Dynamics Based Tracking & Detection of Explosive Threats

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Abstract

This research aims at a substantial enhancement of the **ability to conduct autonomous, video based, persistent intelligent surveillance, and reconnaissance and threat assessment** in highly uncertain, adversarial scenarios such as urban environments.

The main idea is the use of operator theoretic and convex analysis methods to recast the problems of tracking, dynamic appearance, and event detection -into a finite dimensional convex optimization that can be efficiently solved and provides robustness to occlusion and clutter.

The proposed methods have been successfully tested on realistic datasets and are being transitioned to surveillance systems developed at **SIEMENS** and **BAL4**.

Relevance

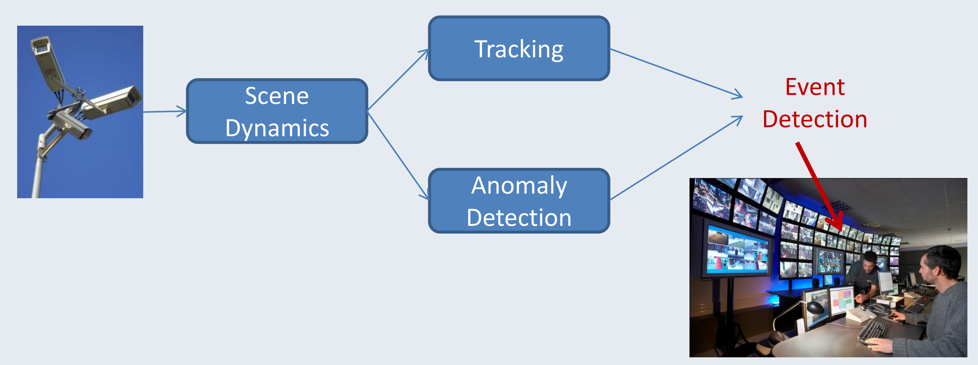
Persistent tracking and event detection in video are key for suspect and threat identification at a distance while reducing surveillance operators' data overload.

State-of-the-art methods often fail in urban environments environments due to prolonged occlusion, target appearance changes, large number of similar targets, and the inherent difficulty of characterizing what constitutes a threat.

The proposed approach overcomes these barriers by exploiting information implicitly encoded in the temporal and spatial ordering of the video data. In particular, the system uses powerful predictive and analysis tools from dynamical systems to improve robustness while reducing computational complexity.

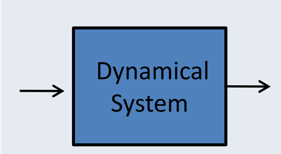
Technical Approach

Proposed System Flowchart



Main Ideas:

We model video features (local HOG, target locations and their appearance, etc.) as the outputs of unknown slowly time varying dynamical systems that are inferred directly from the experimental data:

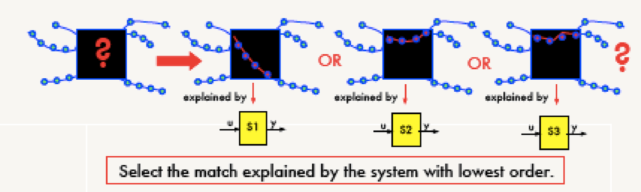


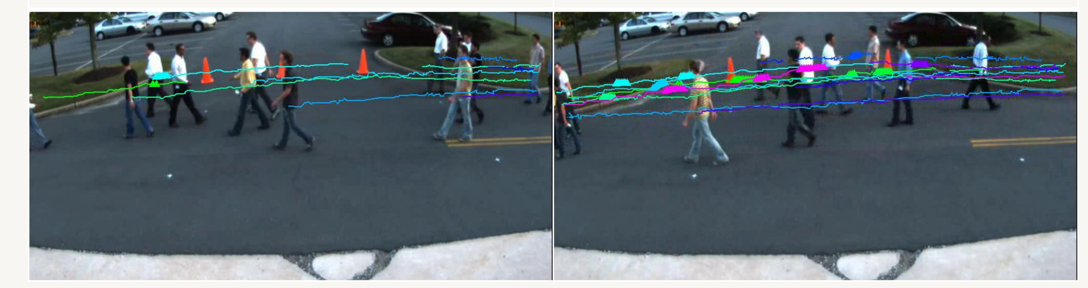
$$\min \operatorname{rank} H = \begin{bmatrix} y_1 & y_2 & \cdots & y_{n/2} \\ y_2 & y_3 & \cdots & y_{n/2+1} \\ \vdots & \vdots & & \vdots \\ y_{n/2} & y_{n/2+1} & \cdots & y_n \end{bmatrix}$$

