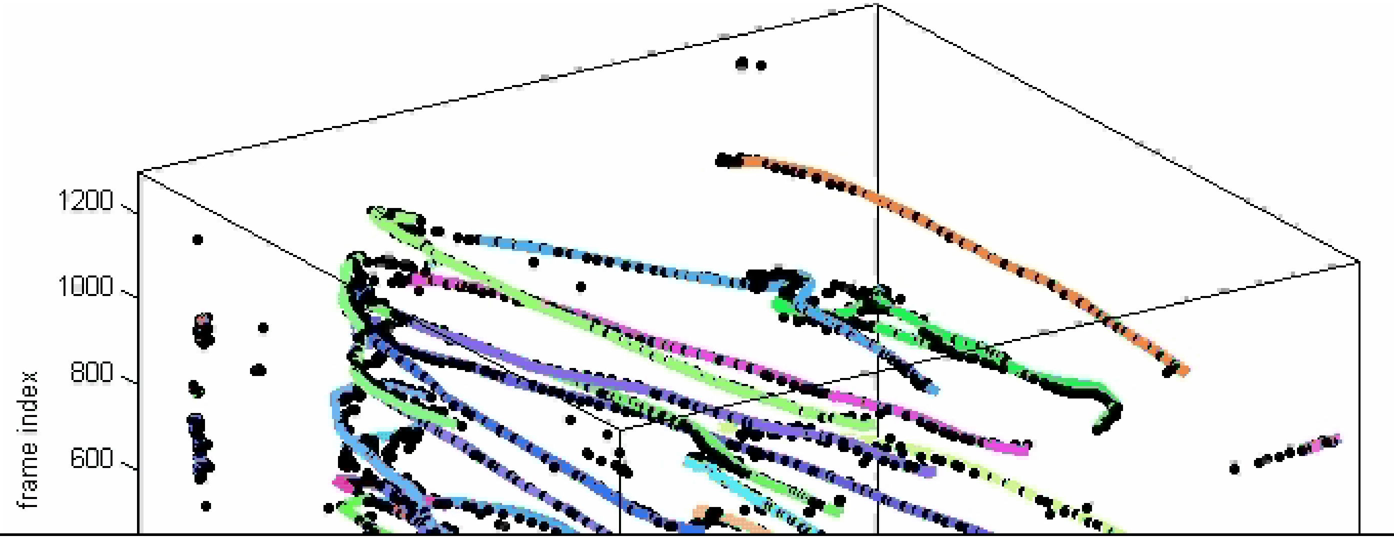


Multiple Object Tracking Using Local PCA

C. Beleznai[1], B. Frühstück[2], H. Bischof[3]

[1]*Advanced Computer Vision GmbH – ACV, Vienna, Austria*

[2]*Siemens AG Austria, Program and System Engineering, Graz, Austria*

[3]*Inst. for Computer Graphics and Vision, Graz University of Technology, Austria*

ADVANCED COMPUTER VISION

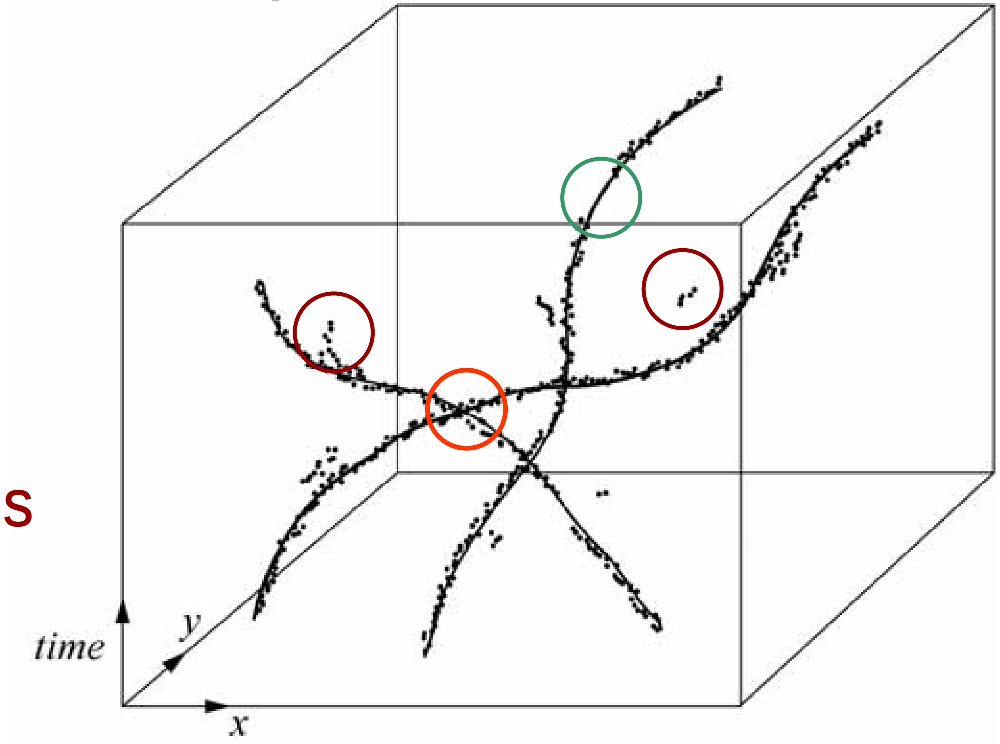
An Enterprise of the Austrian Research Centers

