Final Term Project Presentation

Skeleton-based Gait Recognition via Robust Frame-level Matching

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- Gait
  How a person walks
- Gait Recognition
  Biometric identification method
- Skeleton-Based
  Skeleton joints extracted by 3D motion capture tool
- Frame-Level Matching
  Matching based on the quality of the frame

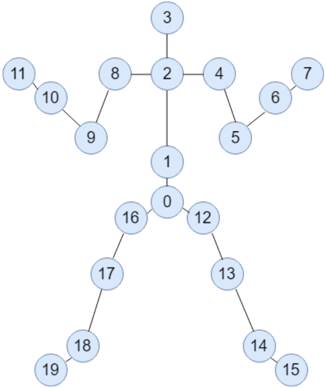


Figure: Extracted Skeleton Joints

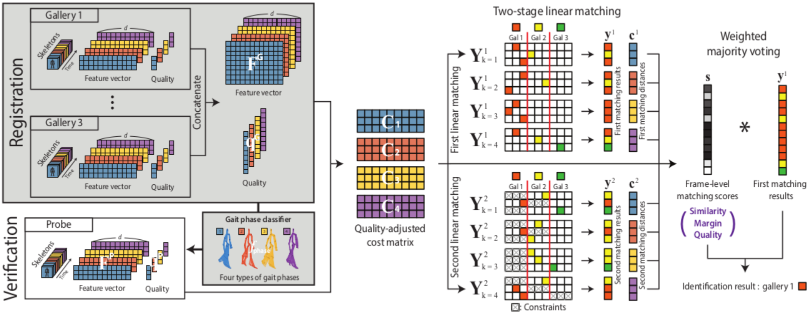
Research Challenges

- Development of view and scale-invariant feature descriptor
- Effective representation of human gait
- Ensuring low computational cost
- Minimize the influence of noise and other covariate conditions

Existing Works

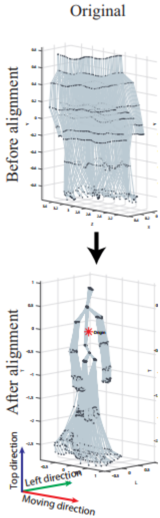
- Appearance-based methods [1], [2]
  - Silhouette information obtained from background subtraction
  - Average aligned silhouettes through statistical analysis - also known as Gait Energy Image
  - Low computational cost
  - Sensitive to changes in observation view
- Model-based methods[3], [4], [5], [6], [7]
  - Analyze the kinematics of human body parts in 3D space
  - Use sensors or motion capturing devices for constructing 3D skeleton
  - Inaccurate skeleton estimation as noisy frames and characteristic frames are equally treated

Overall Framework

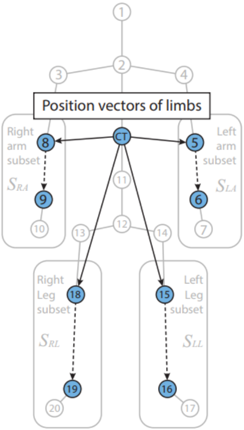


Centroid-based Skeleton Alignment

- Translation vector to move the centers of all skeletons to the origin
  - using centroid of joint position of torso
- Scale vector to make all skeletons equal in size
  - using centroids of the joints of upper torso and lower torso
- Rotation matrix to rotate all skeletons in the same direction
  - using position difference of the centroid to detect moving direction
  - position of centroid taken in variable time interval

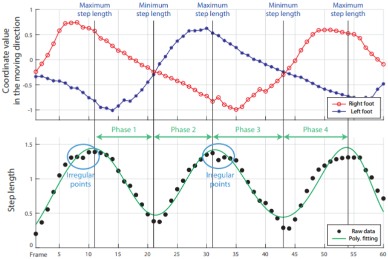


- Combination of position vectors from centroid
  - Left Elbow
  - Right Elbow
  - Left Knee
  - Right Knee
- Other vectors
  - Left Elbow → Left Wrist
  - Right Elbow → Right Wrist
  - Left Knee → Left Ankle
  - Right Knee → Right Ankle
- Contains information about both distance and angles
- Invariant to view and scale due to skeleton alignment
- 8 position vectors to form a 24-dimensional feature vector



