Maintaining Persistence when Tracking

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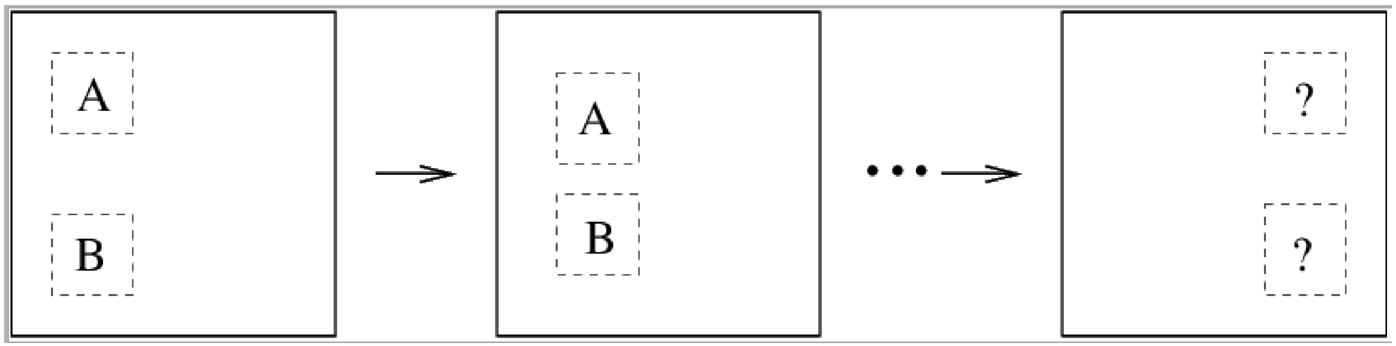
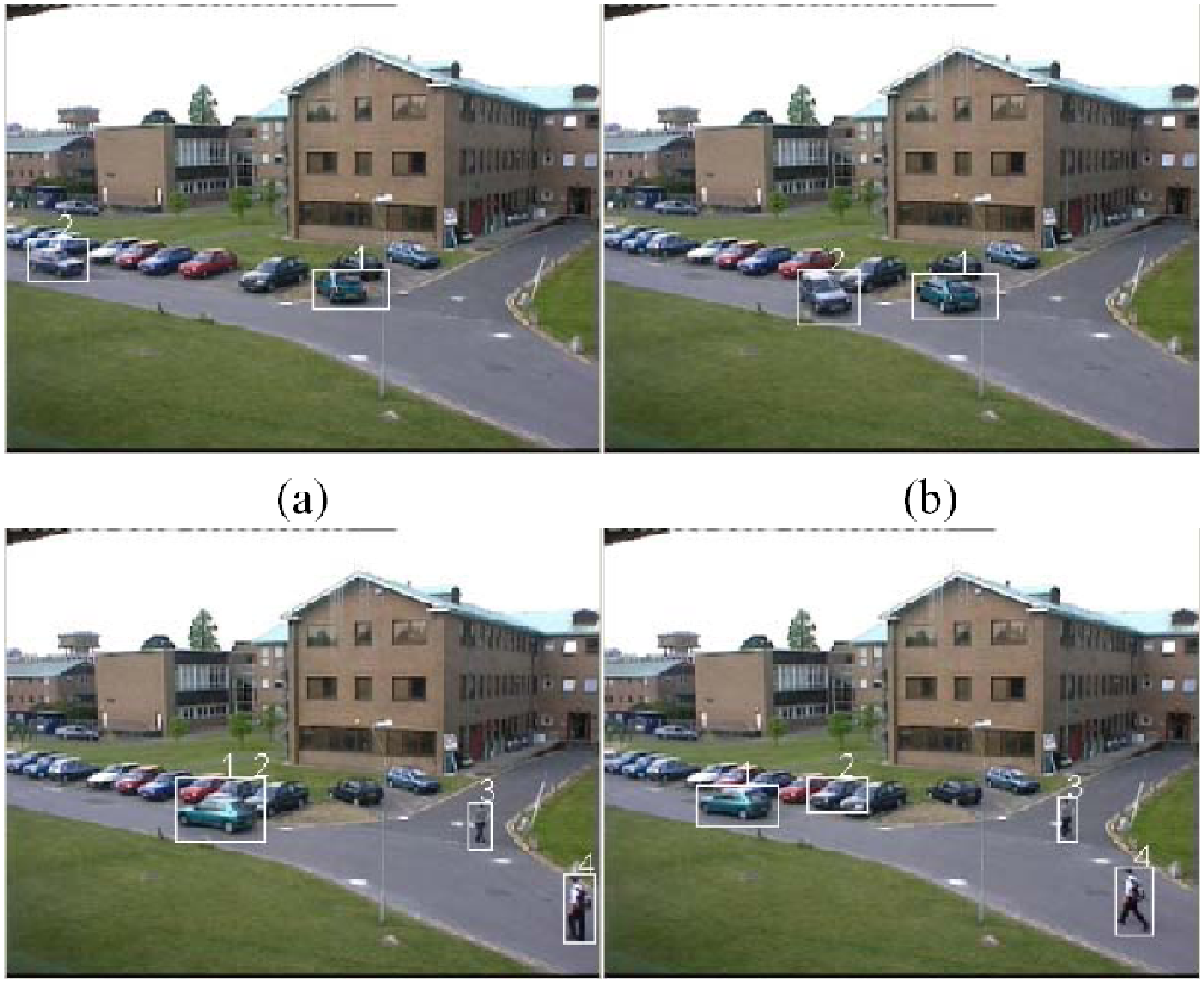
NORMAL TARGET TRACKING