Motivation

Task: tracking multiple objects in the space of observations

$$\mathbf{X}_i = \{\mathbf{x}, t\}, 1 \leq i \leq N$$

Desired output: consistent motion path



Complexity of tracking task:

- interacting objects
- missing observations
- clutter, noisy observations

Contents

Related research

- JPDAF Tracker (Bar-Shalom1987)
  - Single stage approximation using fixed number of targets
  - Can not recover from failure

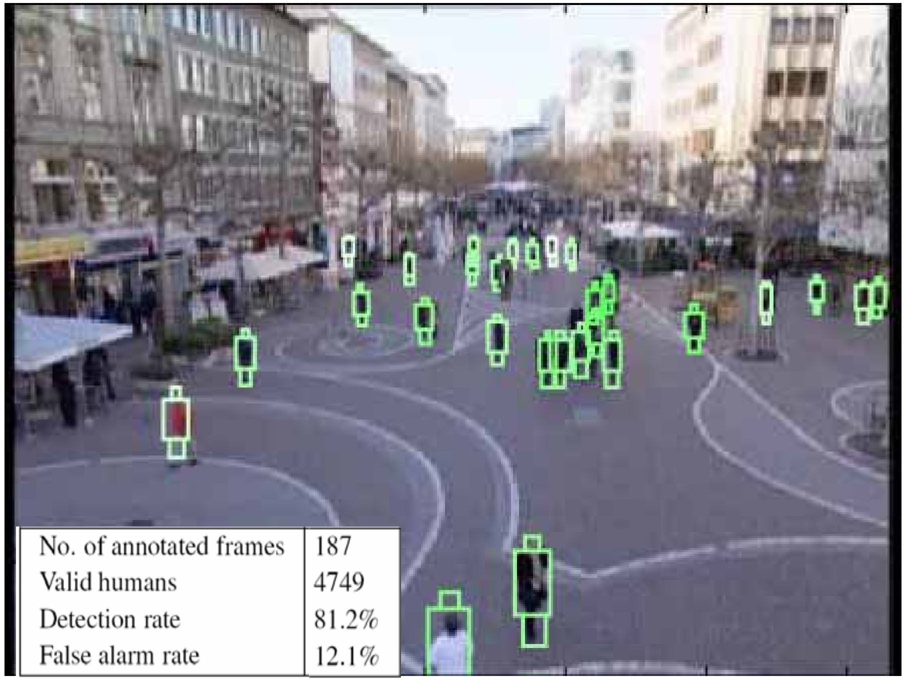
Data association following “deferred logic”

- Multiple Hypothesis Tracker (Reid1979)
  - Heuristics to overcome computational complexity: pruning, gating, *N*-scan back, *k*-best hypotheses
- Monte Carlo methods (Vermaak et. al 2003)
  - Promising performance in challenging scenarios

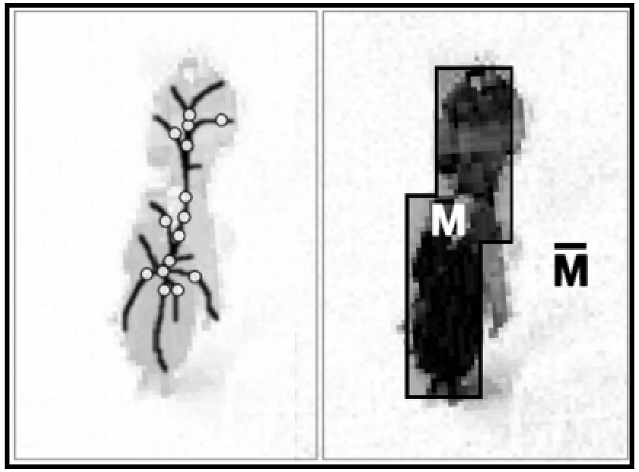
Input data: Motion-based human detection

Fast clustering of the difference image

- Mean Shift procedure using integral images.
- Model-based validation of hypothesized configurations:
  - Removing spurious detections
  - Occlusion handling



