Automatic Gait Recognition

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Gait as a Biometric

- Gait – “A person’s manner of walking”
  - Webster Definition
- It is a non-contact, unobtrusive, perceivable at a distance and hard to disguise
- It is a behavioral biometric and is subject to change (Eg. A person in hurry and the same person when relaxed).

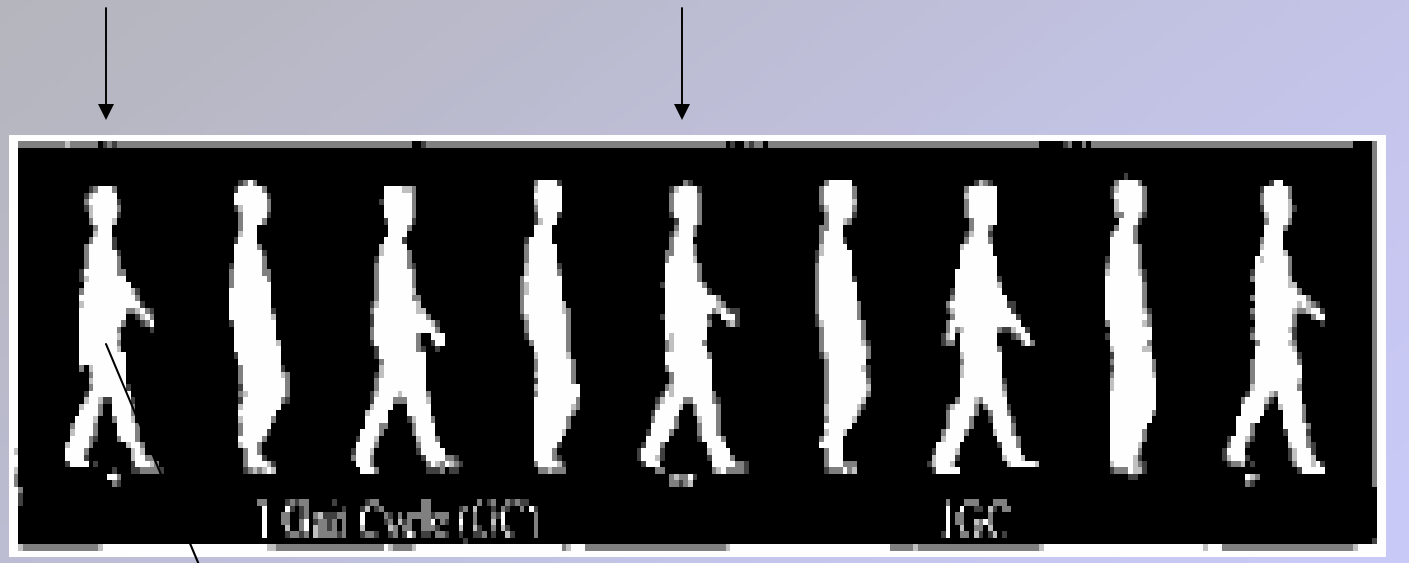
What is Gait?

- Gait is a sequence of images. Hence spatio-temporal correlations must be taken into account.
- Murray et al. expressed gait as “ A total walking cycle”[1].
- A “Gait Cycle” is the time of heal strike between the same leg.

Publicly Available Databases

- HID-UMD databases contain walking sequences of 25-50 people in 4 different poses.[2]
- Nist Gait dataset (Gait Challenge Data)[3]
- Southampton Human ID at a distance database[4]
- UCSD, MIT and CMU databases.

