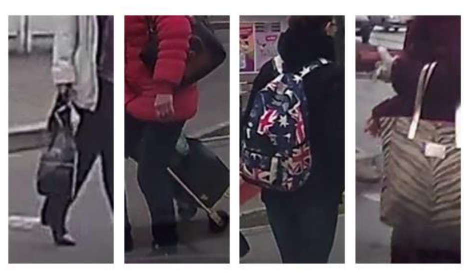
It's Not All About Size: On the Role of Data Properties in Pedestrian Detection

Amir Rasouli, Iuliia Kotseruba and John K. Tsotsos
Dept. of Electrical Engineering and Computer Science and Center for Vision Research
York University, Toronto, Canada
{aras, yulia_k, tsotsos}@cse.yorku.ca

AFOSR Computational Cognition and Machine Intelligence Program
YORK UNIVERSITÉ UNIVERSITY
Centre for Vision Research
NCFRN NSERC Canadian Field Robotics Network
RCCRT Réseau canadien CRSNG pour la robotique de terrain
Chaires de recherche du Canada / Canada Research Chairs
Canada
ECCV 2018 European Conference on Computer Vision

Pedestrian detection is challenging



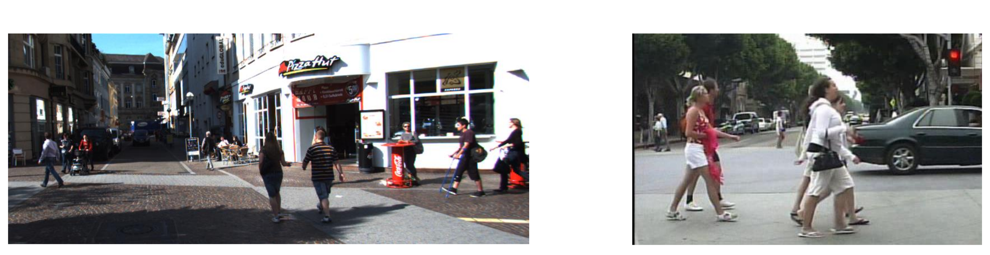
Localization errors:
Due to the presence of attributes such as bags, backpacks and umbrellas that are associated with pedestrians

False positives:
Caused by various factors such as wet surfaces, over-exposure as well as the presence of objects resembling pedestrians

False negatives:
Due to the variation in shape and appearance (e.g. pedestrians wearing hooded jackets, holding umbrellas).

Pedestrian detection, benchmarks and evaluation

- **Data diversity is necessary:** Pedestrian datasets should be diverse to highlight the true performance of detection algorithms
- **Benchmark datasets lack variability:** The widely used benchmark datasets, such as Caltech and KITTI, lack variability:
  - Collected under sunny clear weather conditions
  - Recorded in similar geographical locations
  - Lack variability in pedestrian appearance



