SEGMENTING MULTIVARIATE TIME SERIES WITH INERTIAL HMMS

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Motivation

Yahoo! monitors millions of time series each day, looking for changes in the signals for advanced analytics.

Goal: Given a multivariate time series, find where systematic changes occur and map segments to a small number of states.

Hidden Markov Models

- Work well for segmenting sequential data.
- However, may over-segment.
- We need to impose state-persistence, i.e., few state changes over time.

Dataset

- 45D human activity accelerometer data
  - Activities included jumping, playing basketball, rowing, ascending stairs and walking.
  - Created 100 time series consisting on different combinations of activities and segmentations, 10K time steps each series.
  - Tested inertial methods performed vs standard HMM and Sticky HDP-HMM of Fox et al.

Evaluation Metrics

- Evaluated using:
  - Accuracy (for best permutation of labels)
  - Variation of Information
  - Number of Segments Difference (not shown)
  - Segment Number Ratio (not shown)

Sticky HDP-HMM

- State-of-the-art Bayesian hierarchical Dirichlet process hidden Markov model.
- Used publically available HDP-HMM toolbox, with default parameters for priors.
- \( \kappa \) – parameter, for “stickiness” of states.
- Truncation parameter \( L \) set to correct number of states.
- Sensitive to prior parameter values (see Results).

Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy</th>
<th>Var. of Info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard HMM</td>
<td>0.79</td>
<td>0.38</td>
</tr>
<tr>
<td>Sticky HDP-HMM (( \kappa = 100.0 ))</td>
<td>0.59</td>
<td>0.97</td>
</tr>
<tr>
<td>MAP Inertial HMM (( \kappa = 100.0 ))</td>
<td>0.59</td>
<td>0.97</td>
</tr>
<tr>
<td>PsO Inertial HMM (( \zeta = 49.0 ))</td>
<td>0.94</td>
<td>0.14</td>
</tr>
<tr>
<td>PsO Inertial HMM (( \zeta = 33.5 ))</td>
<td>0.94</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Extensions

- Automated parameter selection for inertial HMMs.
  - Used to select parameters in Results section.
- Online learning of inertial HMM model.

Main Advantages

- Works well on synthetic and real-world data.
- Very simple (change single update equation).
- Computationally efficient.
- Only two parameters, one automatically selected.
- Does not suffer from extreme sensitivity to parameter settings, as does sticky HDP-HMM.

Conclusion

- Simple modification of standard HMMs performs well on unsupervised segmentation task.
- Strongly outperforms state-of-the-art sticky HDP-HMM with default parameters.

References