Gait Cycle



Silhouette

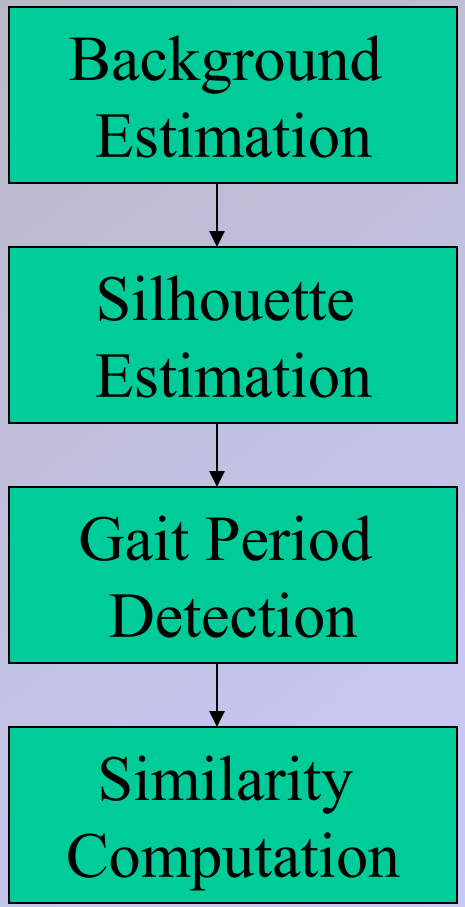
Any General Gait Recognition System

- Human Detection and Tracking
- Feature Extraction
- Training and Classification

Baseline Algorithm[5]

- Algorithm against which any gait recognition algorithm's performance improvements can be measured.
- Designed to be simple, fast, yet effective at computing similarity of gait in video sequences, based on both shape and dynamics.
- The algorithm was not designed to be robust against many well know sources of variations, such as illumination, clothing, 3D viewpoint etc.

Baseline Algorithm



Baseline Algorithm (Background Estimation)

Background Estimation

Semi-automatically mark bounding boxes

↓

Find the coordinates of the Super Bounding box. The background is estimated only for pixels within this super-bounding box.

↓

For each pixel location, use pixel values in the frames when that location is not within the corresponding bounding box to estimate the mean and covariance of the RGB or Chromaticity space.

Baseline Algorithm (Silhouette Estimation)

Silhouette Estimation

- Compute the Mahanalobis distance of each pixel within the bounding from the mean background image.
- Threshold the smoothed distances
- Use Expectation Maximization (EM) to estimate the silhouette from the distances.
- Keep just the largest connected region
- Center the silhouette in the horizontal direction by considering the upper half of the silhouette.
- Size-normalize so that the silhouette occupies the whole length of box.

Baseline Algorithm (Gait Period Detection)

Gait Period Detection

- Consider the number of silhouette pixels mostly from the legs (bottom half of the silhouettes) vs. time.
- Detect the local minima in the above plot
- Compute the median of the distances between minima, skipping every other minimum .
- Take the average of the medians as the gait period

Baseline Algorithm (Similarity Computation)

Similarity Computation

- Break up probe sequence into K subsequences of N_{gait} contiguous frames each.
- For each probe subsequence, estimate the maximum correlation with the gallery sequence.
- Pick the median of the maximum correlations of the probe subsequences as the similarity measure.

Recent Methods

- Structural Methods [6,7,8]
  - 2D or 3D structural model of the human body is assumed and body pose is recovered by extracting image features and mapping them to the structural components of the model Eg. stick model , blob model etc.
- Structure-free Method
  - State-space Methods – These methods represent human movements as a sequence of static configurations. Each configuration is recognized by learning the appearance of the body in the corresponding pose.
  - Spatiotemporal methods – Here, motion is characterized by the entire 3D spatiotemporal data (ie. x, y and time). Eg sequence of gray-scale images. This data is treaded as a large vector and recognition is done by mapping this vector to lower dimension feature vector and applying pattern recognition to it.