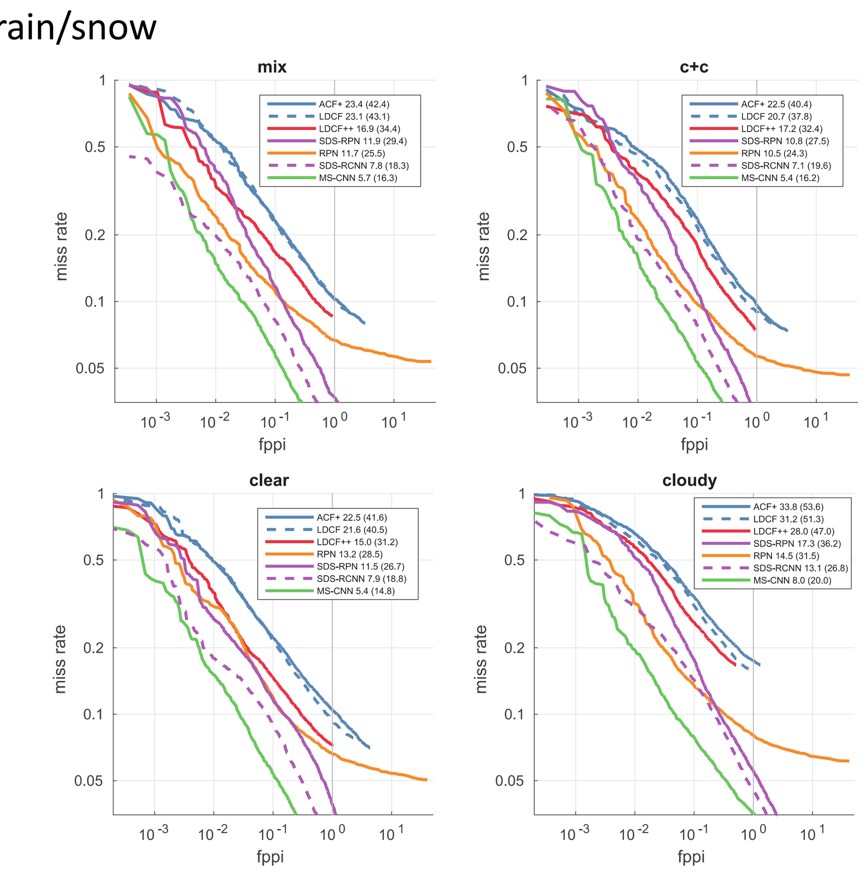
KITTI Caltech

Contributions

- **A large dataset of attributes:** Augmented JAAD dataset with more than 900k attributes
- **Evaluate state of the art:** Highlight the performance of pedestrian detection algorithms under different conditions
- **Cross-evaluation of datasets:** Measure generalizability of datasets according to data properties
- **A software framework for experimentation:** with 10 detection algorithms and 8 common datasets

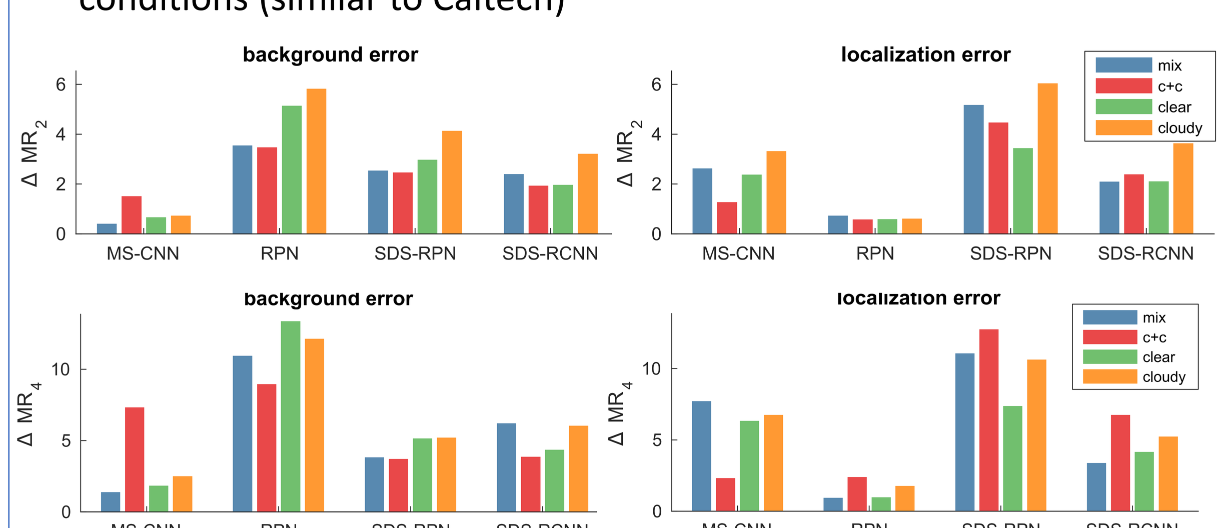
Weather conditions and performance

- JAAD is divided into four subsets:
  - ***Clear:*** Data collected under clear conditions
  - ***Cloudy:*** Data collected under cloudy conditions
  - ***Cloudy + Clear (c + c):*** Data from clear and cloudy subsets
  - ***Mix:*** All weather conditions including extreme weather such as rain/snow



ROC curves for all algorithms trained and tested on different JAAD subsets with detection threshold set to 0.5 IoU.

- *MS-CNN (outside top-5 on Caltech) outperforms SDS-RCNN (best on Caltech)* on JAAD
- Weak-segmentation in *SDS-RPN* is only effective under clear conditions (similar to Caltech)