- •Non-linear dynamics can be approximated arbitrarily well by high dimensional or piecewise low dimensional linear time invariant (LTI) systems.
- •The complexity of the dynamics is given by the rank of the Hankel matrix of the measurements.
- • New (missing) measurements can be predicted (interpolated) by enforcing that they are consistent with the simplest dynamics explaining the available data through a rank minimization of the Hankel matrix of the measurements.
- •Events are reflected in changes in the dynamics explaining the data which can be detected by monitoring the rank of the Hankel matrix or the dynamic subspace angles.

Persistent Tracking in Large Spaces

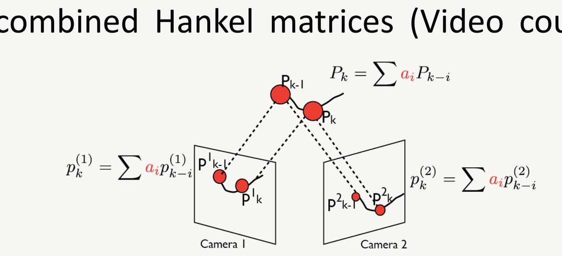
Tracklet Stitching



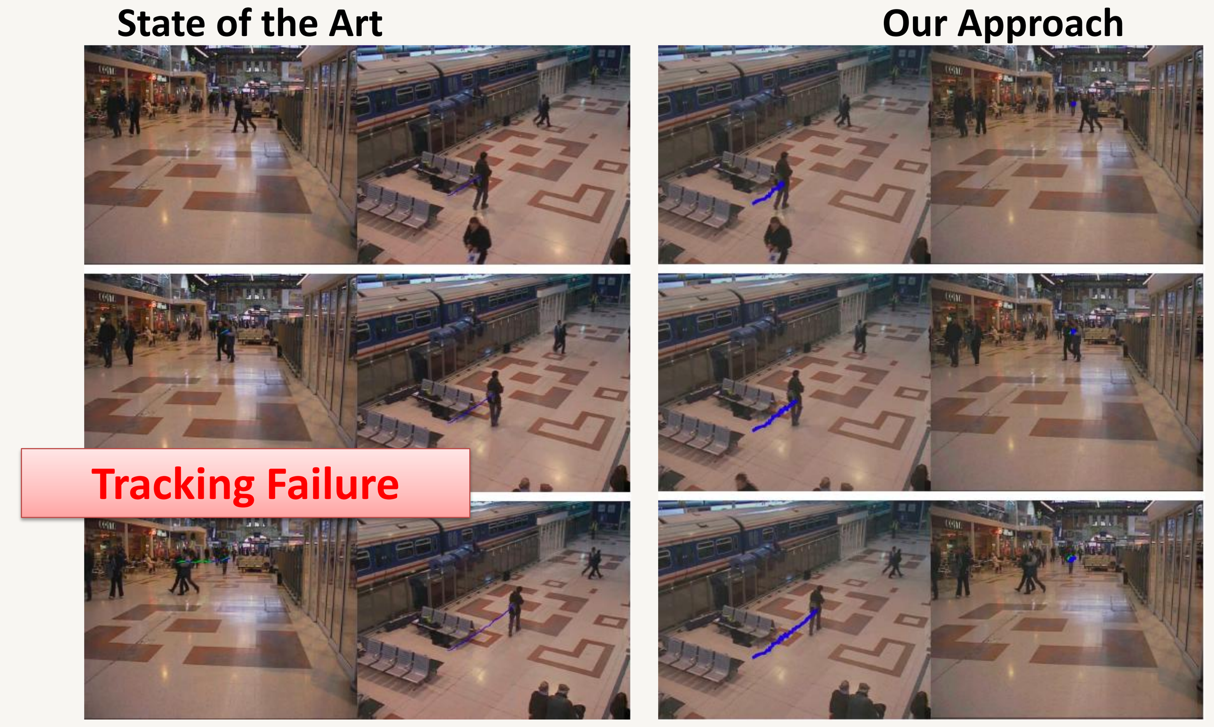


Dense Target Tracking: Multiple individual tracking is highly prone to occlusion. Our system can match partial tracks and keep persistent tracking on the targets by minimizing the rank of their combined Hankel matrices (Video courtesy of **SIEMENS**) .

Multi-camera Tracking

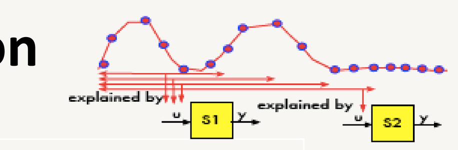


State of the Art | Our Approach

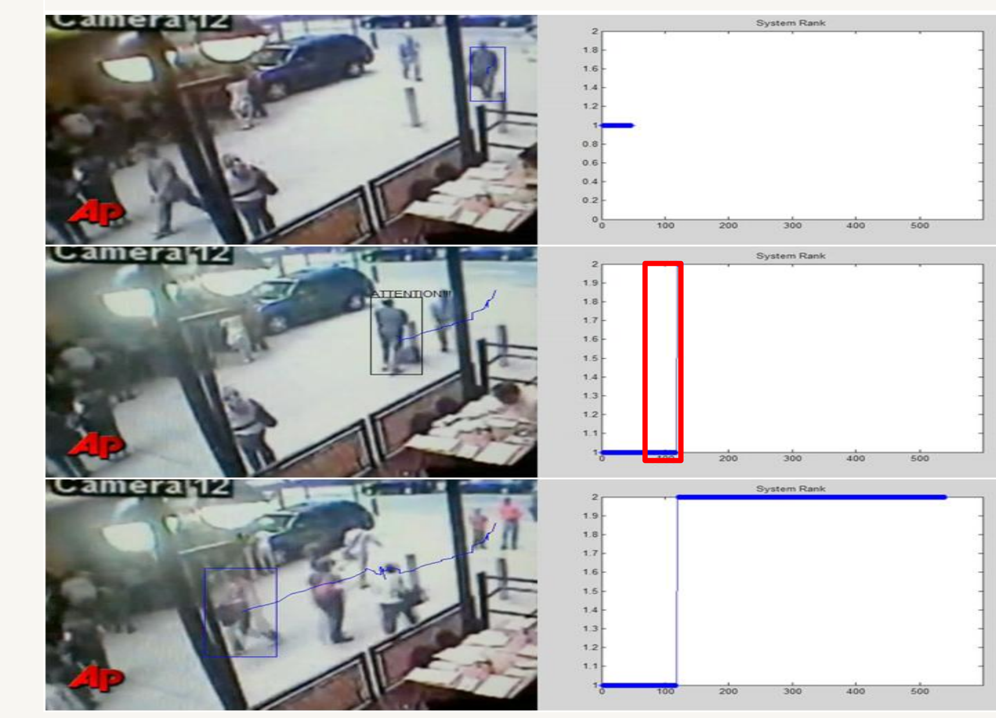


Covering Large Areas: Public large spaces are monitored using multiple cameras. Our system uses data from multiple views and geometric (epipolar geometry) and dynamical (a single dynamical system for all cameras) constraints to track under occlusion. (Video from PETS 2004 Dataset)

