Accelerometer-based gait recognition

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Gait as a biometric

- Biometric-based recognition:
  - figure-prints, signatures, faces, speech ...
  - Intrinsic properties: won't be forgotten, lost or stolen (v.s. RFID, password)
- Gait: the motion of a walking body
- Properties of natural gait: **uniqueness**

Evidence: biomechanical [Murray, 1967], psychological [Cutting & Kozlowski, 1977, Stevenage et al., 1999]

  - Stability
  - Discriminativeness
- Compared with the other biometrics
  - More secure: hard to imitate
  - More user-friendly: no user input

Accelerometer-based gait recognition

- Ways to measure gait: **vision**, sound [Shoji et al., 2005], pressure sensors [Soames, 1985, Koho et al., 2004], accelerometers
- Gait accelerations: direct measurement of body motion
  - Seldom be affected by the environment changes
- Accelerometers are *cheap* and easily be *embedded* in
  - Cellphone, Watch, Tablet PC, Belt, Shoes
  - A good biometric for recognition tasks in mobile environments

Gait accelerations – Ankle

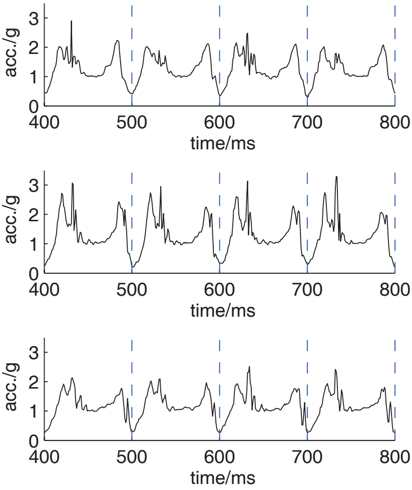


Figure: Gait accelerations measured at ankle (3 different subjects)

Gait accelerations – Waist

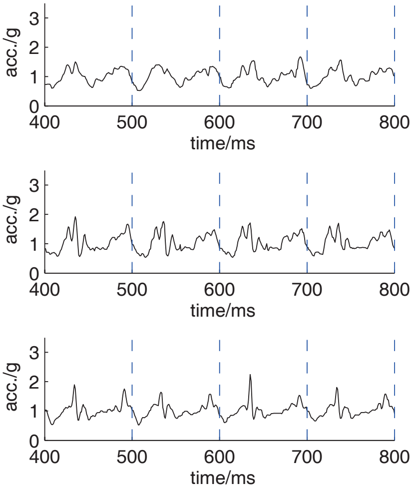


Figure: Gait accelerations measured at waist (3 different subjects)

Characteristics of gait accelerations

- Consistent between different subjects
- Different in **local pattern**
  - Some patterns are more discriminative;
    S/N is low in other parts are small
  - Not temporally aligned
  - Sparse but big noise (e.g. pattern loss)
- Different *body locations* show different gait accelerations
- Quasi-periodicity