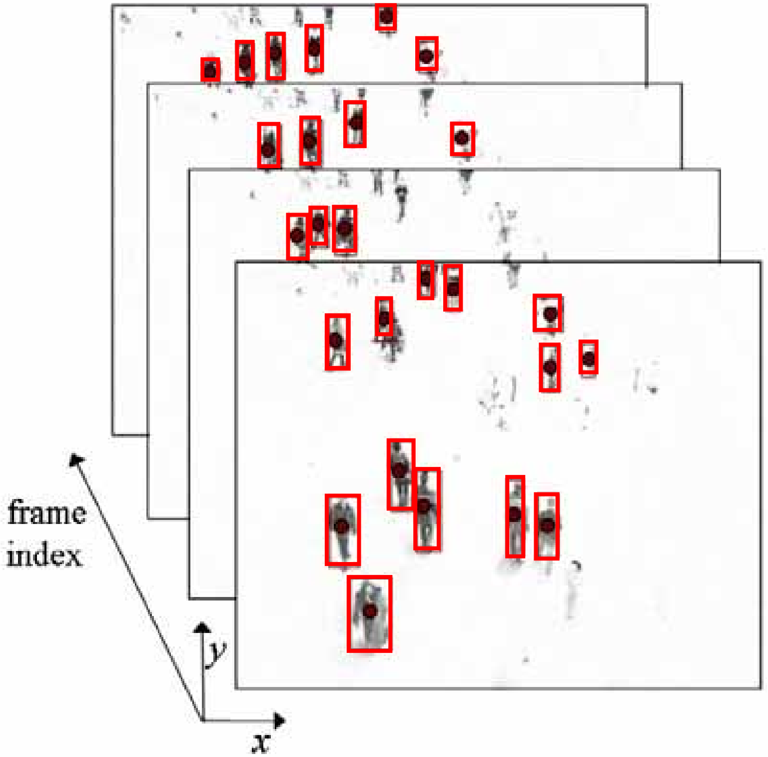
No. of annotated frames	187
Valid humans	4749
Detection rate	81.2%
False alarm rate	12.1%



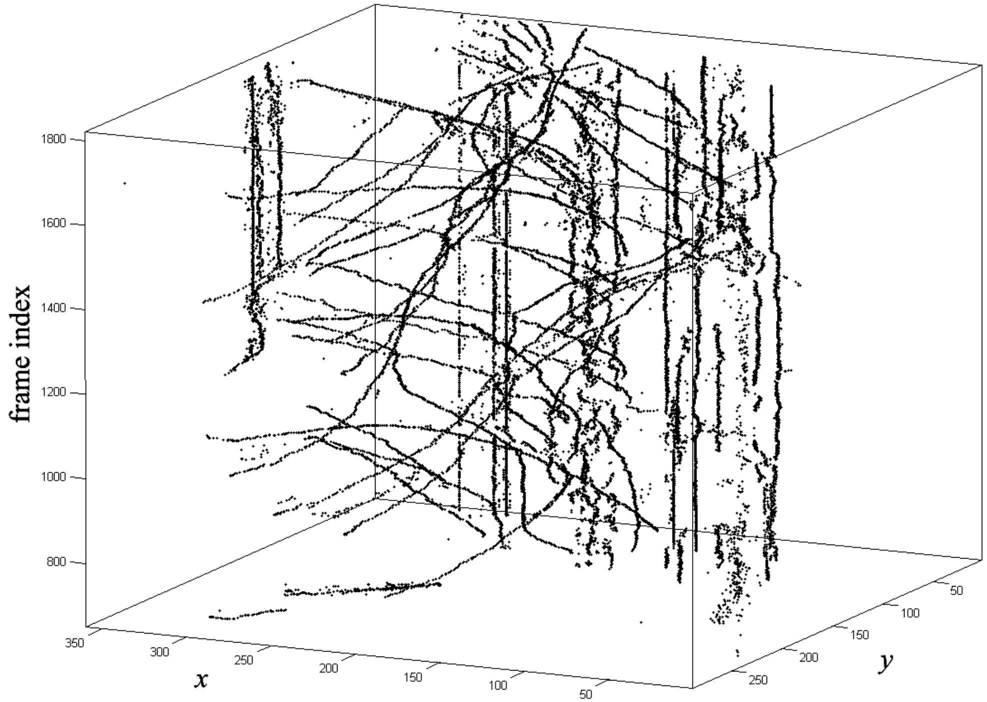
C. Beleznai, B. Frühstück and H. Bischof,
"*Tracking Multiple Humans using Fast Mean Shift Mode Seeking*",
PETS 2005 Workshop

Related background / research

Detecting objects (humans) by difference image clustering
(C. Beleznai et al., ICIP 2004)



Spatio-temporal data points
(observations)



Prior information:

- object size model *H(x)*

Idea

- Motion of real-world objects is subjected to kinematic constraints
- Consequence: Observations at consecutive time instances are strongly correlated.

