Linking Uncertain Events –
Searching the space of globally feasible explanations

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Outline

- Drop-off and Pick-up Problem
  - Ambiguities
  - Formulating the Problem
- Linking Uncertain Events
  - Labelling a Bayesian Network
  - Searching the space - RJMCMC
- Results
  - Datasets
- Carried Object Detection
  - The method
  - Results

22/6/2007: Oxford (1800 bicycle thefts during the last year) city sets up CCTV cameras over bicycle racks.
From the news...

- 23/5/2007 – Catching Daniel Westrop…
  “have been stealing commuters' cycles, often two a day, for the past three years”!!
Associating Drop-offs with Pick-ups

What we see...
Associating Drop-offs with Pick-ups

What the computer sees…

Trajectories

Blobs
Associating Drop-offs with Pick-ups

The required explanation..

1. What each person did (drop/pick/pass-by)
2. Which bicycle did he drop/pick
3. Try to connect a pick to a previous drop (if observed)
1. Deciding on dropping people, picking people and passer bys.
1. Deciding on dropping people, picking people and passer bys.
2. Linking people to the blobs they interacted with.
   - Spatial Proximity
   - Change in Edge features

Masked edges

‘before’ reference image

‘after’ reference image
3. Connect drops to picks.
   - Pixel-wise matching of difference masks
Associating Drop-offs with Pick-ups

- Dropping
- Picking
- Pass-by

- Drop
- Pick
- Pick-Drop
Hierarchical Explanation

The diagram illustrates a hierarchical explanation of actions involving people and bicycles. The actions are categorized under 'drop' (d) and 'pick' (p) with subcategories for 'person' (t) and 'bicycle' (b). The nodes 'dp' represent the overall action of drop-pick. The diagram also includes a list of variables labeled 't1' to 't5' and 'b1' to 'b4'.
Linking Uncertain Events

- Separately
  - Find the best explanation for each observation
  - Constrained linkage

- Jointly
  - Label and link simultaneously
Similar Work – Radar Surveillance
Similar Work – Radar Surveillance

- Reid (1979) – MHT
- Cox (1993) – Review
  - NN
  - MHT
  - JPDAF
- Poore (1994) – Bayesian MHT
- Oh, Russell, Sastry (2004) - MCMC


- Pasula et. al. (2003)
Similar Work – Visual Data

- Huang and Russell (1998), Pasula et. al. (1999)
- Zajdel and Krose (2005)
Linking Uncertain Events
Linking Uncertain Events

- Observations
  - $O_{x1}$
  - $O_{x2}$
  - $O_{x3}$
  - $O_{y1}$
  - $O_{y2}$

- Atomic Events
  - $X_1$
  - $X_2$
  - $X_3$
  - $Y_1$
  - $Y_2$

- Linking Nodes
  - $Z_1$
  - $Z_2$
  - $Z_3$
  - $Z_4$
  - $Z_5$
  - $Z_6$

- Constraints
  - $S_{11}$
  - $S_{12}$
  - $S_{21}$
  - $S_{22}$
  - $S_{31}$
  - $S_{32}$
Linking Uncertain Events

The Bicycles Problem expressed as two-layers linkage
Searching the space of Explanations

\[ \omega^* = \arg \max_{\omega} p(\omega|Y) \]

- MCMC samples the space focusing on where posterior is concentrated
Introduction to MCMC

- MCMC – Markov Chain Monte Carlo
- When?
  - You can’t sample from the distribution itself
  - Can evaluate it at any point
  - Ex: Metropolis Algorithm
Suggested Moves

- Connect and disconnect
- Change
- Switch
Suggested Moves – Bicycles 1

(A) Connect Agent

(B) Change Agent

(C) Change Bike

(D) Switch Bikes
Suggested Moves – Bicycles 2

(E) Connect Drop-Pick

(F) Change Drop

(G) Change Pick

(H) Switch Drop-Pick
MCMC General Algorithm

Markov Chain Monte Carlo

initialize $\omega_0$

for $i = 1$ to $n_{mc}$
    sample $m$ from $\xi_i$
    sample $\omega^*$ from $Q_m(\omega^*|\omega_{i-1})$

    calculate $\alpha(\omega^*|\omega_{i-1}) = \left( \frac{\pi(\omega^*)}{\pi(\omega)} \right) \frac{Q(\omega|\omega^*)}{Q(\omega^*|\omega)}$

    sample $u$ from $\mathcal{U}[0,1]$
    if $u < \alpha(\omega^*|\omega_{i-1})$
        $\omega_i = \omega^*$
    else
        $\omega_i = \omega_{i-1}$
Examples

- Dropping
- Picking
- Pass-by
- Drop
- Pick
- Pick-Drop

Select move type

Switch Agents

$\omega_{init}$
Examples

\[ \alpha = 1.0 \]
\[ U = 0.33 \]

Move Accepted

\[ \omega_{init} \]

Switch Agent
Specific dist.

407, 343
Examples

\[ \alpha = 1.0 \]
\[ U = 0.24 \]
Move Accepted

\[ n_{mc} = 2 \]

Switch Drop-Pick.

(319,603), (385,1173)
Examples

- **Dropping**
- **Picking**
- **Pass-by**
- **Drop**
- **Pick**
- **Pick-Drop**

\[ \alpha = 0.11 \]
\[ U = 0.74 \]

**Move Rejected**

\[ n_{mc} = 3 \]
Examples

$\alpha = 0.91$

$U = 0.36$

Move Accepted

$n_{mc} = 4$

Connect Agent
MCMC General Algorithm

Markov Chain Monte Carlo

initialize $\omega_0$

for $i = 1$ to $n_{mc}$
    sample $m$ from $\xi_i$
    sample $\omega^*$ from $Q_m(\omega^*|\omega_{i-1})$

    calculate $\alpha(\omega^*|\omega_{i-1}) = \left( \frac{\pi(\omega^*)}{\pi(\omega)} \right) \frac{Q(\omega|\omega^*)}{Q(\omega^*|\omega)}$

    sample $u$ from $\mathcal{U}[0,1]$
    if $u < \alpha(\omega^*|\omega_{i-1})$
        $\omega_i = \omega^*$
    else
        $\omega_i = \omega_{i-1}$
Dataset
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
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<td>Drops</td>
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<td>20</td>
<td>20</td>
<td>14</td>
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<td>39</td>
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<tr>
<td>Picks</td>
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<td>12</td>
<td>19</td>
<td>10</td>
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<td>11</td>
<td>18</td>
<td>20</td>
<td>13</td>
<td>14</td>
<td>22</td>
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Results
## Results

<table>
<thead>
<tr>
<th>Split</th>
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<th>SAMCMMC</th>
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<tbody>
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</tbody>
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Haritaoglu’s work
Our Method (Damen and Hogg, ECCV 08)
Another Example
Another Example
Demo

New
Current and Future Work

- Grammar-based representation of events of hierarchies
- Automated method to solve similar problems
Thank you 😊

Damen, Dima and Hogg, David (Oct 2008). Detecting Carried Objects from Short Video Sequences. European Computer Vision Conference (ECCV 08).


http://www.comp.leeds.ac.uk/dima