Correlation-based ConvNet for Small Object Detection in Videos

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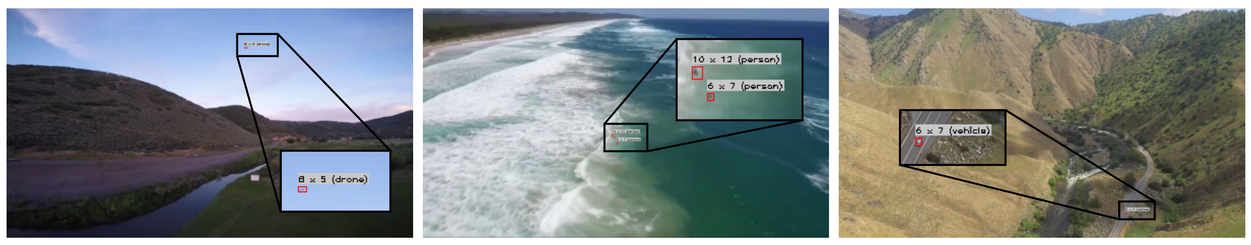
OVERVIEW

Goal:

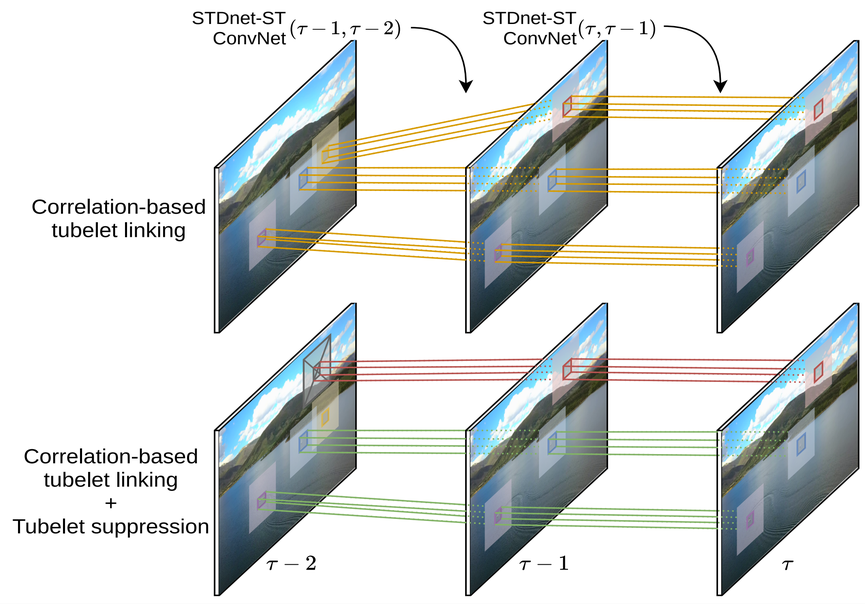
To detect small objects (under 16 x 16 px) in videos



