_{\text{act}}$
t
t+1
t+2
Data $\mathbf{X}^i_{\text{trans}}$
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spatial
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Pool
channel
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MLP g_k

Experiment Configurations

- Unsupervised approaches

  - Train the classifier with pretrained encoder fixed.

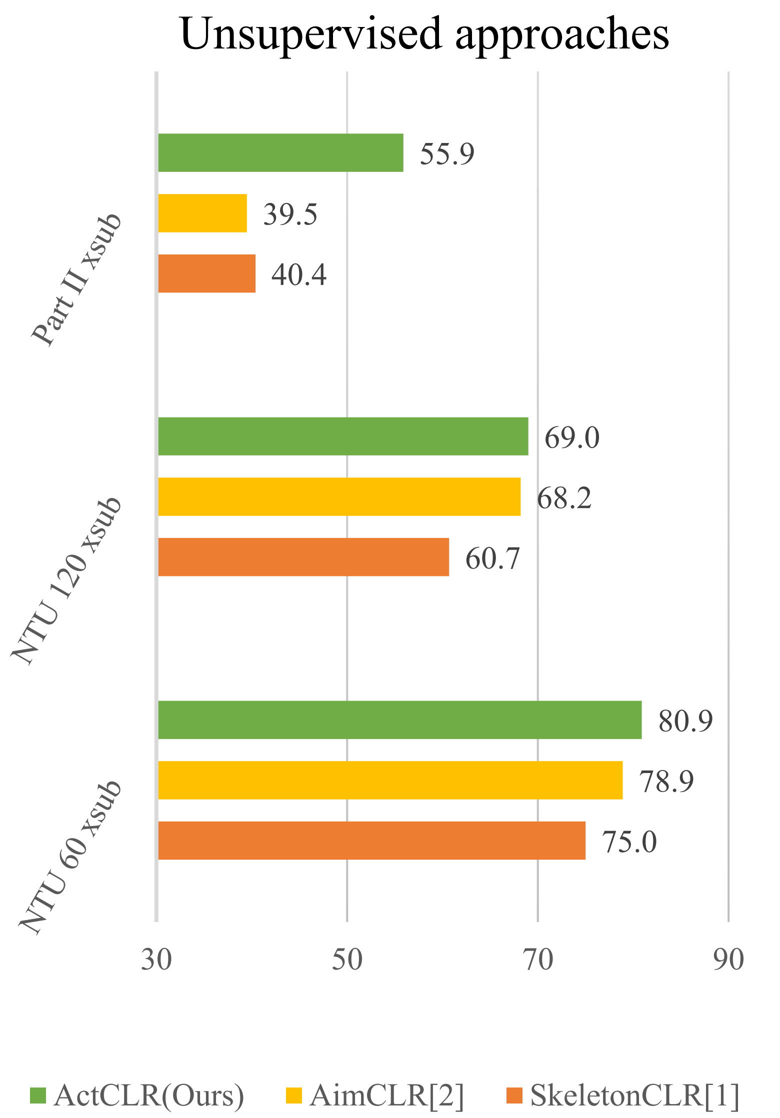
- Semi-supervised approaches

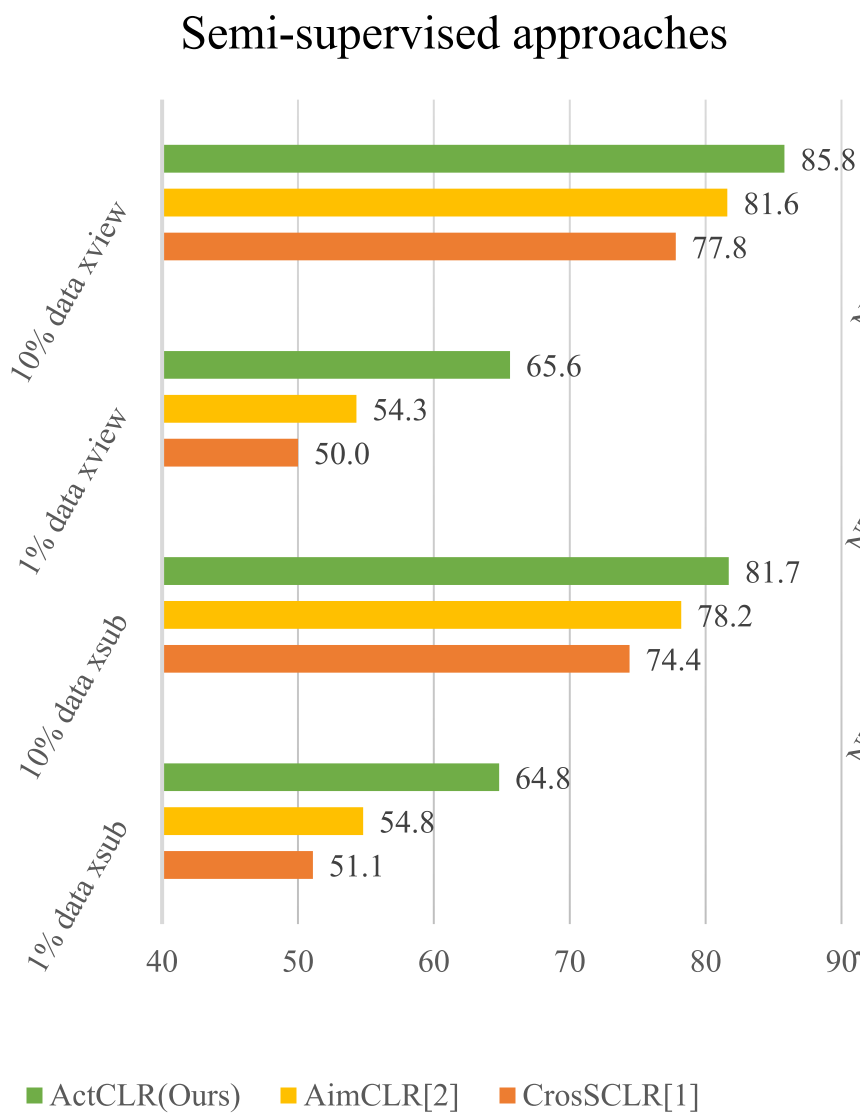
  - Jointly train the classifier and encoder with partial labeled data.

