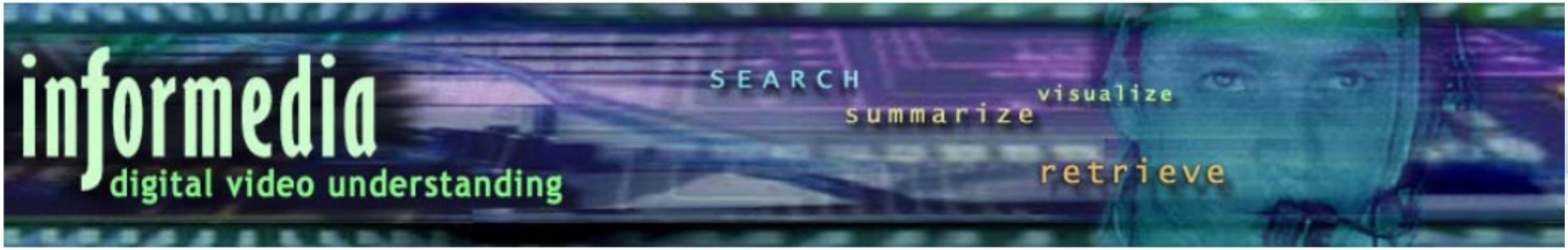

CMU Informedia at TRECVID 2021: Towards Better Spatial-Temporal Activity Detection

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NIST ActEV

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DIVA

Overview

System/Team	$nAUDC@0.2T_{fa}\downarrow$	Mean $P_{miss}@0.15T_{fa}\downarrow$	Mean $wP_{miss}@0.15R_{fa}\downarrow$	
Argus++ (Ours)	**0.39607**	**0.30622**	0.81080	1st
BUPT	0.40853	0.32489	**0.79798**	
UCF	0.43059	0.34080	0.86431	
M4D	0.84658	0.79410	0.88521	
TokyoTech_AIST	0.85159	0.81970	0.94897	
Team UEC	0.96405	0.95035	0.95670	

TRECVID 2021 Leaderboard*

*Snapshot: *Updated: 2021-10-25 11:02:47 -0400 https://actev.nist.gov/trecvid21#tab_leaderboard*