General problem: in first image have R targets $\{F_i\}$
In next image have L targets $\{N_i\}$
How to pair the targets out of the $(R+1)^L$ possibilities?



Video rate fast → targets don't move much
Kalman Filter predicts position
Overlap with detected target makes correspondences

TARGET 1 & 2 PERSISTENCE

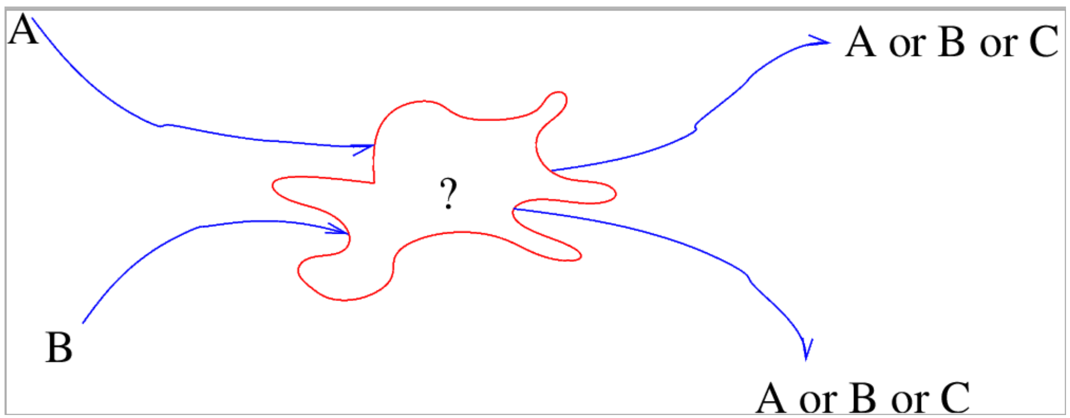


(a) (b)