Suspicious Activity Detection

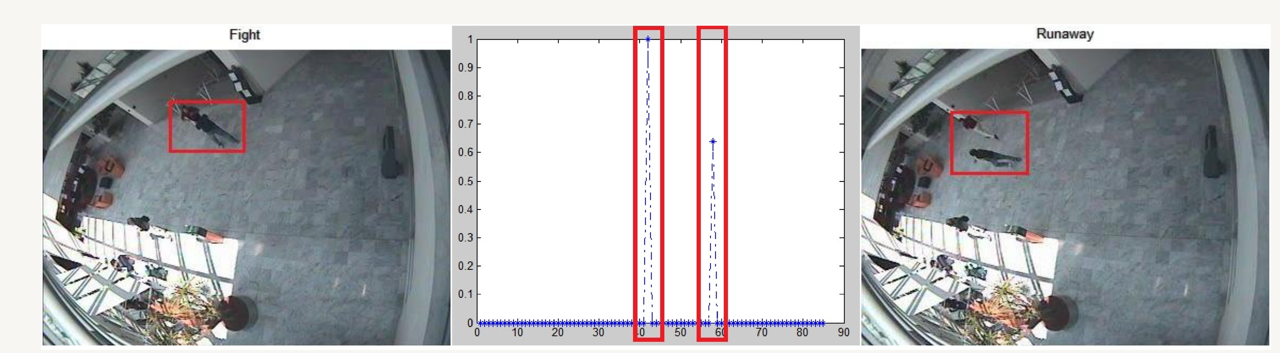


Individual Anomalous Behavior



Flagging Interesting Events: Prune data by selecting key frames with events that might be of interest. In this example, our system tracked the suspect of the 2010 bombing attempt in NYC and detected when he stopped to take off some clothing (Video from AP News).

Scene Anomaly Detection



Flagging Interesting Events: Anomaly detection over the whole scene. The system monitors the complexity of the dynamics needed to explain HOG variations in small image regions. The first detection corresponds to two people starting a fight, the second detection corresponds to two people running away. (CAVIAR dataset)

Accomplishments Through Current Year

- Maintain target identity through occlusion and clutter using one or more surveillance cameras.
- Reduce surveillance operators' overload by calling their attention to events that might be of interest.
- Initiated transitions to industrial partners.

BAL4 Technologies   SIEMENS

Future Work

- •Tracking / event detection under appearance changes in very dense crowds.
- •Event characterization.
- •Multiple people relational tracking.

Opportunities for Transition to Customer

The proposed systems promise robust tracking and event detection on real scenarios. They are already prototyped using MATLAB and their accuracy have been demonstrated on realistic datasets. They only require minor speed improvements to code them in C++ and migrate them into products.

Patent Submissions

None at this time.

Publications Acknowledging DHS Support

"The Role of Dynamics in Extracting Information Sparsely Encoded In High Dimensional Data Streams," M. Sznaier, O. Camps, N. Ozay, T. Ding, G. Tadmor and D. Brooks, in Dynamics of Information Systems, Hirsch, M.J.; Pardalos, P.M.; Murphey, R. (Eds.), pp. 1- 28, Springer Verlag, 2010 .

"A Moments-Based Approach To Estimation and Data Interpolation for a Class of Wiener Systems," M. Ayazoglu, M. Sznaier, C. Lagoa and O. Camps, IEEE CDC 2010.

"A rank minimization approach to trajectory (in)validation," M. Sznaier and O. Camps, ACC 2011, to appear.

"Dynamic Subspace-based Coordinated Multicamera Tracking," M. Ayazoglu, B. Li, C. Dicle, O. Camps and M. Sznaier, submitted to ICCV 2011.

"Scene Anomaly Detection using Dynamic Subspace Angles," T. Mao, O. Camps and M. Sznaier, in preparation.

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