➡ LPCA

Tracking by local PCA

(1) Selecting an initial point

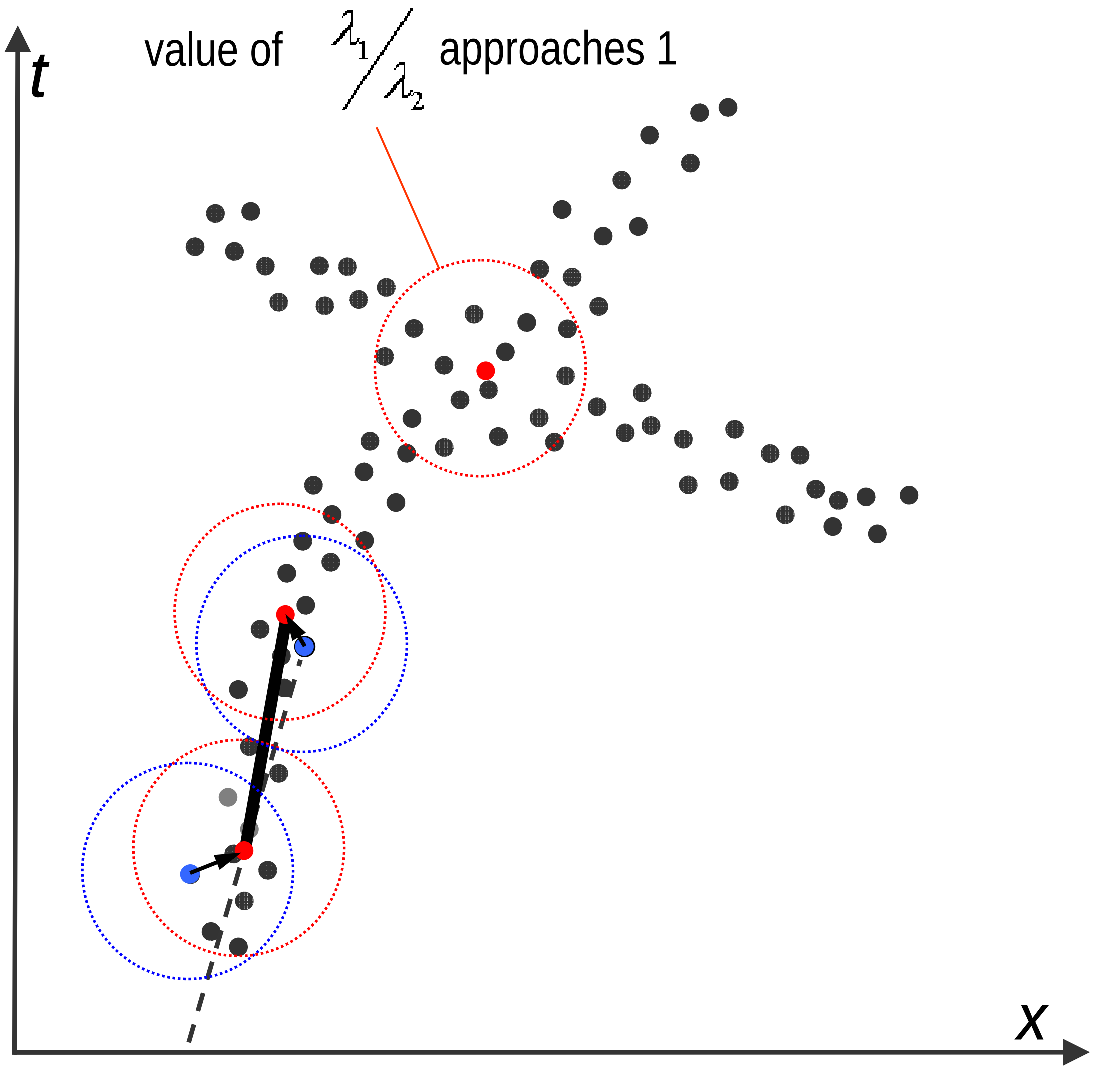
(2) Mean shift iterations to nearby mode

(3) LPCA within the analysis window

(4) Repeating from Step (2)

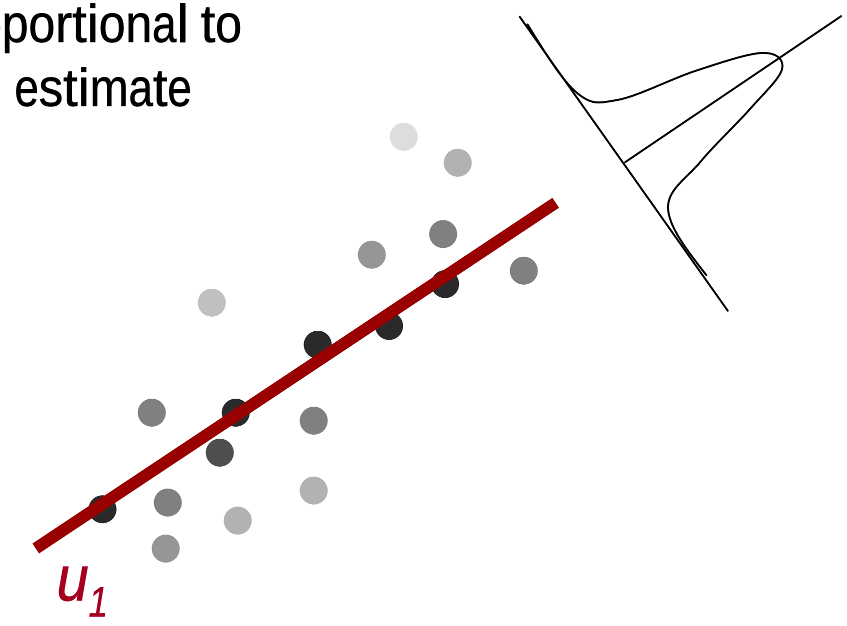
(5) Computing local anisotropy measure

(6) Stopping if:
- no more data available
- distribution shows no anisotropy



Motion model

- The first eigenvector u_1 can be interpreted as a velocity estimate
  - Simple update: $\mathbf{v}(t+\Delta) = \alpha_s \cdot \mathbf{v}(t) + (1-\alpha_s) \cdot \mathbf{u}_1$
  - Computing data weights inversely proportional to the distance between data and motion estimate
  - Applying weighted local PCA



