MMTrack: Max-Margin Offline Pedestrian Tracking with Multiple Cues

Bahman Yari Saeed Khanloo¹, Ferdinand Stefanus¹, Mani Ranjbar¹, Ze-Nian Li¹, Nicolas Saunier², Tarek Sayed³, Greg Mori¹

¹School of Computing Science
Simon Fraser University

²Dept. of Civil, Geological and Mining Engineering
Ecole Polytechnique de Montreal

³Dept. of Civil Engineering
University of British Columbia
Outline

1. Overview and Previous Works
2. MMTrack
3. Learning Procedure
4. Features
5. Experimental Results
Single Object Tracking

How to combine the features?
Prior Works

• Online selection of discriminative tracking features [Collins et al, PAMI05]
  - Single type of features
  - Appearance model

• MILTrack [Babenko et al, CVPR09]
  - Combine complete trackers
  - Independent learning of relative weightings

• Tracking with multiple observers [Stenger et al, CVPR09]
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MMTrack

- Different feature types
- Includes Motion Model
- Training sequences

Learning

- Joint parameter learning
- Model Parameters

Test frames

Inference

Track result
Learned Appearance Parameters
Learned Motion Parameters

First Order Model
Trajectory Scoring
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Structural SVM Learning

- Objective: find parameters that produce ‘good’ tracks
- How to measure ‘goodness’ of a track? Loss function $\Delta(y_i, y)$
- We use total Euclidean distance

![Graph showing ground truth and hypothesis tracks]

*Ground truth ($y_i$)*

*Hypothesis ($y$)*
Structural SVM Formulation

\[
\min_{w,\varepsilon} \frac{1}{2} \|w\|^2 + \frac{C}{N} \sum_{i=1}^{N} \varepsilon_i, \text{ s.t. } \forall_i, \varepsilon_i \geq 0
\]

- Regularizer
- Slack variables

\[
\forall i, \forall y \neq y_i: \langle \phi(x_n, y_i), w \rangle - \langle \phi(x_n, y), w \rangle \geq \Delta(y_i, y) - \varepsilon_i
\]

Score for ground truth \( y \)
Score for hypothesized track \( y \)

[Tsochantaridis et al, ICML04]
Structural SVM Learning
Structural SVM Learning

\[
\min_{w, \varepsilon} \frac{1}{2} \|w\|^2 + \frac{C}{n} \sum_{i=1}^{N} \varepsilon_i, \text{ s.t. } \forall \ v_i, \varepsilon_i \geq 0
\]

Regularizer

Slack variables

\[
\forall i, \forall y \backslash y_i: \langle \phi(x_n, y_i), w \rangle - \langle \phi(x_n, y), w \rangle \geq \Delta(y_i, y) - \varepsilon_i
\]

\[
\forall i, \forall y \backslash y_i: \langle \phi(x_n, y_i), w \rangle \geq \Delta(y_i, y) + \langle \phi(x_n, y), w \rangle - \varepsilon_i
\]

\[
\arg\max_{y} \Delta(y_i, y) + \langle \phi(x_n, y), w \rangle
\]

[Tsochantaridis et al, ICML04]
Structural SVM Learning

Init parameters

Do

For each example

Find the most violated constraint

Update parameters

End for
Structural SVM Learning
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Features – HOG Score Map

• Histogram of Oriented Gradient [Dalal&Triggs, CVPR05]
Features – Appearance Templates

- Object templates from initial and previous frames
- Compute sum of absolute difference at nearby locations
Features – Color Histogram Distance
Features

12 features: HOG + 9 histogram difference + 2 appearance template
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UBC Dataset
Experimental Results

- Left: HOG + 9 histogram
- Middle: HOG + appearance templates
- Right: HOG + 9 histogram + appearance templates
## Experimental Results

<table>
<thead>
<tr>
<th>Tracker</th>
<th>#CDT (max=22)</th>
<th>Avg CT</th>
<th>Avg Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMTrack: all features</td>
<td>21</td>
<td>0.66</td>
<td>7.01</td>
</tr>
<tr>
<td>MMTrack: HOG + Hist</td>
<td>10</td>
<td>0.47</td>
<td>14.40</td>
</tr>
<tr>
<td>MMTrack: HOG + Template</td>
<td>14</td>
<td>0.52</td>
<td>22.24</td>
</tr>
<tr>
<td>MILTrack [1]</td>
<td>19</td>
<td>0.61</td>
<td>19.87</td>
</tr>
<tr>
<td>Collins-Liu [2]</td>
<td>14</td>
<td>0.54</td>
<td>21.24</td>
</tr>
</tbody>
</table>

[1]. B. Babenko et al, CVPR09  
[2]. R. Collins et al, PAMI05
More Experimental Results