MAINTAINING TARGET PERSISTENCE

Issue: tracking targets breaks down when close or occluded

Solution: need identity persistence through occlusion



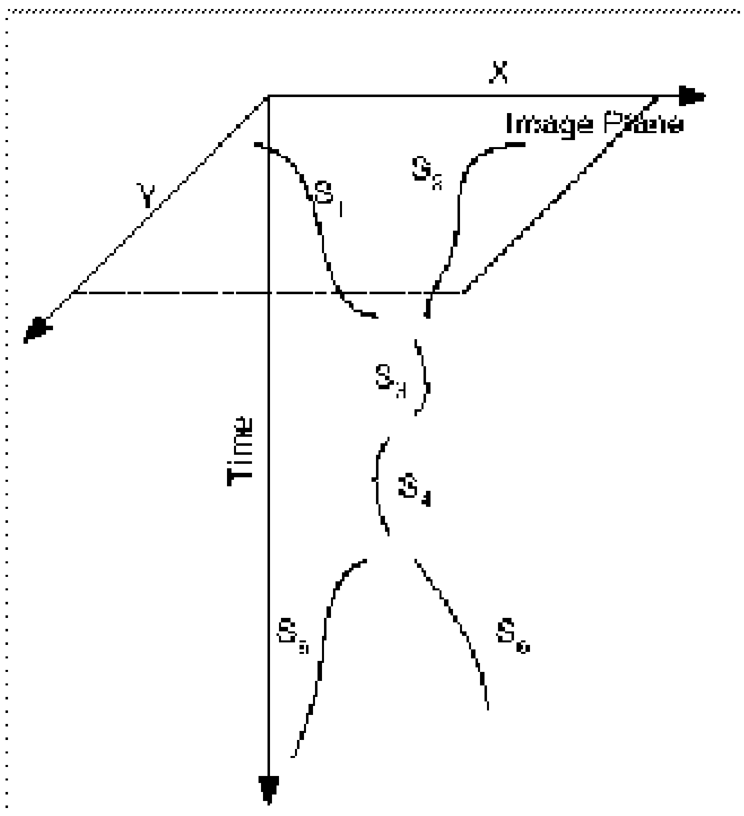
Jorge et al: Bayesian network

PROBLEM REPRESENTATION

Break trajectories at occlusions

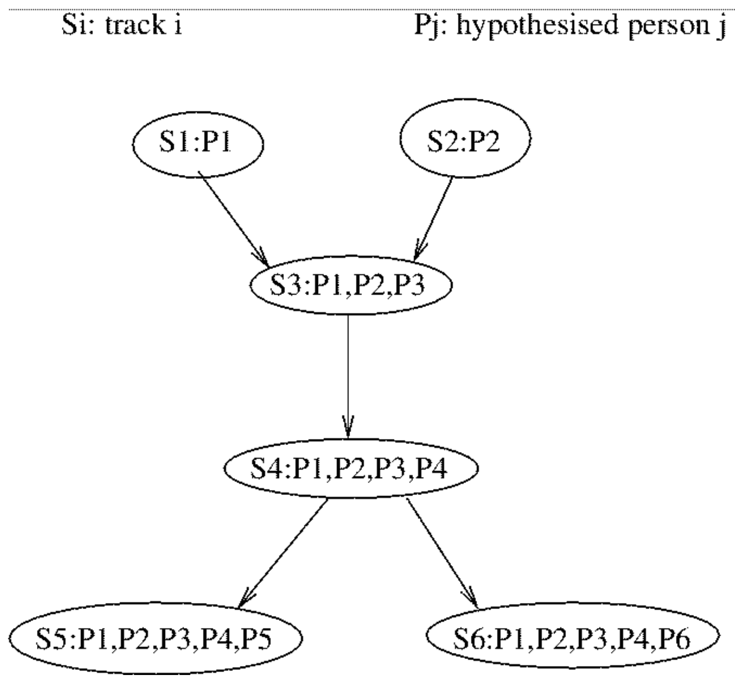
Create label nodes X_i for each track S_i, also inheriting previous tracks

Target tracks



Initial hypothesis

Nodes



MATCHING COLOUR TARGETS I

Assume binary mask of target

Use mask to select target pixels $\{(r_i, g_i, b_i)\}$

Compute RGB histogram over all pixels in region and all frames in segment (eg. maybe 20K values):

$$\forall i \ h_1(r_i, g_i, b_i) = h_1(r_i, g_i, b_i) + 1$$

How well does distribution $h_1(r_i, g_i, b_i)$ match distribution $h_2(r_i, g_i, b_i)$?

MATCHING COLOUR TARGETS II

Normalize:

$H_j(r,g,b) = h_j(r,g,b)/\Sigma_{r,g,b}(h_j(r,g,b))$

Use Bhattacharyya distance:

$$d(H_1,H_2) = -ln(\sum_{r,g,b}\sqrt{H_1(r,g,b)\times H_2(r,g,b)})$$

If $d(h_1,h_2)$ small then likely same target

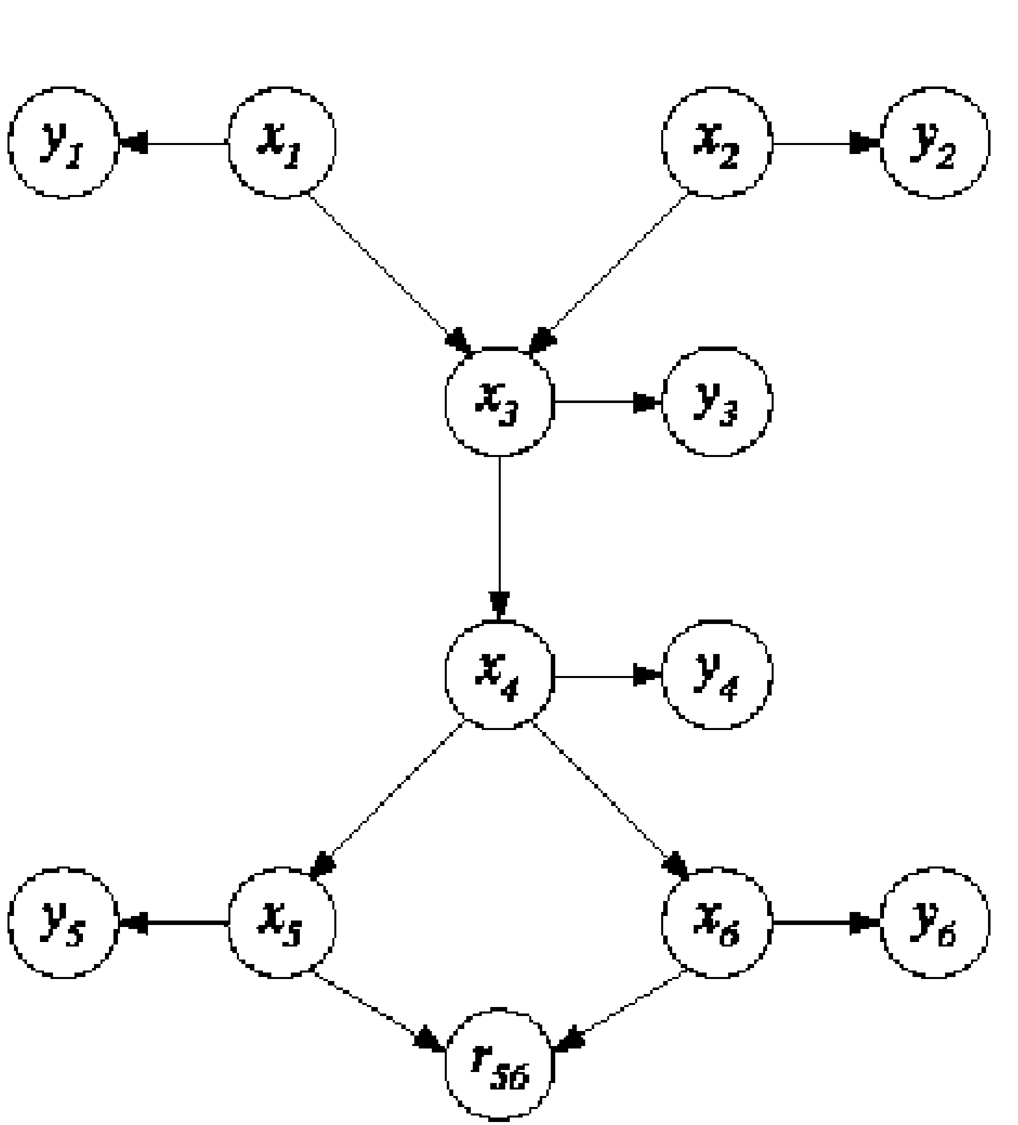
Group colour levels together (eg. 0-31, 32-64, ... 224-255) because so few pixels

EXTENDING NETWORK

Create label nodes X_i for each segment section S_i

Add data matching nodes Y_i (color histogram of target appearance)

Add restriction nodes R_i enforcing mutual exclusion between sibling nodes


y_1
x_1
x_2
y_2
x_3
y_3
x_4
y_4
y_5
x_5
x_6
y_6
r_{56}

EVALUATING PERSISTENCE

Find labeling $\vec{X}$ that maximizes

$$p(\vec{X} \mid \vec{Y}, \vec{R})$$

Probability of labeling $\vec{X}$ given data $\vec{Y}$ and restrictions $\vec{R}$

Gives probability that each person P_i is observed in track X_j

Use standard conditional probability propagation algorithm

PROBLEM 1: REAL-TIME ANSWERS

Full network evaluation is expensive

Incremental evaluation, using Bayes rule after the k^{th} block of T frames:

$$p(x_i \mid \vec{Y}_0^t, \vec{R}_0^t) = \alpha p(\vec{Y}_{kT}^t, \vec{R}_{kT}^t \mid x_i) p(x_i \mid \vec{Y}_0^{kT}, \vec{R}_0^{kT})$$