Characteristics of gait accelerations – Local pattern

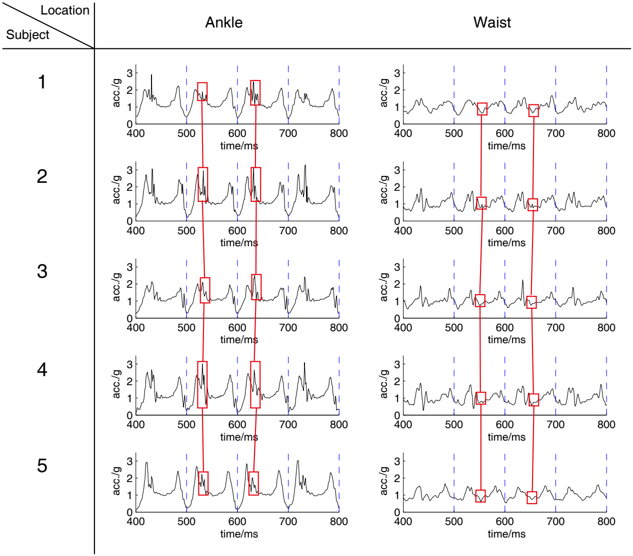


Figure: Local pattern differences

Characteristics of gait accelerations – Local pattern

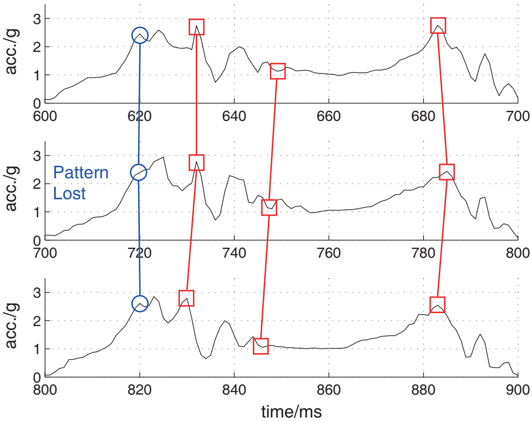


Figure: Local pattern loss and disalignment

Previous work

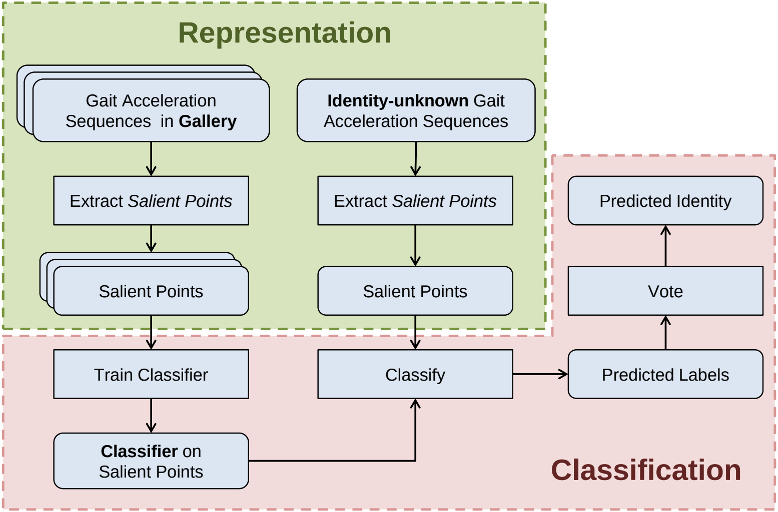
- Histogram: histogram on raw signal

  [Mäntyjärvi et al., 2005, Gafurov et al., 2006b, Gafurov et al., 2007]
- Frequency: Fourier transform

  [Mäntyjärvi et al., 2005, Rong et al., 2007]
- Cycle-template: detect cycle, average cycle, NN classifier

  [Mäntyjärvi et al., 2005, Gafurov et al., 2006a, Gafurov et al., 2006b, Gafurov et al., 2007, Rong et al., 2007]
- Do not make good use of the characteristics
  - except for the quasi-periodicity

Our approach for identification



- [Pan et al., 2009]: G. Pan, Y. Zhang, and Z. Wu, "Accelerometer-based gait recognition via voting by signature points," *Electronics Letters*, vol. 45, no. 22, pp. 1116–1118, October 2009.

- The representation

$$a(t) \rightarrow \{s_1, s_2, \ldots, s_m\},$$

where $a(t)$ is a gait acceleration sequence, s_i is a salient point.

- Salient point localization
  - Detect and normalize gait cycles
  - 1-D SIFT [Lowe, 2004]: extrema in multiple DoG filtered sequences
  - $\mathrm{rloc}(s)$ is the relative location of s in its gait cycle
- Salient point descriptor: neighboring signals

$$\Phi(s) = (a(s-h), \ldots a(s), \ldots, a(s+h)),$$

where h is the half size of s's neighborhood.

Our approach – Classification

Gallery: the salient points of N persons' gait accelerations.
For the unknown gait acceleration $a(t)$:

- k-NN classify s_i, and get the predicted label l_i. The metric is

$$d(s_1, s_2) = \begin{cases} \left\| \Phi(s_2) - \Phi(s_1) \right\|, & |\operatorname{rloc}(s_2) - \operatorname{rloc}(s_1)| < \delta, \\ +\infty, & \text{otherwise.} \end{cases}$$

- Histogram on labels $(c_1, c_2, \ldots, c_N)$, where $c_j = |\{l_i | l_i = j\}|$.
- Final prediction: $l = \arg\max_j c_j$.

For the cases of multiple body locations:

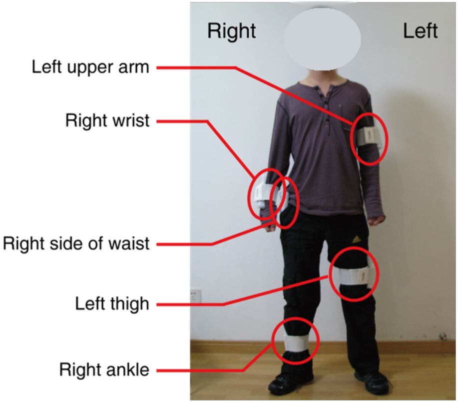
- Classification is done separately for different body location
- Histogram is computed together on all the body locations

Our approach – Advantages

- **Salient point**:
  - extract significant local patterns
  - throw away other patterns (considered to be noise)
- **Voting (histogram)**:
  - Implicitly align the local pattern
  - Robust to pattern loss and big distortions

Experiments – Dataset

- Hardware:
  - Wii Remotes, Bluetooth
- Body locations (see the figure)
- 30 subjects (more in the furture)
- 2 days per subject
- 6 sequence per day per subject
- one day for training, the other day for testing



Experiments – Results on identification

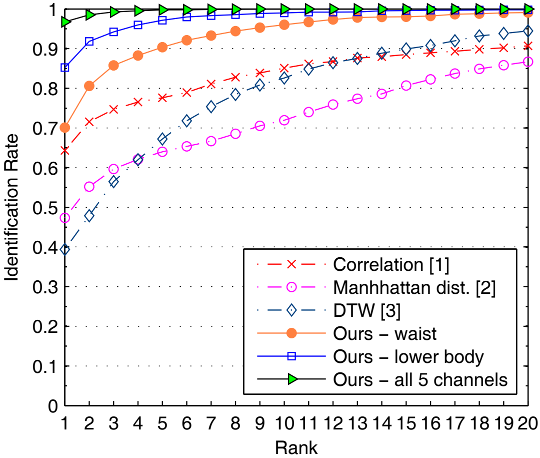


Figure: Cumulative Match Characteristics, CMC

[1] - [Mäntyjärvi et al., 2005]; [2] - [Gafurov et al., 2007]; [3] - [Rong et al., 2007]

Summary

- Accelerometer-based gait recognition has advantages over other approaches, especially in mobile environments.
- Gait acceleration shows several important characteristics.
- We proposed a gait acceleration representation based on salient points.
- We proposed a classification methods using the above representation.

Thank you!

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