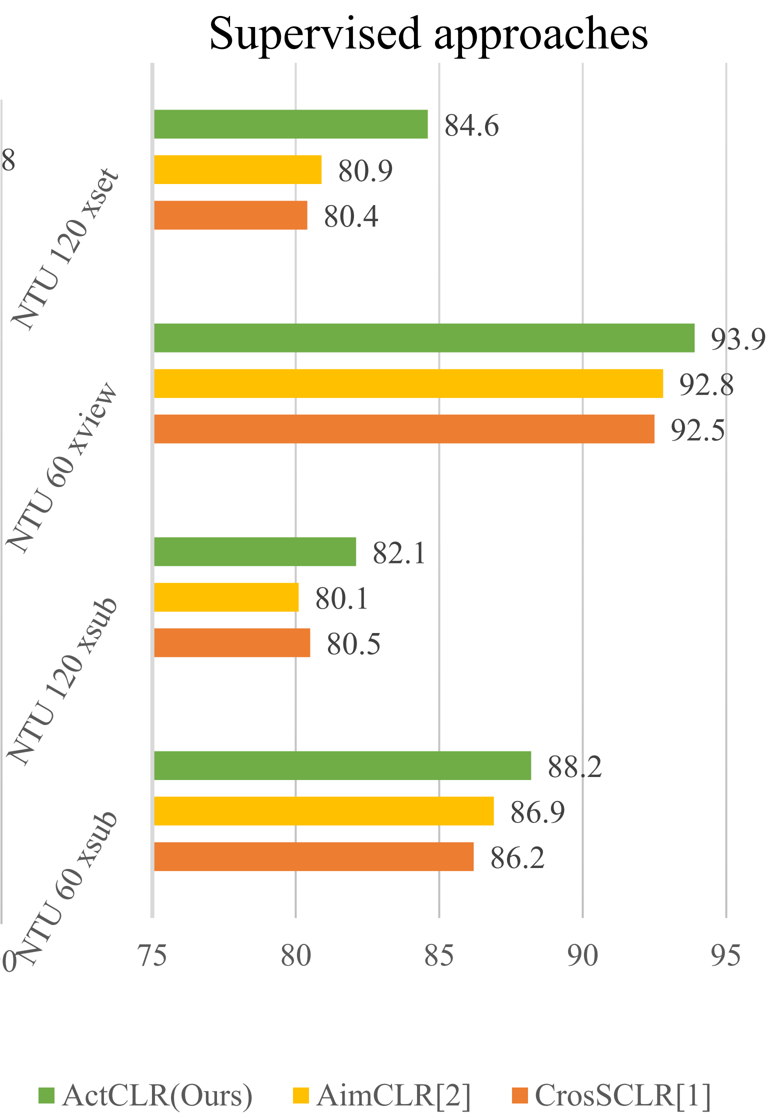
- Supervised approaches

  - Jointly train the classifier and encoder with full labeled data.

Experiment Results







[1] Li et al. 3D human action representation learning via cross-view consistency pursuit. CVPR 2021.

[2] Guo et al. Contrastive learning from extremely augmented skeleton sequences self-supervised action recognition. AAAI 2022.

Conclusion

- **Skeleton Based Action Recognition**
  - Unsupervised Actionlet Selection
  - Actionlet-Guided Contrastive Learning
- **Experimental Results**
  - Impressive results compared with other methods
  - Generalizable in different settings

Project

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STRUCT: www.wict.pku.edu.cn/struct/