State Space Method

1. Template matching method using parametric eigenspace representation.[9]
2. Cluster based approach using eigenspace representation of silhouette images.[10]
3. There is a Markovian dependence from one stance to another. The gait cycle can be viewed as a doubly stochastic process in which the hidden process is represented by the transitions across the stances while the observable is the image generated when in a particular stance. The HMM is best suited for describing such a situation. [11]

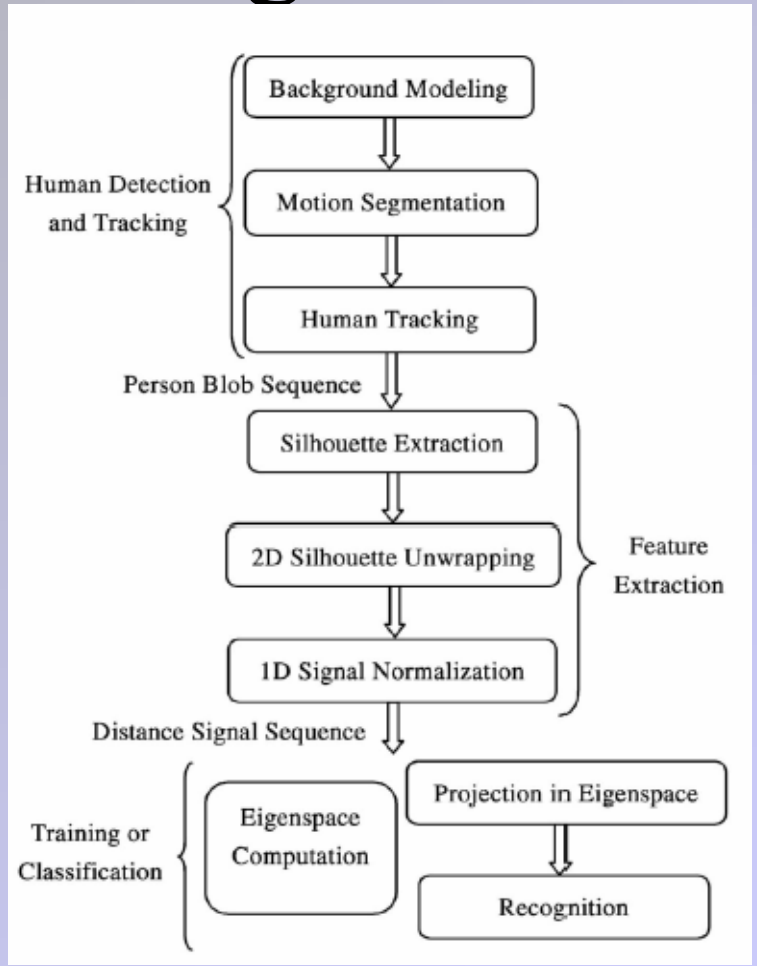
Spatiotemporal Method

- Self-similarity plots[12]

$$S(t_1, t_2) = \sum_{(x,y) \in B_{t_1}} |O_{t_1}(x, y) - O_{t_2}(x, y)|.$$

where $1 \leq t_1, t_2 \leq N$, B_{t_1} is the bounding box of the person in frame t_1, and $O_{t_1}, O_{t_2}, ..., O_{t_N}$ are the scaled image templates of the person.

Silhouette Analysis-based Gait Recognition[13]