Activity detection

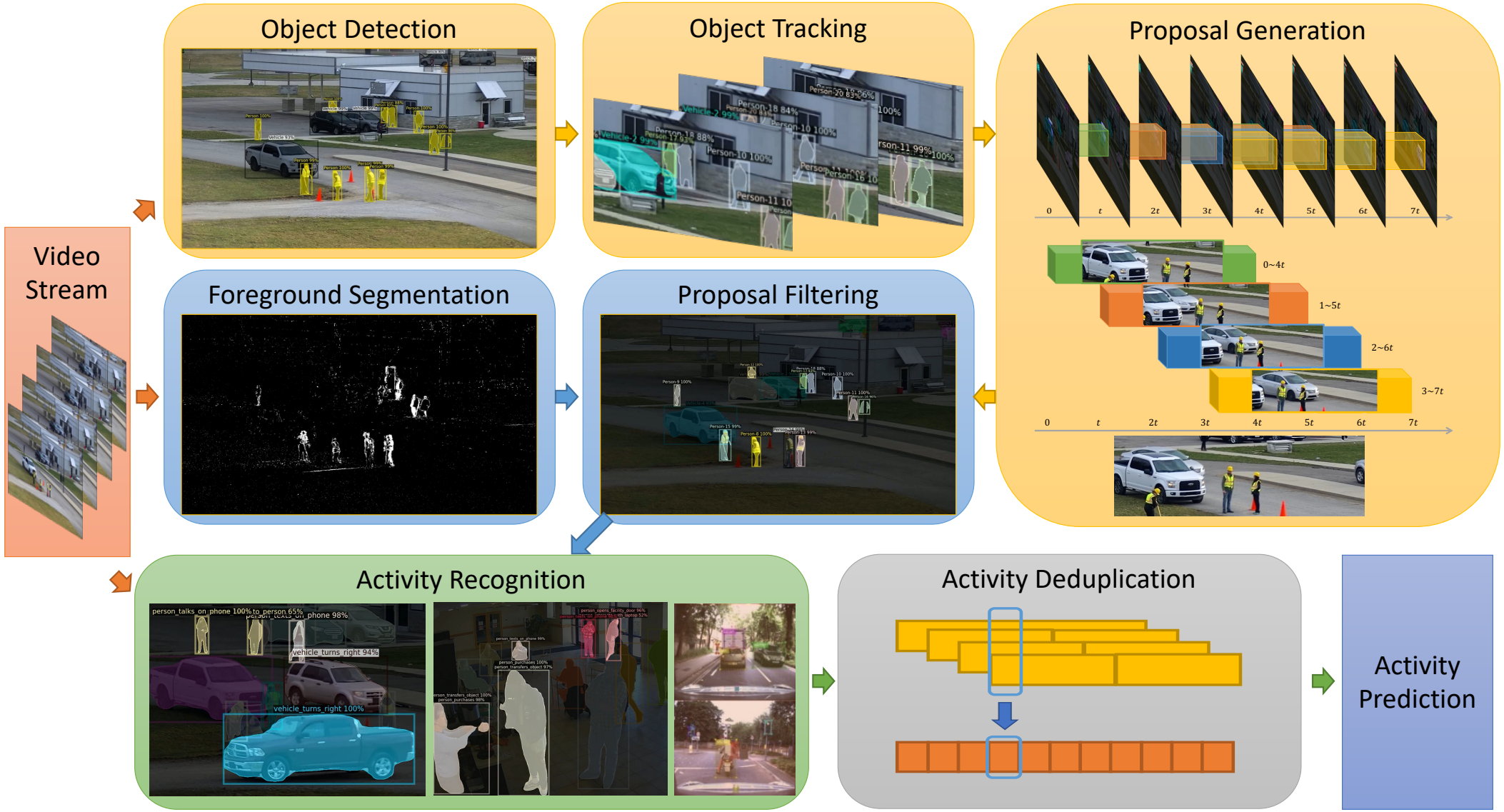
- In ***unconstrained*** videos:
  untrimmed and with large field-of-views
- Three aspects
  - Temporal localization
  - Spatial localization
  - Action classification

Target

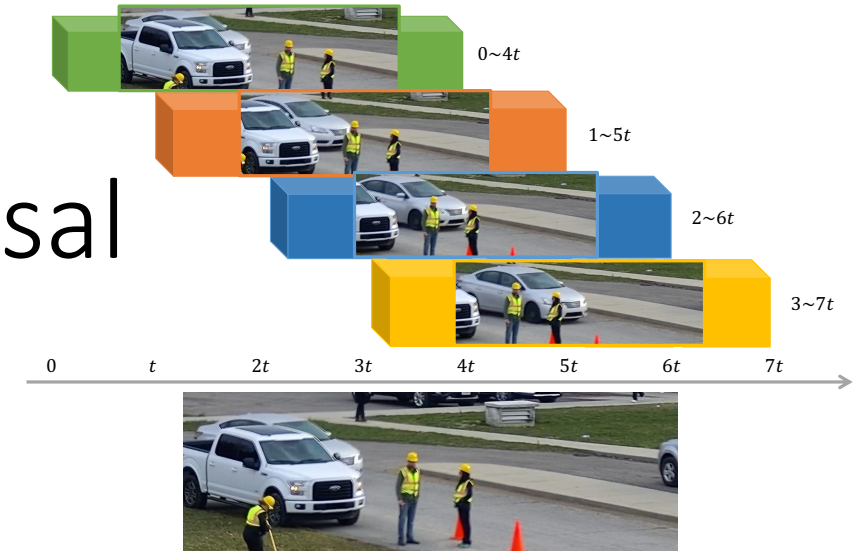
- Detect either atomic activities (e.g., standing up) or continuous repetitive activities (e.g., walking)
- Match multiple non-overlapping predictions to each ground truth