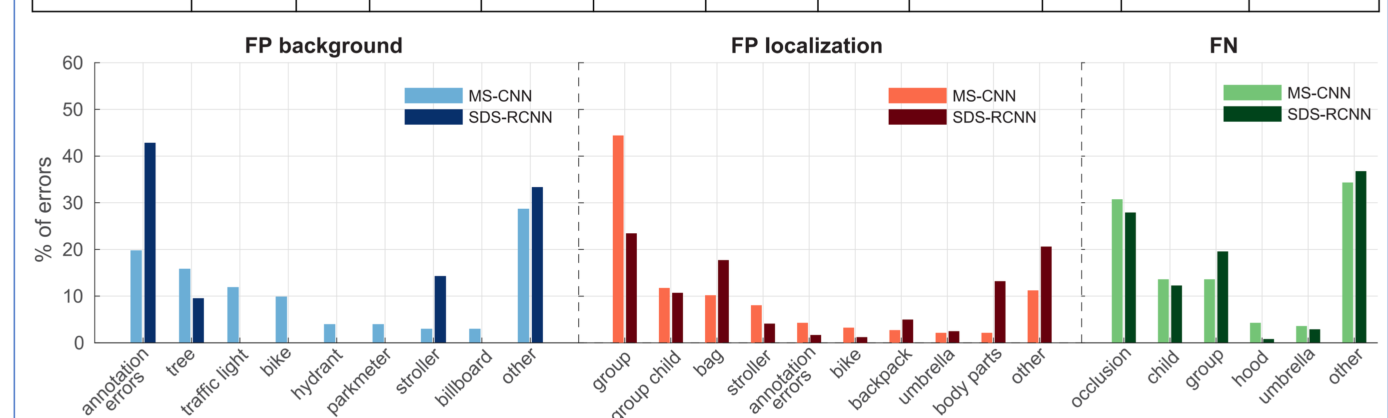
The relative contribution of background and localization errors to the performance of state-of-the-art pedestrian detection algorithms.

- There are two sources of error:
  - ***Background error:*** Ignoring all false positives resulting from poor localization
  - ***Localization error:*** Ignoring all false positives resulting from background misdetections
- Different algorithms are prone to different sources of error:
  - Adding weak-segmentation to *RPN* reverses the contribution of error from background to localization
  - *SDS-RCNN* has a more balanced performance compared to *MS-CNN* which has poorer localization error vs background error
- Under different weather conditions sources of error differ:
  - *MS-CNN* is more prone to background error under *c+c* conditions

Pedestrian attributes and performance

The performance of pedestrian detection algorithms in the presence of individual attributes. The results are reported as MR_4 metric

Algorithms	Attributes										
	female	*male*	*pose_back*	*pose_front*	*pose_left*	*pose_right*	*child*	*backpack*	*bag*	*cap/hood*	*umbrella*
ACF+	38.96	34.66	39.71	38.28	34.70	33.91	60.92	38.88	36.00	40.21	69.18
LDCF+	37.02	33.84	35.27	37.24	32.90	30.94	55.02	33.50	33.94	28.27	68.16
LDCF++	30.09	28.30	34.41	31.79	26.44	26.71	55.16	32.76	26.69	33.29	56.64
MS-CNN	**13.49**	**14.03**	17.77	**14.00**	15.20	**11.19**	45.37	16.01	**10.77**	**14.08**	31.06
RPN	21.99	25.79	28.03	26.82	22.72	21.34	53.59	24.59	19.48	28.97	37.35
SDS-RPN	24.31	22.57	26.58	23.67	21.51	22.74	52.54	19.50	20.12	24.61	31.68
SDS-RCNN	14.30	15.77	**17.72**	15.29	**14.46**	13.60	**43.14**	**15.85**	12.25	15.68	**25.57**