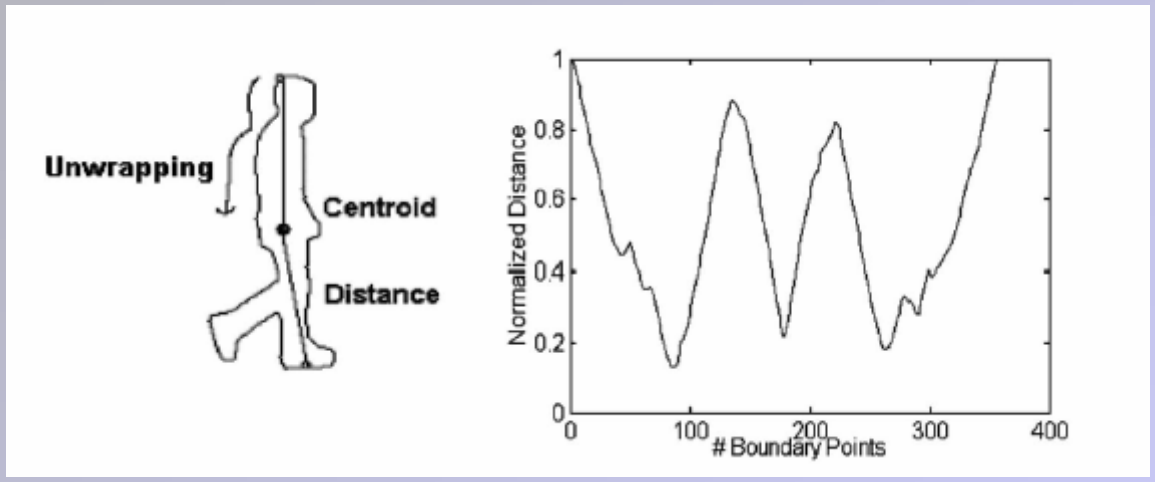
Human Detection and Tracking

- Background Modeling using Least Median of Squares.
- Background Subtraction and binerization to get Silhouette

Feature Extraction (Silhouette Representation)

- Binerization is performed to make the features insensitive to color and texture.
- An important cue in determining underlying motion of a person is the temporal changes in the silhouette.
- This can be captures by outline of the silhouette.
- Now to reduce computational cost we can take the outline of the silhouette and convert it to 1D.

Feature Extraction (Silhouette Representation)



- If we consider a flat surface on which people are walking, the centroid is pretty much fixed.
- Using centroid we unwrap the silhouette clockwise around the centroid using euclidian distance from centroid.
- This gives the representation invariance to noisy silhouette data.

Recognition

- First use PCA to project data into lower dimensions.
- A normalized Euclidian distance used for similarity measurement.
- Finally a simple K-Nearest Neighbor model is used to classify the sequences. The distance metric used is Normalized Euclidian distance.

Performance Analysis

- NLPR gait database It includes 20 different subjects, and three views, namely lateral view, frontal view and oblique view with respect to the image plane. The captured 24-bit full color images of 240 sequences have a resolution of 352*240.

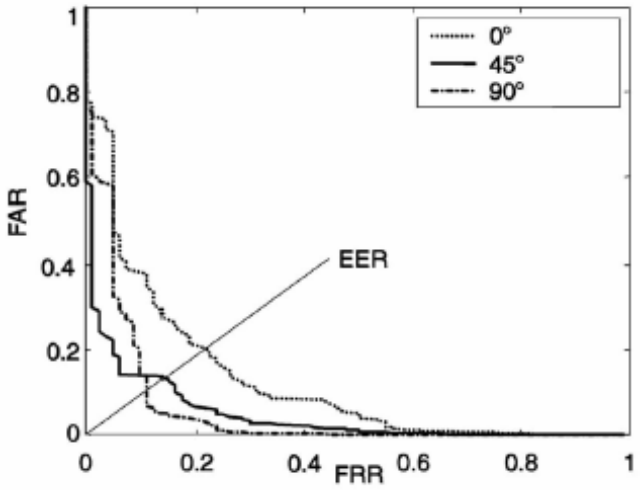


Fig. 9. ROC curves of gait classifier based on NED with respect to three viewing angles.

Comparison With Other Methods (Critical Tests)

Methods	Top 1 %	Top 5 %	Top 10 %	Computational costs (min/seq)
Baseline [5]	78.75	91.25	98.75	Highest(200)
Self-Similarity [12]	72.5	88.75	96.25	Medium(8.45)
Model Based approach[8]	87.5	98.75	100	Low(2.365)
PCA Template Based Approach [9]	71.25	78.75	87.5	High(17.807)
Silhouette Analysis-Based Gait Recognition [13]	82.5	97.5	100	Low(2.054)

Future Work

- Invariance to speed of walking.
- Robustness against subject walking over uneven surface.
- Real time gait recognition.
- Better accuracy!!!

References

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Questions ?