Argus++ Framework

Argus++ Architecture



Intermediate Concept: Cube Proposal



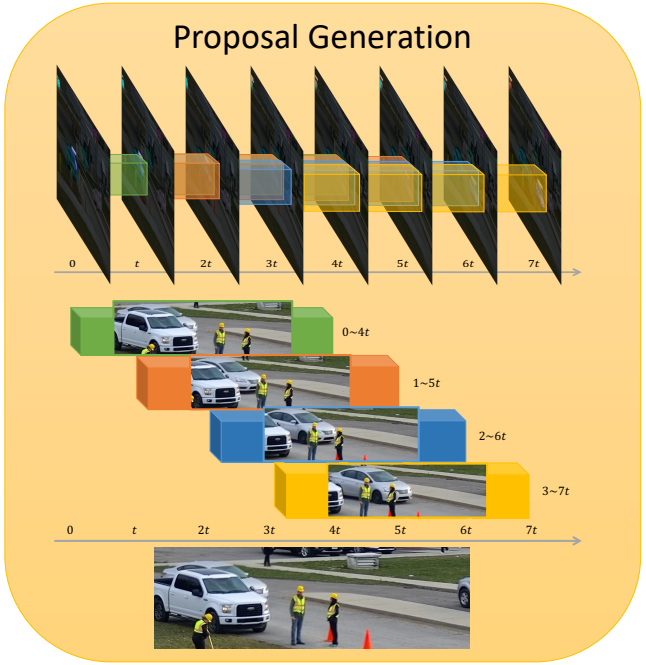
- Proposal
  - A candidate region where activity may occur
  - Processing element for activity recognition

- Spatio-temporal cube proposal
  - A simple six-tuple defining the boundaries in three dimensions

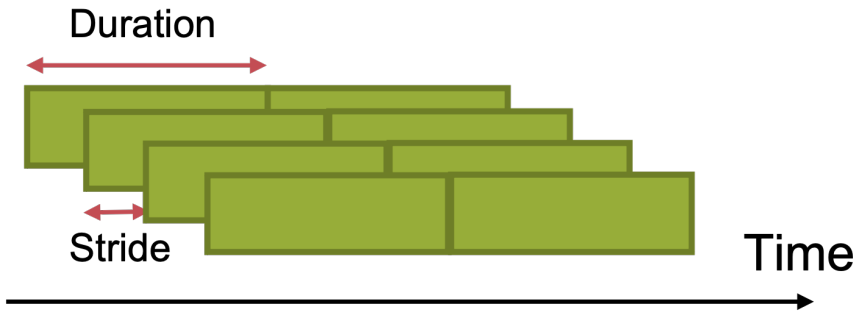
$$p_i = (x_0^i, x_1^i, y_0^i, y_1^i, t_0^i, t_1^i)$$

  - Fixed temporal duration when sampled
  - Much simpler than activity instances or tube proposals

Proposal Generation



- Proposal sampling
  - Dense overlapping sampling on untrimmed videos
  - Ensure completeness and coverage of any activity instance

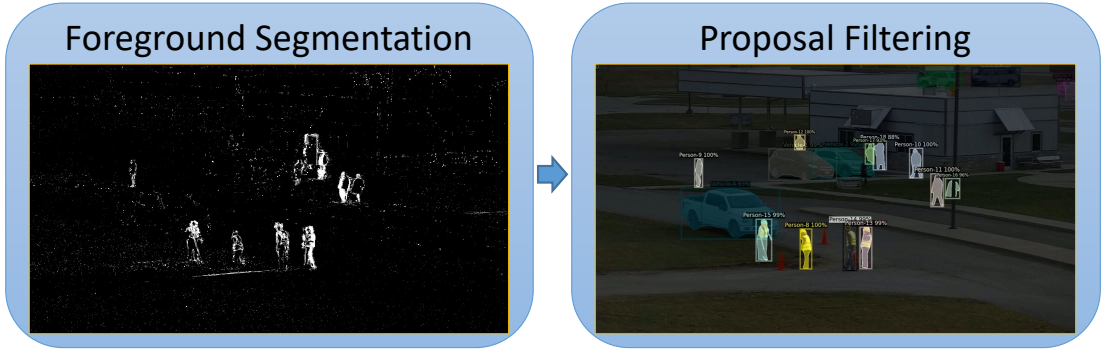


- Proposal refinement
  - Seed track ids from central frame in each temporal window
  - Enlarge bounding boxes as union across the window

$$(x_0, x_1, y_0, y_1)_k = \bigcup(\{(x_0, x_1, y_0, y_1)_{i,j} \mid t_0 \le i \le t_1, tr_{i,j} = tr_{t_c,k}\})$$
$$k = 1, \cdots, n_{t_c}$$