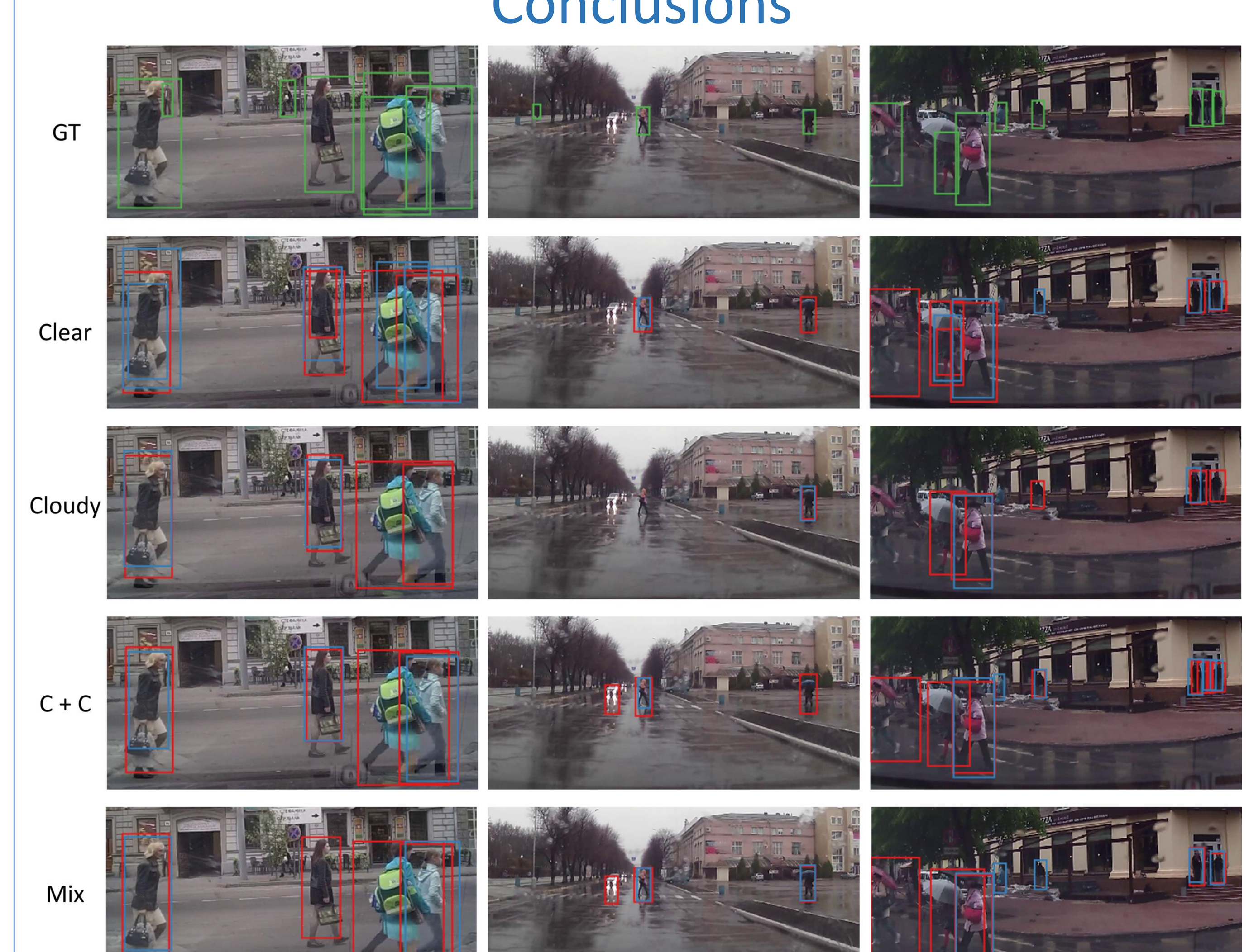
The breakdown of false positive and false negative errors grouped by the corresponding attributes.

Data properties and generalizability

The performance detection algorithms on the Caltech and JAAD subsets. *Left*, the results for algorithms trained and tested on the same dataset. *Right,* trained and tested on different datasets ($J = JAAD, C = Caltech$). MR^o and MR^N refer to old and new Caltech annotations. The best and second best results are highlighted with blue and green color respectively

Algorithms	$C \rightarrow C$ MR_2^N (MR_2^o)	$mix \rightarrow mix$ MR_2	$C \rightarrow mix$ MR_2	$J \rightarrow C$ MR_2^N (MR_2^o)			
				mix	c + c	cloudy	clear
ACF+	26.27 (30.55)	23.36	77.94	46.97 (53.63)	49.52 (55.06)	70.79 (74.06)	49.99 (55.23)
LDCF+	23.07 (25,79)	23.07	54.82	43.61 (49.93)	44.89 (50.85)	59.18 (64.11)	47.29 (52.54)
LDCF++	13.66 (16.10)	16.90	47.94	37.66 (46.04)	40.41 (48.54)	54.86 (60.72)	44.77 (51.93)
RPN	11.71 (14.33)	11.71	40.15	27.80 (41.19)	25.74 (38.18)	34.67 (47.34)	28.75 (40.05)
MS-CNN	9.47 (11.21)	5.70	35.09	22.87 (34.83)	26.30 (38.11)	31.55 (46.35)	29.49 (41.64)
SDS-RPN	8.15 (9.27)	11.89	43.40	24.24 (30.84)	26.64 (33.61)	35.62 (42.90)	30.85 (38.52)
SDS-RCNN	6.58 (7.59)	7.78	25.45	21.47 (27.73)	25.29 (32.69)	35.20 (42.35)	23.81 (31.75)

