A comparison of human skeleton extractors for real-time human-robot interaction

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Motivation:

Safety insurance

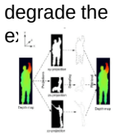
Context understanding

Ergonomic adaptation

Multi-modal data for activity recognition:

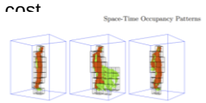
3D silhouette

- Limited for atomic actions recognition
- Occlusion will degrade the e:



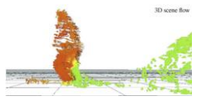
Space-time occupancy pattern

- Pattern can be sparse.
- High computation cost



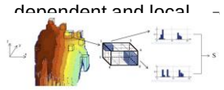
3D optical flow

- Computationally costly
- Not suitable for real time application



Local spatial temporal features

+ No need for segmentation or tracking
- The feature is view-dependent and local



Skeletal data

+ Invariant to the camera location, subject appearance and human body size
+ Can be combined with biomechanical model
- Current estimation algorithm is not perfec

Skeleton extraction frameworks comparison:

General functionality:

Skeleton extractors	Framework	Output	Technique	Specialty
Detectron2	Pytorch	17 key-points	Segmentation on each key-point, one-step estimation	Segmentation
MediaPipe	Tensorflow	33 key-points with 3d inference	Two-step estimation, region of interest detector + joint position tracker	Joint position tracking
YOLOv7	Pytorch	17 key-points	One-step estimation	Occlusion does not influence detection
ALPHA POSE	Pytorch	17/26/136 key-points	Two-step estimation	Pose aware identity mechanism
OpenPose	Caffe	15/18/25/67/137 key-points	Two-step estimation, Using part affinity fields	Direct C++ API is available 3D estimation is possible upon multiple synchronized camera views

Performance evaluation:

Skeleton extractors	Identification	Multi-person detection	Foot keypoints	Hand keypoints	Facial keypoints	Easy C++ interfacing	Robustness with respect to motion	GPU integration	Framerate
Detectron2	×	✓	×	×	ears,eyes,nose	×	✓	✓	3.57 fps
Mediapipe	✓	×	✓	✓	ears,eyes, nose,mouth	×	×	✓on Linux	17 fps
YOLOv7	×	✓	×	×	ears,eyes,nose	×	✓	✓	11.04 fps
Alphapose	✓	✓	×	×	ears,eyes, nose,mouth	×	✓	✓	9.74 fps
Openpose	×	✓	✓	✓	ears,eyes, nose,mouth	✓	✓	✓	9.91 fps

Future work:

- Quantitative comparison of 5 frameworks' outputs
- Using OpenPose library with human biomechanical model to estimate human skeleton on image inputs in real-time
- Human activity classification based on joint space information

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