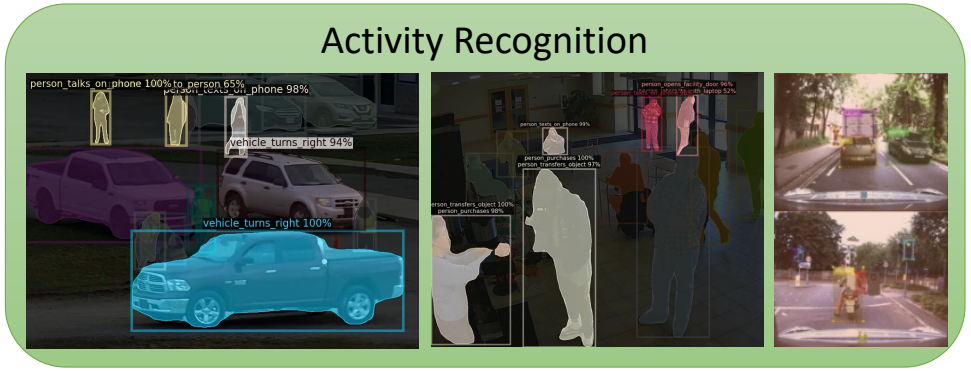
Proposal Generation: An Example

Proposal Filtering

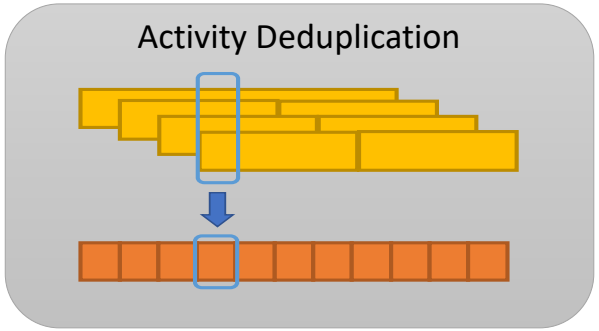


- Foreground segmentation
  - Frame-level binary mask for foreground pixels
  - Proposal foreground score as average value of pixel mask inside the cube
  - Learn a filtering threshold by allowing up to some sacrificed true positive
- Label assignment
  - Convert annotation into cube format by dense sampling
  - Estimate spatial IoU between proposal and ground truth cubes
  - Follow Faster R-CNN in selecting positive and negative samples
- Proposal evaluation
  - Assume perfect classifier by using assigned labels
  - Pass through following steps and use official metrics to estimate upper bound

