Cooperative Object Tracking with Multiple PTZ Cameras

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Overview

• Introduction
• Calibration
• Tracking
• Segmentation
  – Target handover
• Conclusion

Introduction

• Current research in Visual Surveillance
  – Scene understanding
• Sensor networks
  – heterogeneous
• Advantages of PTZ cameras
  – Active
  – High resolution imaging
Introduction

• Current research on Visual Surveillance
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• Goal: PTZ tracking with target handover
Calibration

- Communication about target location
- Cameras calibrated wrt common ground plane

(0,0,0)
Calibration

• Geometry!

![Diagram of camera and coordinate system]

Calibration

• From pixels to world coordinates

\[
X = \mu \begin{bmatrix}
\cos p' & -\sin p' & \cos t & \sin p' & \sin t \\
\sin p' & \cos p' & \sin t & -\cos p' & \sin t \\
0 & 0 & 1 & 0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
\alpha' \Delta y \\
-\alpha' \Delta t \\
1 \\
0 \\
U \\
V \\
H \\
\end{bmatrix}
\]  

• \(H,p_0,U,V\) resolved by least squares \((p'=p+p_0)\)

Calibration

• Example

![Image of calibration example]

Tracking

• Let camera move along with target

  • Problems with motion detection
  • Mean Shift
    – Assumed initialised
    – Target representation & localisation
Tracking

• Let camera move along with target
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Mean Shift

– Target representation: colour histogram
– Target $q$, candidate $p$
– Weighted by kernel $K(x)$
  • Profile $k(||x||^2)$
• Mean Shift
  – Target representation: colour histogram
  – Target \( q \), candidate \( p \)
  – Weighted by kernel \( K(x) \)
    • Profile \( k(||x||^2) \)

• Candidate profile: function of new target centroid \( y \)
  – \( k(||y-x||^2) \)
  • Metric between \( p \) and \( q \) function of \( y \)
    – Bhattacharya distance

\[
d(\hat{y}, q) = \sqrt{1 - \rho(\hat{y}, q)}
\]
\[
\rho(\hat{y}, q) = \sum_{S \in \mathcal{H}} \sqrt{\hat{y}(S)q(S)}
\]
Tracking

- Target localisation
  - Minimise $d(p(y), q)$ wrt $y$
- New centroid $y$: kernel and data weighted sum over pixels locations

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\[
\hat{y} = \frac{\sum_{i=1}^{m} x_i w_i \delta \left( \frac{\|x_i - y\|^2}{\|y - x_i\|^2} \right)}{\sum_{i=1}^{m} w_i \delta \left( \frac{\|y - x_i\|^2}{\|y - x_i\|^2} \right)}
\]

\[
w_i = \frac{\sqrt{\frac{\hat{q}_i}{p_i(\hat{y})}} \delta \left( b(x_i) - u \right)}{g(x) = -k'(x)}
\]
Tracking

• Example

Segmentation

• Target handover
  • Statistical framework
    – Find target given the colour model and location estimate of the other camera

• $P(O|c,i)$
  – Proportional to $p(i|O)p(c|O)$
Segmentation

- Classify pixels
- Open image
- Find connected components
- Constrain blob on size
Segmentation

• Playing hide and seek
  – Init cam 1
  – Cam1 tracks target
  – Cam 2 counts to 5
  – Cam 2 seeks target
  – When found: Cam 2 tracks target
  – Cam 1 counts to 5
  – Etcetera

Conclusion

• Successful target handover
  – In real time
• Simple target representation
  – Drawbacks
• Indoor setting
• Need for automation
• Camera quality
• Zoom
• Semantics
• Evaluation

The End

• Thank you
Colour

- The problem with colour
- Different data acquisition processes
- Find out how different
- Experiments
Generate distributions of $K$ patches of $J$ colours in $S$ colour spaces for $C$ cameras. Analyse!

Remarkable result in $xy$ colour space

$x=X/(X+Y+Z)$ etc

Experiment: analyse displacement between peaks in quantised spaces of both cameras
Colour

• Remarkable result in xy colour space
• \( x = X/(X+Y+Z) \) etc

• Experiment: analyse displacement between peaks in quantised spaces of both cameras

Colour

• Displacement plot
• Structure!

Colour

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• Structure!

Colour

• Compensate for it: colour calibration
Colour

- Displacement plot
- Structure
- Compensate for it: colour calibration

- Conclusion
  - $xy$ shows hardware difference