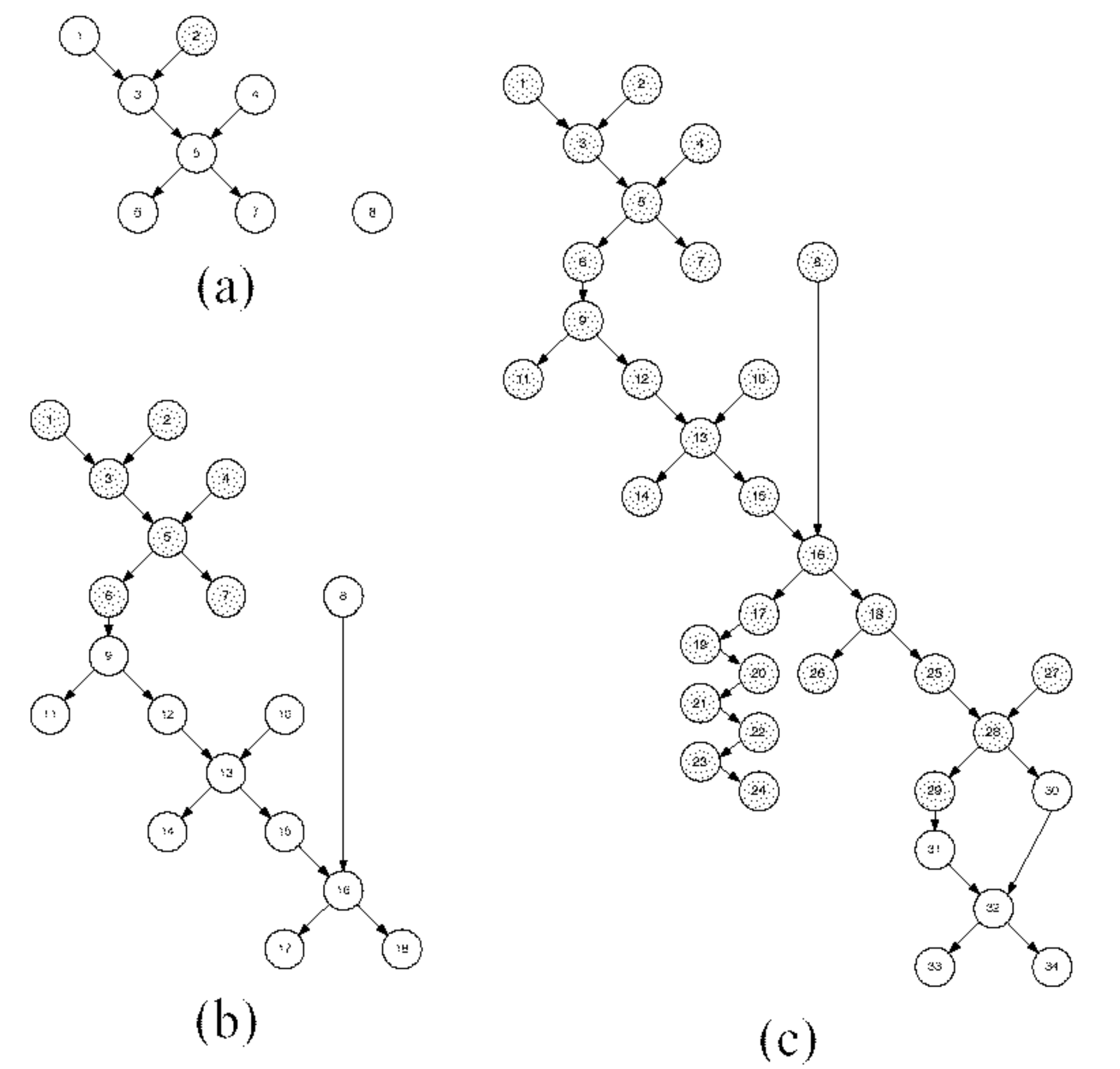
PROBLEM 2: GROWTH OF NETWORK

Each new track inherits labels plus adds a new one: network grows large

Solution: freeze all but N most recent nodes

Freeze: fix most probable identity for track S_i rather than keep all possible ids (which could change with future evidence)

ACTIVE NODES AT 3 TIMES



SUMMARY

Problem with occlusion: lose identity

Formulate matching problem as a Bayesian network

Use colour histogram matching for image evidence

Propagate probability of identity through network

Periodically 'freeze' network to limit computational complexity