Activity Recognition

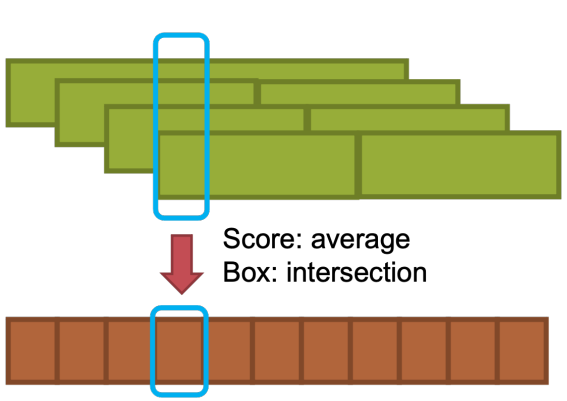


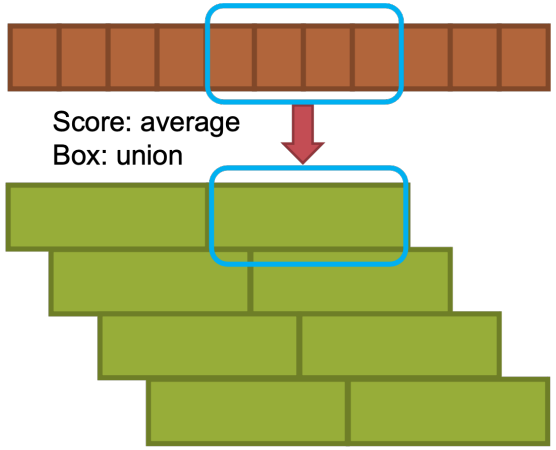
- Multi-label Classification
  - Binary cross entropy loss
  - Weighted by proposal scores
  - Balance activity-wise pos/neg samples
  - Balance samples of different activities
- Action-wise late fusion

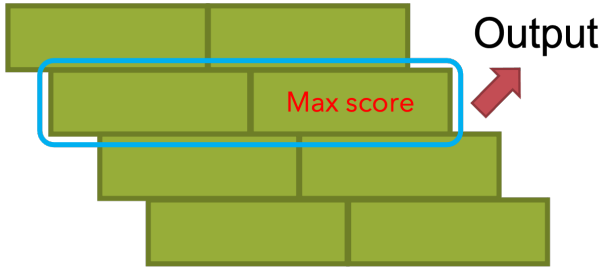


Activity Deduplication

- Overlapping instances







- Adjacent instances
  - Merge adjacent cubes above certain threshold, subject to a minimum duration

Experimental Results

Implementation Details

- Object detection: Mask R-CNN with Resnet-101 on COCO, stride=8
- Multi-object tracking: Towards-Realtime-MOT
- Foreground segmentation: HoG
- Proposal: duration=64, stride=16
- Classifiers: R(2+1)D, X3D, TRM

NIST TRECVID 2021 ActEV

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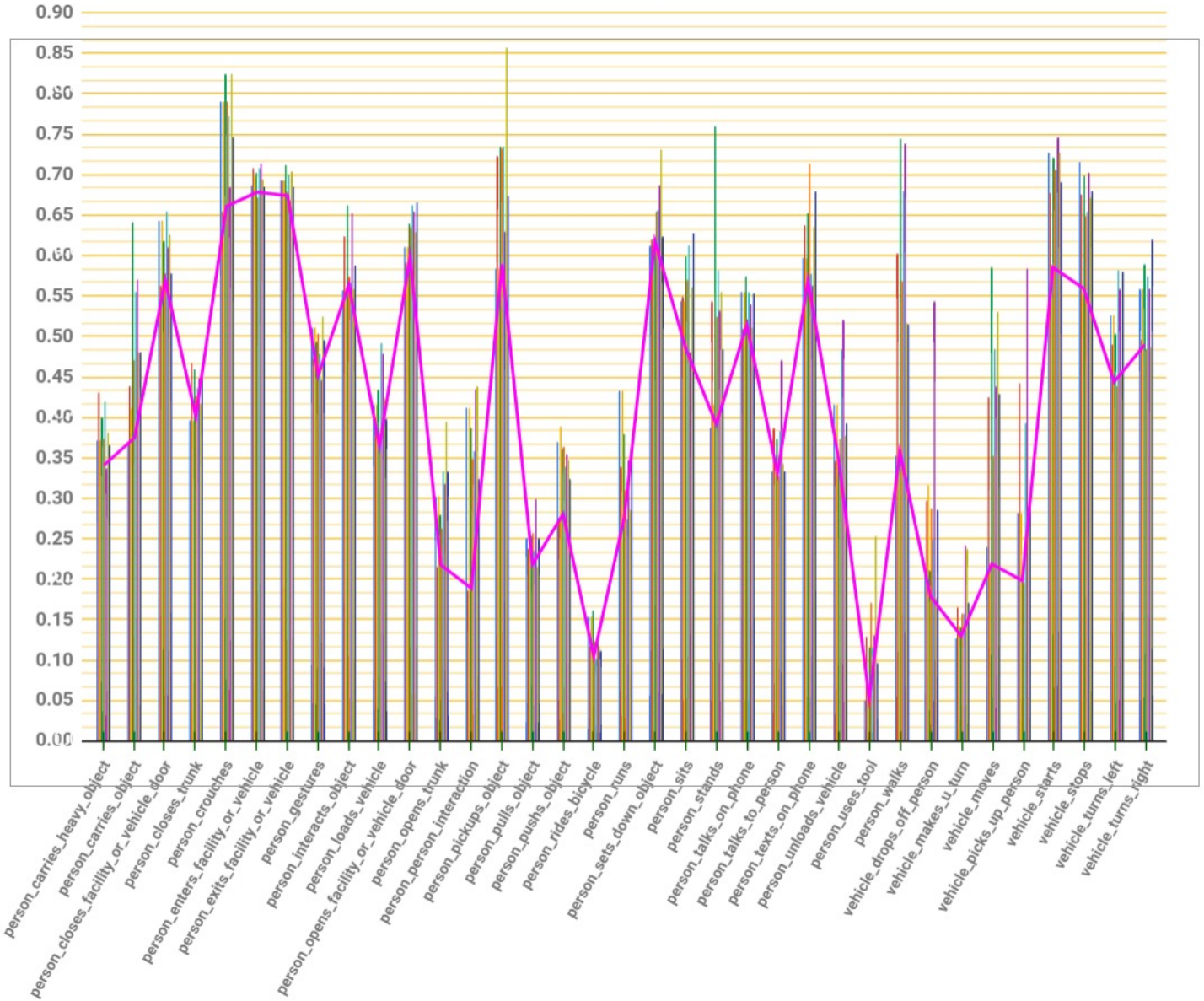
NIST TRECVID 2021 ActEV -Fusion