ADVANCED COMPUTER VISION
An Enterprise of the Austrian Research Centers

Trajectory segment linking

K generated trajectory segments

$$\{T_i\}_{i=1..K}$$

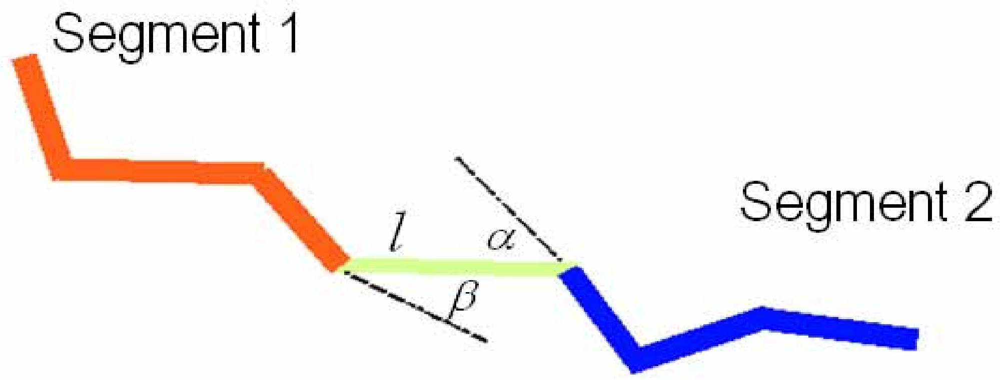
Constraints:

- temporal ordering
- spatio-temporal smoothness

$$C(L) = \frac{l(L)}{H(\mathbf{x}_c)} + \delta S(L)$$

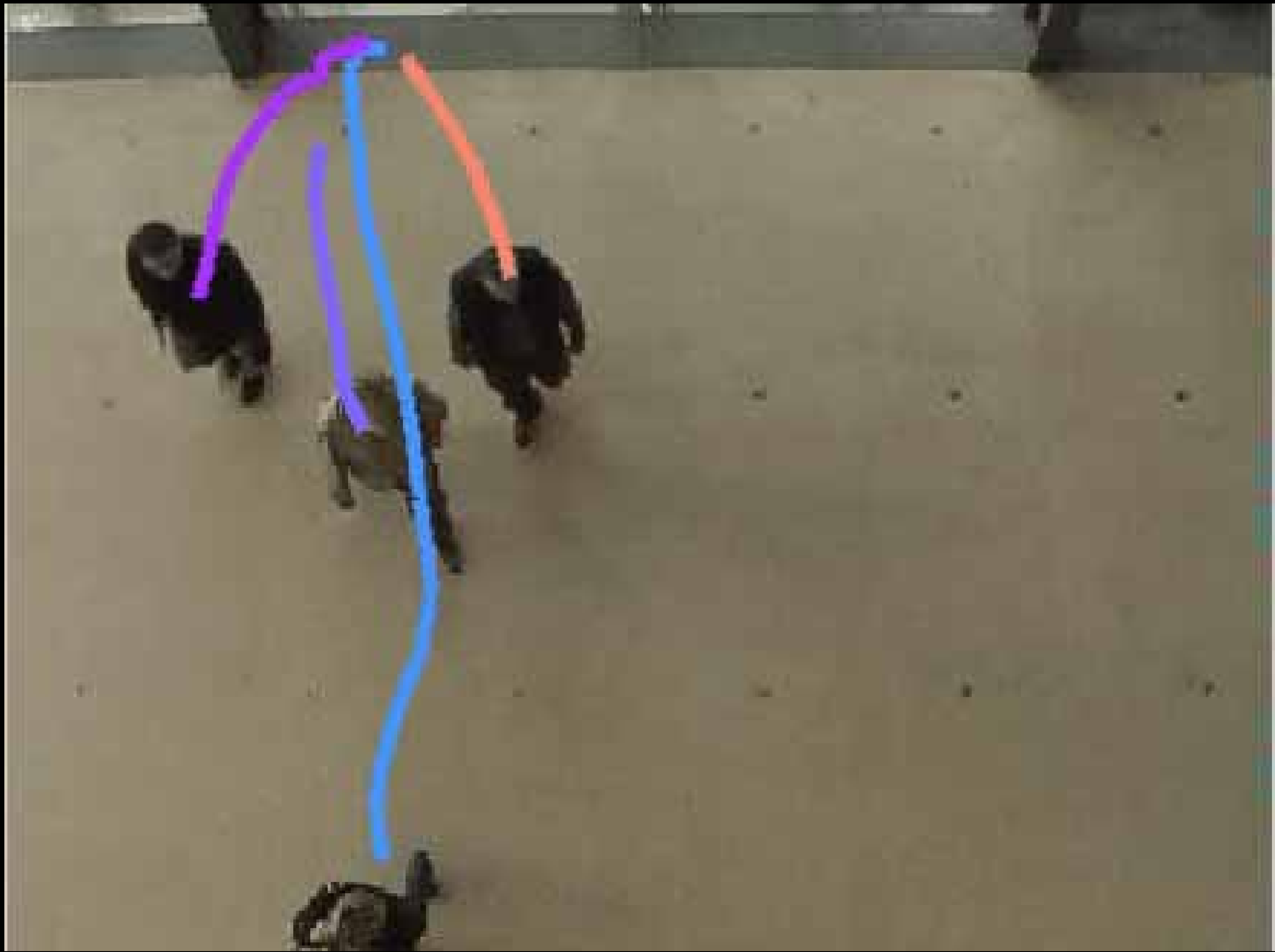
l(L) – length of a link

S(L) – sum of angles: $(\alpha+\beta) / \pi$

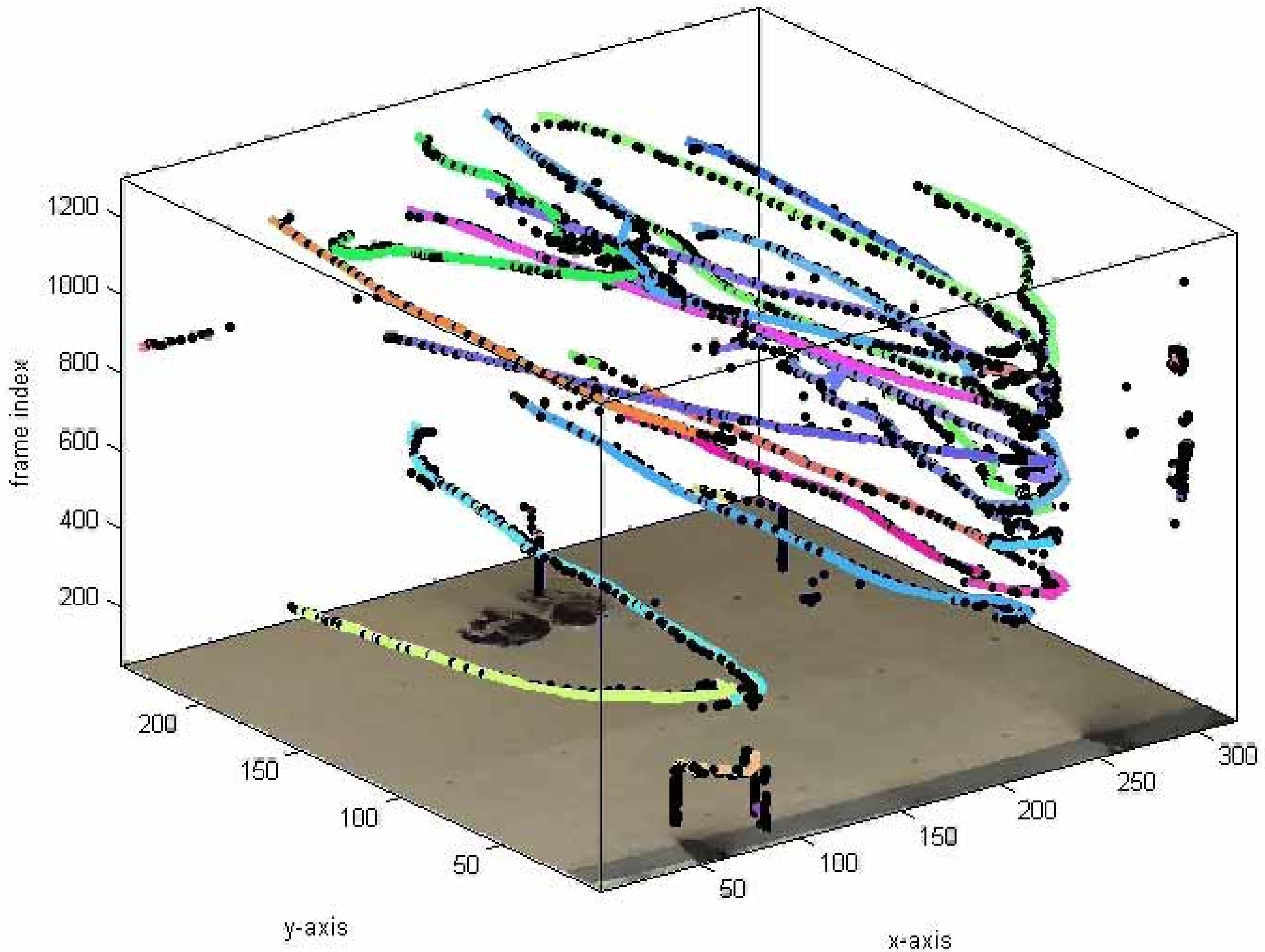


Greedy strategy to incrementally link segments (stopping criterion)