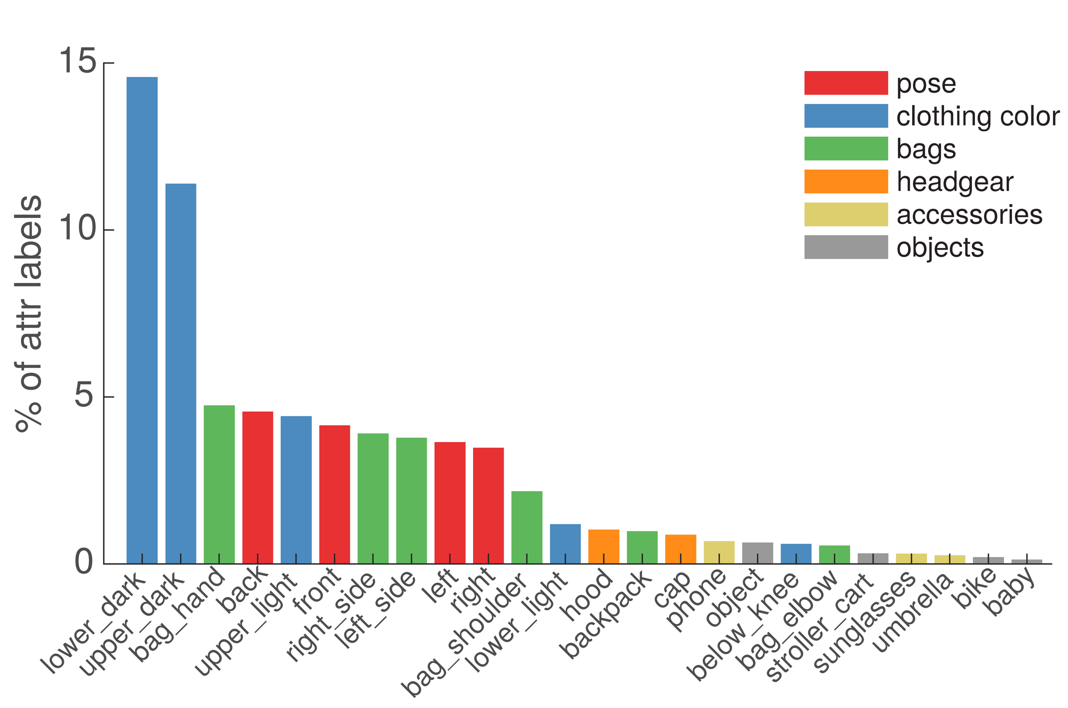
Conclusions



The performance of state of the art on different subsets of JAAD. Colors green, red and blue correspond to the ground truth, MS-CNN and SDS-RCNN respectively.

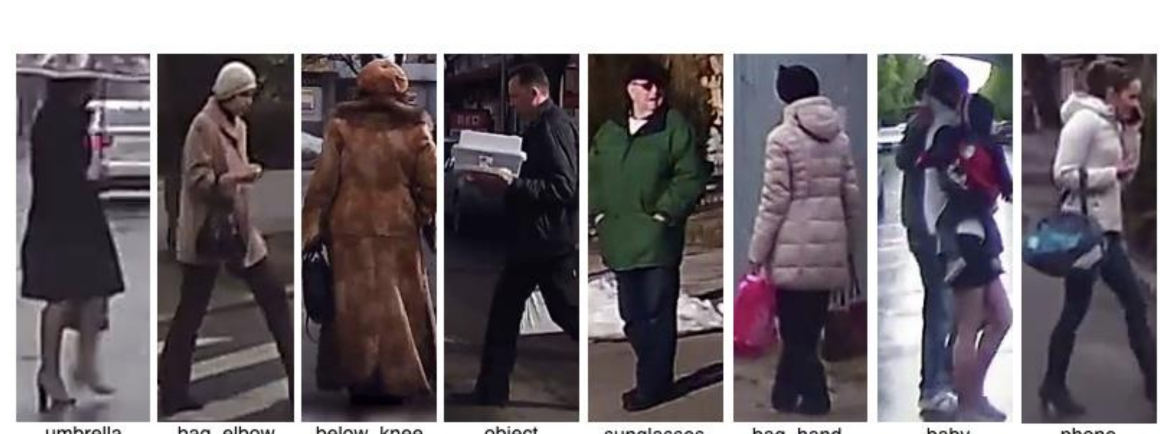
- Data properties influence the performance of algorithms differently
- Diverse benchmark datasets give an unbiased estimate of pedestrian detection algorithms performance
- Diversity of data increases algorithms' generalizability even with fewer samples
- Benchmark datasets should be designed following protocols to minimize any unevenness in the statistical distribution of different aspects of the driving task

JAAD-Attributes: A dataset of pedestrian attributes and poses



Types and frequency of new attribute labels in the JAAD dataset color-coded based on the attribute type (e.g. pose, clothing color, accessories)

http://data.nvision2.eecs.yorku.ca/JAAD_dataset/



Samples of pedestrians with select attribute labels shown