CMU best submission (26562) is an action-wise fusion system (the pink curve) and ranks first on the ActEV TRECVID21 Leaderboard.

Ablation Study

- Coverage of Proposal Formats

Table 8. Lower Bounds of $nAUDC@0.2T_{fa}$ on VIRAT Validation Set with different proposal formats. Italic values are non-overlapping proposals while the others are overlapping proposals. Duration and stride are in the unit of frames.

Duration / Stride	16	32	64	96
32	0.0705	*0.1208*	-	-
64	**0.0127**	0.0621	*0.0673*	-
96	0.0275	0.0504	-	*0.0688*

- Performance of Proposal Filtering

Table 9. Statistics of Proposals on VIRAT Validation Set

Name	Unfiltered	Filtered
Number of Proposals	211271	62831
Positive rate	0.1704	**0.5204**
Rate of unique label	0.4558	0.4415
Rate of two labels	0.4127	0.4252
Rate of three labels	0.1017	0.1060

Table 7. Proposal Quality Metrics on VIRAT Validation Set

$nAUDC@0.2T_{fa}$	IoU			Reference Coverage		
Threshold	Average	≥ 0	≥ 0.5	Average	≥ 0.5	≥ 0.9
Unfiltered Proposals	0.2358	0.0772	0.1518	0.1562	0.1125	0.4211
Filtered Proposals	0.2352	0.0772	0.1469	0.1563	0.1099	0.4280

Table 10. Proposal Filter on NIST ActEV'21 SDL Unknown Facility Micro Set

Proposal Filter	$nAUDC@0.2T_{fa} \downarrow$	Processing Time
Enabled	**0.4822**	0.582
Disabled	0.5176	0.925

Conclusion and Future Work

Conclusion and Future Work

- Argus++: Robust Real-time Activity Detection System
- Overlapping Spatio-temporal Cube proposal works
- Action-wise classifier fusion works
- Superior performance in TRECVID ActEV 2020/2021

- Extending to stricter settings: bipartite matching with spatial localization
- Generalizing to more scenarios such as UAV videos
- Zero-shot or Few-shot Activity Detection
- System submission for speed evaluation
- Code validation for reproduction

Acknowledgements

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Thank You!