ACM MM 2020 Tutorial on “Effective and Efficient: Toward Open-world Instance Re-identification”

Vehicle Re-identification: Past, Present and Future

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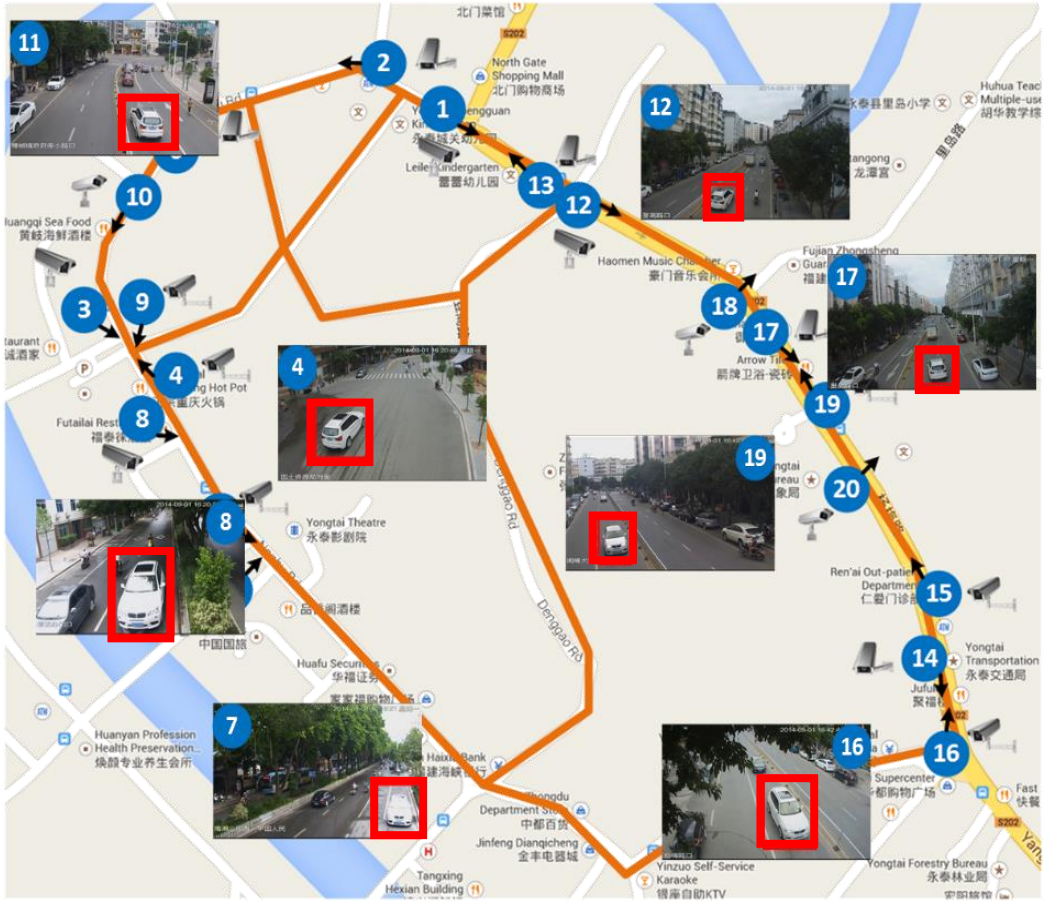
What is Vehicle Re-Identification?

Probe vehicle image

Vehicle Re-Identification



Quickly discover, locate, and track the target vehicles in large scale urban surveillance videos!

Pervasive Applications

Crime Investigation

Park Management

Intelligent Transportation

Urban Computing

Challenges

Vehicle variety

- Large number of types & models
- Trivial inter-class differences
- Large intra-class differences

Environmental factors

- **Various viewpoints**
- Uncertain illuminations
- Clutter and occlusion

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1 Datasets

2 Methods

3 Discussion

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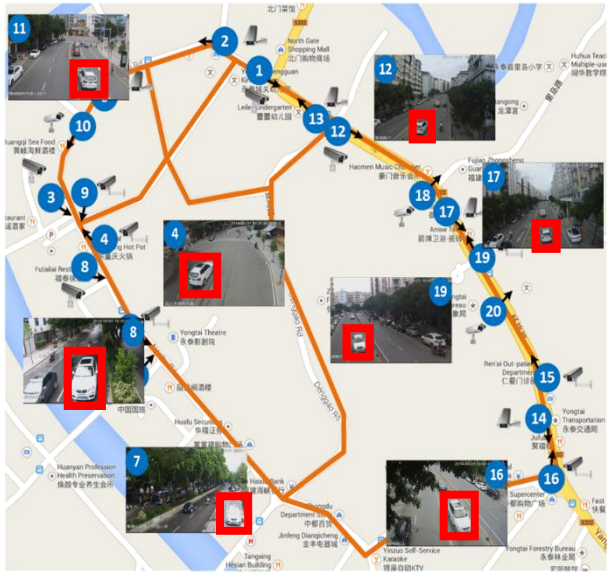
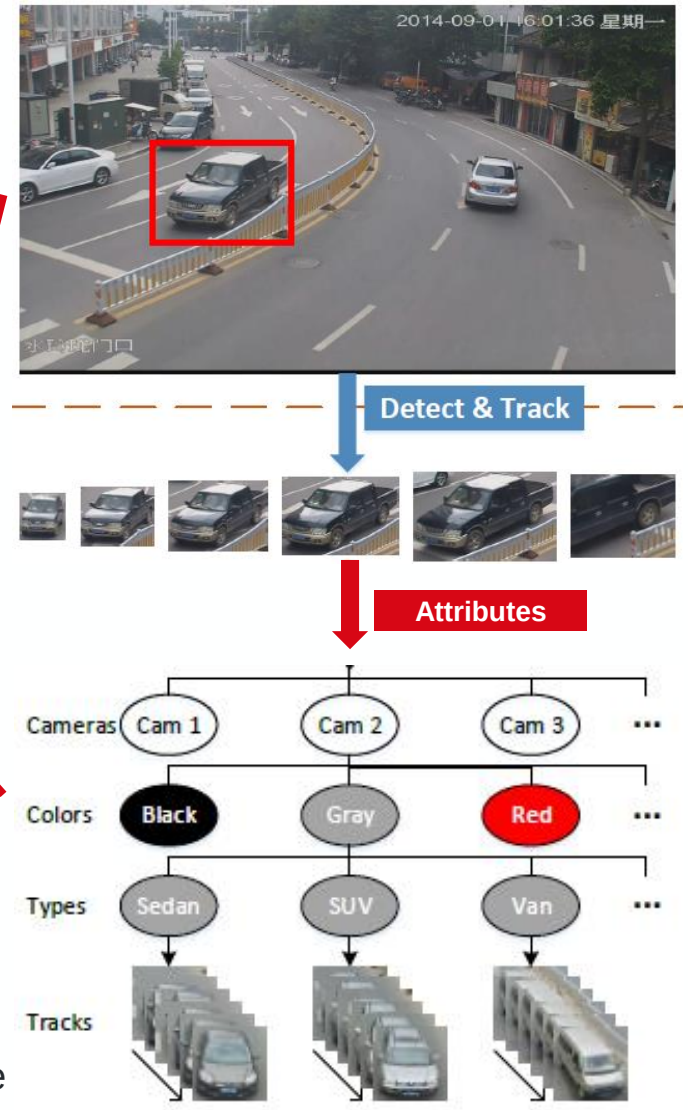
Datasets