Temporal Segmentation of Gait Cycle

- Divide recurrent gait cycle into 4 gait phases based on the movement of feet
- Estimate label of each gait phase based on which foot is in front
- Polynomial fitting to the raw step length to reduce irregularities in step length measurement
- Use Random Forest classifier to estimate labels



Two-stage Linear Matching

Preprocessing

- Pairwise distance between two vectors - Manhattan distance
- Measure quality of skeleton based on symmetry of human body using arm and leg symmetry
- The more assymmetric the length of the arm or leg, the lower the skeleton quality
- Create cost matrix using distance of test frame and stored frame, and quality
- Compute cost matrix for phases of stored frame that are identical to phases of test frame to reduce computational cost

Two-stage Linear Matching

Stage 1

- Linear assignment problem - Combinatorial optimization to find minimum weight matching given a cost matrix
  Solution: Hungarian Algorithm
- Solve linear assignment problem with cost matrix to find the person having the most similar pattern from stored frames

Stage 2

- Again solve linear assignment problem with second-most similar pattern
- To prevent matching with same person give infinite cost penalty to the first matched person

Weighted Majority Voting

- Using quality of the input frame, assign weight to each of the matched phases
- Calculate similarity of each pattern using inverse of distance from stored pattern
- Calculate margin between two matched patterns using ratio of their distance from the matched frame
- Calculate frame-level matching score using the combination of these three
- Vote the user with the most matching score

Referenced Paper

Choi, S., Kim, J., Kim, W., & Kim, C. (2019). Skeleton-based Gait Recognition via Robust Frame-level Matching. *IEEE Transactions on Information Forensics and Security.*

Tools Used

- MATLAB

Dataset

- UPCVgait
- CILgait
  - CIL-S (Stops Walking)
  - CIL-SC (S+Calling Pose)
  - CIL-SV (S+Looking at phone)
- UPCVgaitK2 (Not Freely Available)
- SDUgait (Not Freely Available)

Result Analysis

Accuracy

Method	UPCV1	CIL-S	CIL-SC	CIL-SV
Implementation	99.07	87.50	75.00	83.33
Ball et al. [3]	58.09	8.33	4.17	0.00
Preis et al. [4]	81.58	20.83	20.83	16.67
Kastaniotis et al. [5]	70.22	33.33	16.67	33.33
Ahmed et al.[6]	82.13	20.83	12.50	12.50
Kastaniotis et al. [7]	94.11	58.33	41.67	54.17

Runtime on UPCV1 dataset

Method	Runtime (seconds)
Implementation	3.05
Ahmed et al. [6]	8.07
Kastaniotis et al. [7]	61.58

Future Scope

- Reducing frame-by-frame comparison by finding representative patterns
- Use other image based 3D pose estimation techniques instead of Kinect

References

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5. Kastaniotis, D., Theodorakopoulos, I., Economou, G., & Fotopoulos, S. (2013, July). Gait-based gender recognition using pose information for real time applications. In *2013 18th International Conference on Digital Signal Processing (DSP)* (pp. 1-6). IEEE.
6. Ahmed, F., Paul, P. P., & Gavrilova, M. L. (2015). DTW-based kernel and rank-level fusion for 3D gait recognition using Kinect. *The Visual Computer*, 31(6-8), 915-924.
7. Kastaniotis, D., Theodorakopoulos, I., Theoharatos, C., Economou, G., & Fotopoulos, S. (2015). A framework for gait-based recognition using Kinect. *Pattern Recognition Letters*, 68, 327-335.

THANK YOU