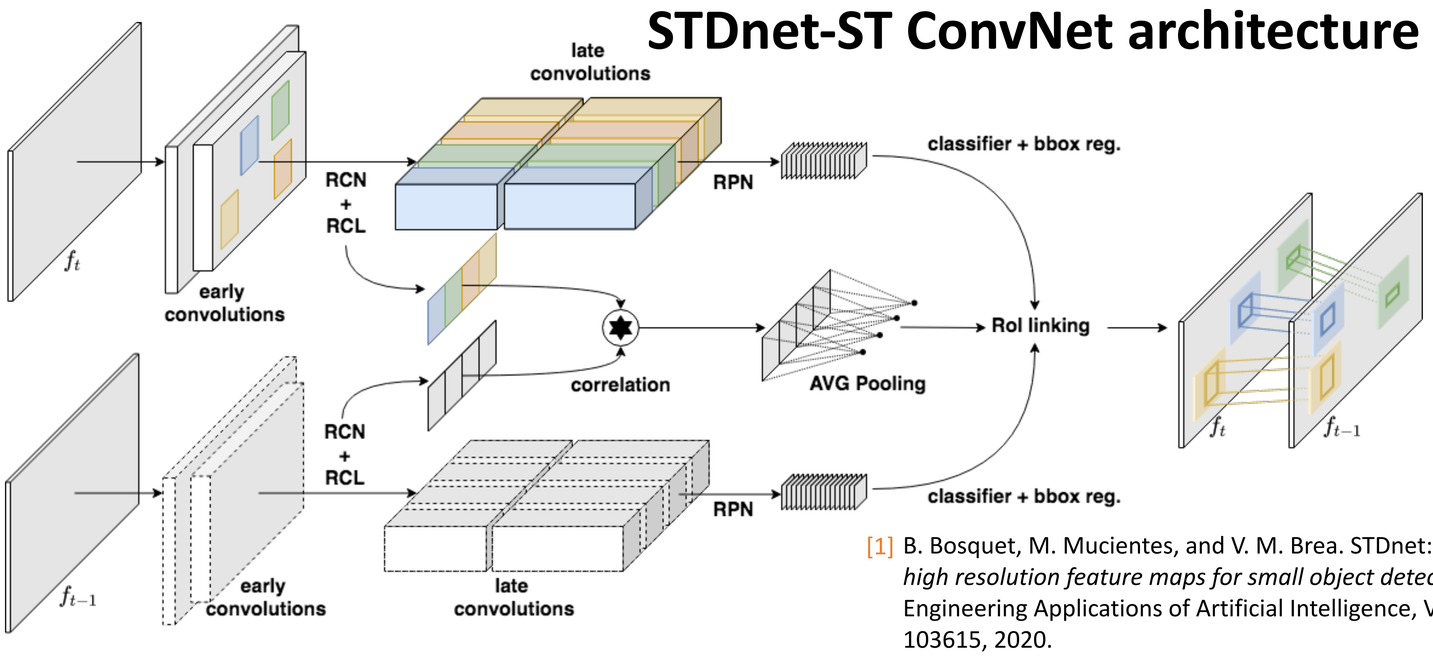
How it works:

Spatio-temporal STDnet (STDnet-ST) comprises two steps:

- **STDnet-ST ConvNet**: computes the detections of two consecutives frames and the correlation scores between them
- **STDnet-ST tubelet linking:**
  1. *Correlation-based tubelet linking*: generate object associations (tubelets) over time based on the Viterbi algorithm
  2. *Tubelet suppression algorithm*: identify and remove incorrect data associations



STDnet-ST ConvNet architecture



[1] B. Bosquet, M. Mucientes, and V. M. Brea. STDnet: *Exploiting high resolution feature maps for small object detection*. Engineering Applications of Artificial Intelligence, Vol. 91, No. 103615, 2020.

Two STDnet[1] branches

Correlation module

- *Correlation*: RCN regions[1]
- *RoI linking*: propagate correlation scores to final detections

STDnet-ST tubelet linking

a) Correlation-based tubelet linking

1. Compute score matrix for pair of frames
   - Replaces IoU with the correlation score

$$s_t^{ij} = p_{t-1}^i + p_t^j + \lambda \cdot c_t^{ij} \qquad c_t^{ij} = \rho\left(r_{t-1}^{k(i)}, r_t^{l(j)}\right)$$

