Coherent Filtering: Detecting Coherent Motions from Crowd Clutters

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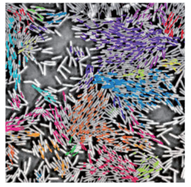
Motivation

Coherent motions widely exist in natural phenomena


Bacteria


Fish shoal


Pedestrian crowd

Objectives:

1. revealing the prior underlying coherent motions;
2. proposing the algorithm of coherent motion detection.

The Prior: Coherent Neighbor Invariance (CNI)

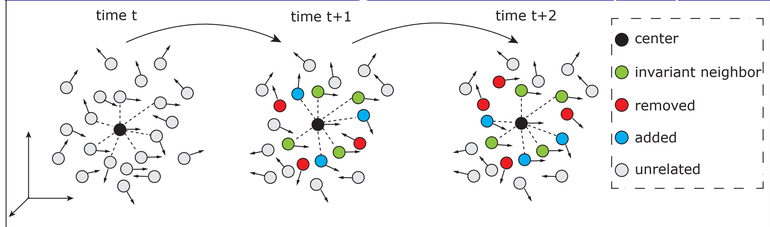


Illustration of CNI in K nearest neighbor (K=7)

Two key properties:

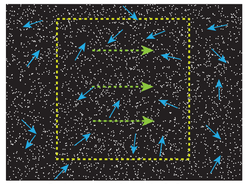
Invariance of spatiotemporal relationships

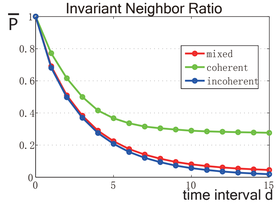
The neighborship of individuals with coherent motions tends to remain invariant over time

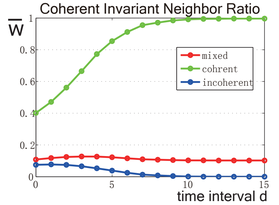
Invariance of velocity correlations

The velocity correlations of neighboring individuals with coherent motions remain high when being averaged over time

Studying CNI through Random Dot Kinematogram


Coherence Level=0.3





We define two ratios to quantify CNI in K nearest neighbor

$$P^i_{t\to d} = \frac{|M^i_{t\to d}|}{K}, \qquad W^i_{t\to d} = \frac{|C^i_{t\to d}|}{|M^i_{t\to d}|}$$

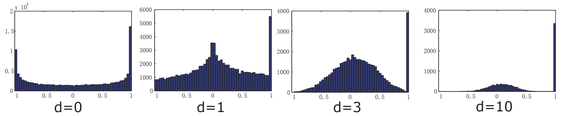
coherent neighbor set / invariant neighbor set

Invariant Neighbor Ratio — Coherent Invariant Neighbor Ratio

Pairwise velocity correlations averaged from time t to t+d

dot i
invariant neighbors i_k

$$g^{i_k}_{t\to d} = \frac{1}{d+1}\sum_{\tau=t}^{t+d} \frac{v^i_\tau \cdot v^{i_k}_\tau}{\|v^i_\tau\| \cdot \|v^{i_k}_\tau\|}$$



we can remove incoherent dots by thresholding the pairs

Algorithms of Coherent Filtering

Algorithm 1: detecting coherent motion patterns at one frame

FUNCTION $(F_1, \ldots, F_N) = \text{CoheFilterDet}(I)$

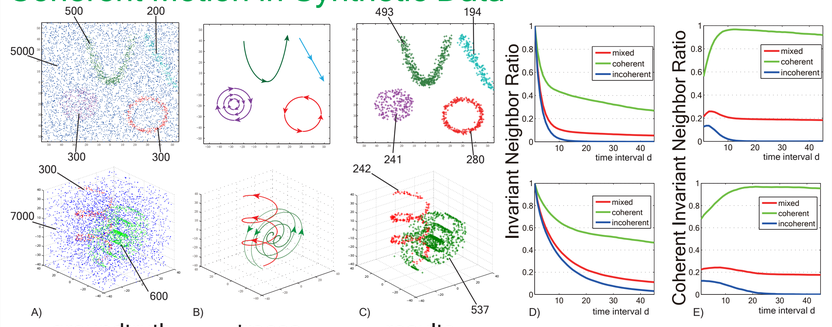
01: for $\tau = t$ to $t+d$
02: search K nearest neighbor set as N^i_τ for each dot $i \in I$
03: for each dot $i \in I$
04: search the invariant neighbor set as $M^i_{t\to d}$
05: for each $i_k \in M^i_{t\to d}$
06: compute the averaged velocity correlations $g^{i_k}_{t\to d}$
07: include (i, i_k) in R if $g^{i_k}_{t\to d} > \lambda$
08: Build a graph from R. Remove incoherently moving individuals as the isolated node, identify coherent motion $\{F_1, \ldots, F_N\}$ as the connected components of the graph.

Algorithm 2: associating continuous coherent motion over time

relying on the overlap between clusters detected at consecutive frame

Experimental Results & Applications

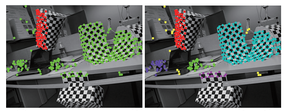
Coherent Motion in Synthetic Data



3D Motion Segmentation

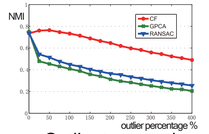
Hopkins155 Database


Checkboard — Traffic — Articulated


Comparison with the groundtruth

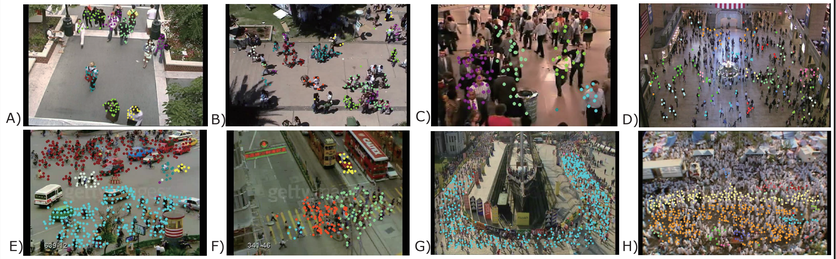
NMI	GPCA	RANSAC	CF
Checkboard	0.699	0.736	0.744
Traffic	0.858	0.829	0.705
Articulated	0.821	0.727	0.748
All sequences	0.748	0.758	0.735
Average Time	1.02s	7.58s	321ms

Quantitative Results



Outlier test result

Coherent Motion Detection in Crowd



More information at http://zhoubolei.com