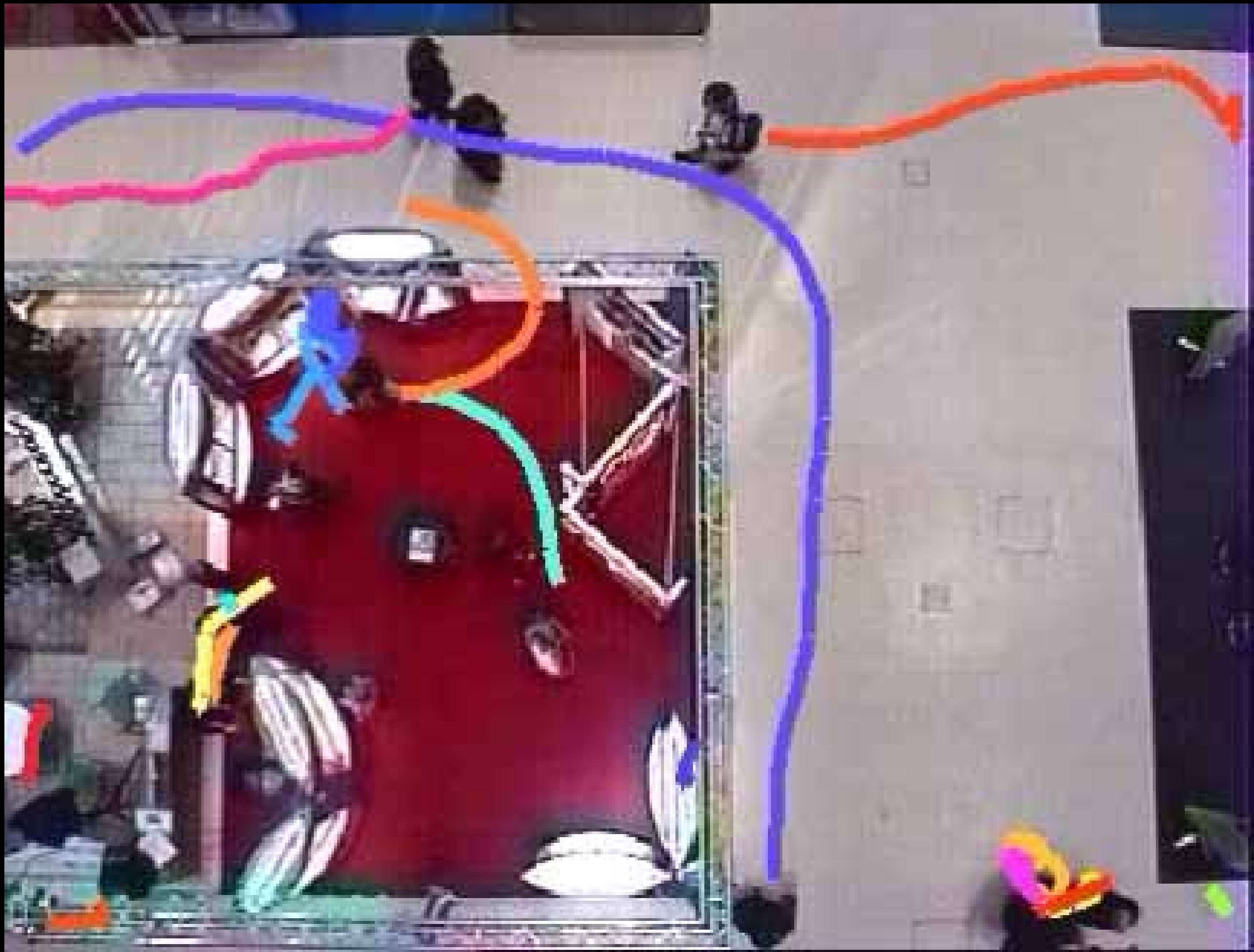
Results – Sequence 1



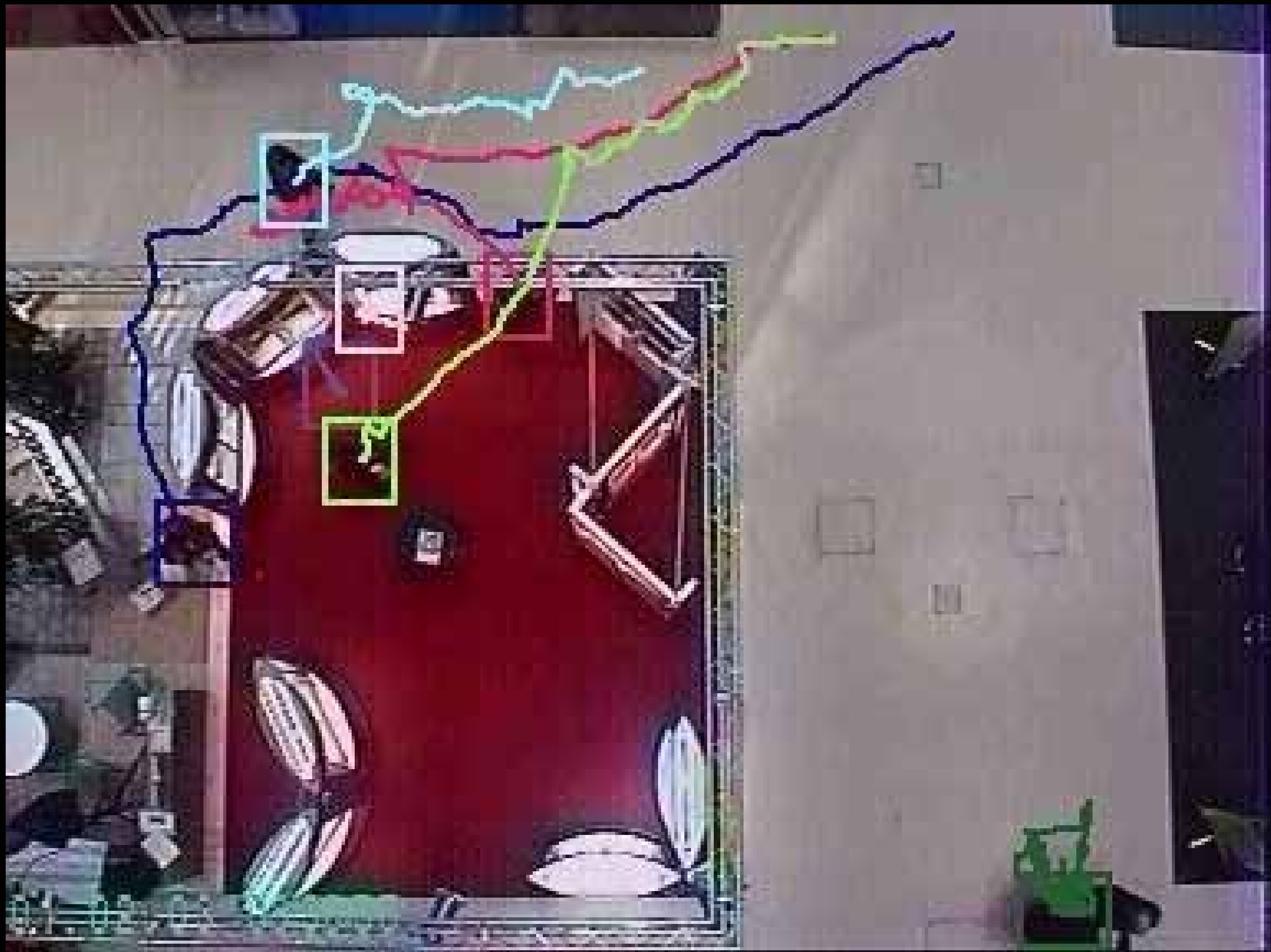
Results – Sequence 1



Results – Sequence 2



Results – Sequence 2 – frame-to-frame tracking

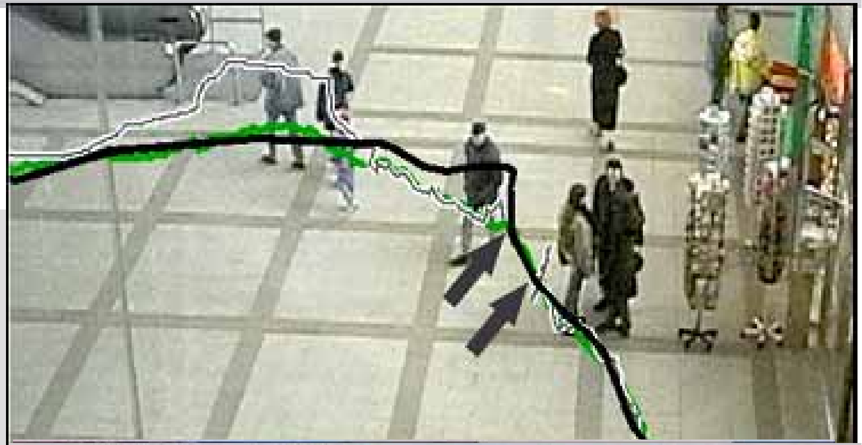


Results – Evaluation of tracking performance

Norm. spatial deviation between ground truth and measurement: $D(j) = \frac{|\mathbf{x}_j^m - \mathbf{x}_j^0|}{H(\mathbf{x}_j^0)}$

Comparing to 42 annotated trajectories in 1013 frames:

Tracking method	# of detected trajectories	Avg. norm. dev.
LPCA	62	0.19
Frame-to-frame	93	0.3



Comparing to 47 annotated trajectories in 2200 frames:

Tracking method	# of detected trajectories	Avg. norm. dev.
LPCA	89	0.11
Frame-to-frame	129	0.18

ADVANCED COMPUTER VISION
An Enterprise of the Austrian Research Centers

Conclusions

- A simple and novel tracking approach.
- Two passes:

    (1) LPCA-based trajectory segment generation,

    (2) Trajectory segment linking.

- Tracker produces stable results at a low computational demand.
- Possible improvements:

    (1) combining forward and backward tracking,
    (2) hierarchical grouping of local trajectory estimates,
    (3) embedding complementary tracking mechanisms