2. Generate *tubelets* (Viterbi):

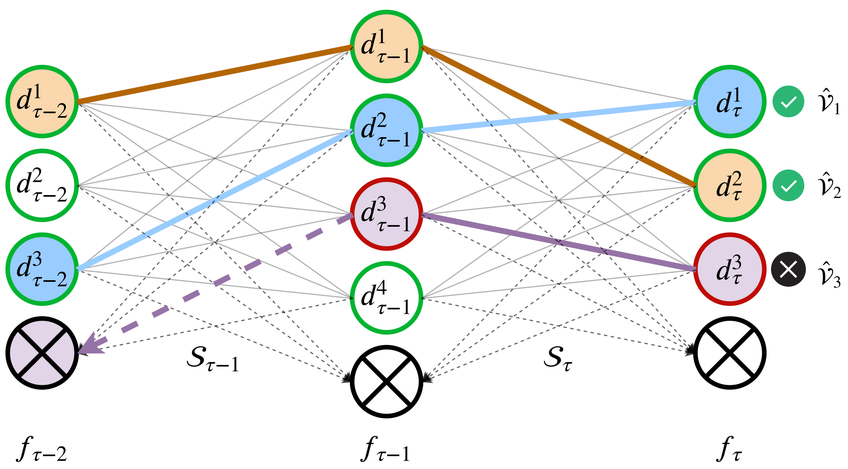
$$p_\tau^{i(\hat{v})} = \frac{1}{\tau}\sum_{t=1}^{\tau} p_t^{i(\hat{v})}$$

3. Confidence variability:

$$p_\tau^{i(\hat{v})} = \begin{cases} \max_{t=1}^{\tau} p_t^{i(\hat{v})} & \text{if } \sigma(\{p_t^{i(\hat{v})}\}_{t=1}^{\tau}) \leq \kappa \\ \frac{1}{\tau}\sum_{t=1}^{\tau} p_t^{i(\hat{v})} & \text{otherwise} \end{cases}$$

b) Tubelet suppression algorithm

- Discard unlikely tubelets using **dummy nodes** (⊗)



RESULTS & ACHIEVEMENTS

UAVDT

Method	$AP_{xs}^{@[.5,.95]}$	$AP_{xs}^{@.5}$
Faster R-CNN [27]	6.6	26.0
R-FCN [27]	9.2	32.5
RON [27]	3.7	19.7
SSD [27]	6.0	23.5
FGFA [154]	6.3	20.7
RDN [23]	9.3	27.9
MEGA [16]	9.2	26.6
FPN [78]	11.8	29.7
FPN-t	12.0	30.3
Cascade-FPN [13]	12.0	30.5
Cascade-FPN-t	12.3	31.2
STDnet [9]	12.5	35.1
STDnet++	12.6	35.4
STDnet-ST	13.1	36.0
STDnet-ST++	**13.3**	**36.4**

VisDrone2019- VID

Method	$AP_{xs}^{@[.5,.95]}$	$AP_{xs}^{@.5}$
FGFA [154]	3.8	16.8
RDN [23]	4.7	20.7
MEGA [16]	4.8	21.0
FPN [78]	6.2	19.9
Cascade-FPN [13]	6.1	20.2
FPN-t	6.3	20.2
Cascade-FPN-t	6.2	20.4
STDnet [9]	7.2	21.4
STDnet++	7.3	22.0
STDnet-ST	7.5	21.9
STDnet-ST++	**7.5**	**22.4**

USC-GRAD-STDdb

Method	$AP_{xs}^{@[.5,.95]}$	$AP_{xs}^{@.5}$
FGFA [154]	11.7	37.5
RDN [23]	15.5	48.6
MEGA [16]	17.4	53.1
FPN [78]	17.3	54.5
Cascade-FPN [13]	17.4	55.9
FPN-t	18.7	57.2
Cascade-FPN-t	19.1	58.9
STDnet [9]	18.3	57.8
STDnet++	18.9	59.1
STDnet-ST	20.1	62.1
STDnet-ST++	**21.4**	**63.4**

- **State-of-the-art** results:
  - UAVDT (*xs* subset)
  - VisDrone (*xs* subset)
  - USC-GRAD-STDdb[1]

- STDnet-ST generates object associations regardless the object temporal spatial distance. Critical for:
  - Small objects or fast motions
  - Low frame rate or skipping frames