- VeRi Dataset [Liu, ICME16&ECCV16]

Dataset construction



1. vehicle recurrences in 20 cameras
2. 50K+ Boxes, 9000+ tracks, 776 vehicles
3. 10 colors, 9 types and 30+ brands
4. Spatio-temporal + License Plate



Xinchen Liu, Wu Liu, Huadong Ma, Huiyuan Fu: Large-scale vehicle re-identification in urban surveillance videos. ICME 2016: 1-6

Xinchen Liu, Wu Liu, Tao Mei, Huadong Ma: A Deep Learning-Based Approach to Progressive Vehicle Re-identification for Urban Surveillance. ECCV (2) 2016: 869-884

Datasets

- PKU VehicleID [Yan, ICCV17]

		Training	Testing
VD1	No. of vehicle	70,591	71,165
	No. of model	1,232	1,232
	No. of color	11	11
	No. of image	422,326	424,032
VD2	No. of vehicle	39,619	40,144
	No. of model	1,112	1,112
	No. of color	11	11
	No. of image	342,608	347,910

Hongye Liu, Yonghong Tian, Yaowei Wang, Lu Pang, Tiejun Huang: Deep Relative Distance Learning: Tell the Difference between Similar Vehicles. CVPR 2016: 2167-2175

Ke Yan, Yonghong Tian, Yaowei Wang, Wei Zeng, Tiejun Huang: Exploiting Multi-grain Ranking Constraints for Precisely Searching Visually-similar Vehicles. ICCV 2017: 562-570

Datasets

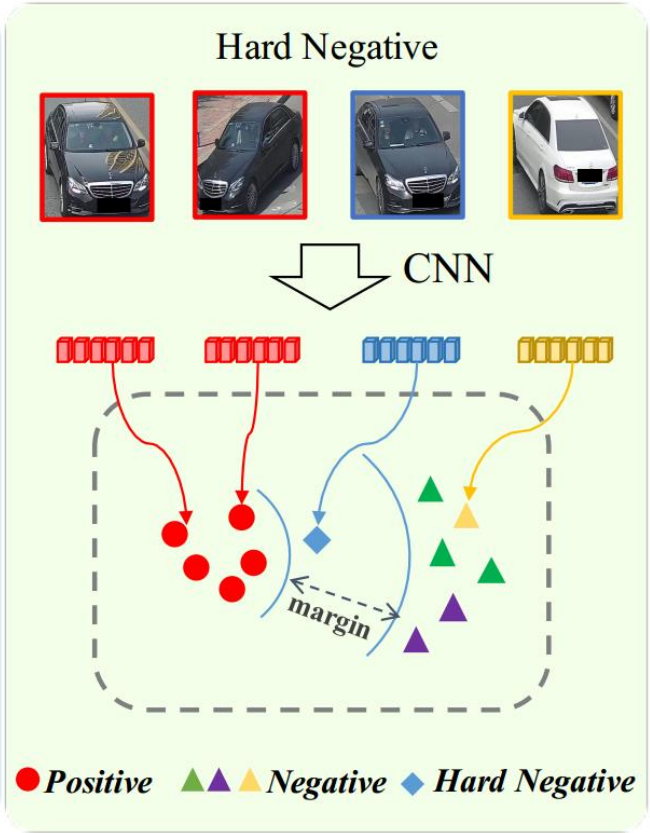
- Vehicle-1M [Guo, AAAI 2018]

- Day and night, head or rear
- Multiple surveillance cameras installed in several cities
- 936,051 images from 55,527 vehicles and 400 vehicle models
- Labeled with attributes (make, model and year)

Haiyun Guo, Chaoyang Zhao, Zhiwei Liu, Jinqiao Wang, Hanqing Lu: Learning Coarse-to-Fine Structured Feature Embedding for Vehicle Re-Identification. AAAI 2018: 6853-6860

Datasets

- VERI-Wild [Lou, CVPR19]

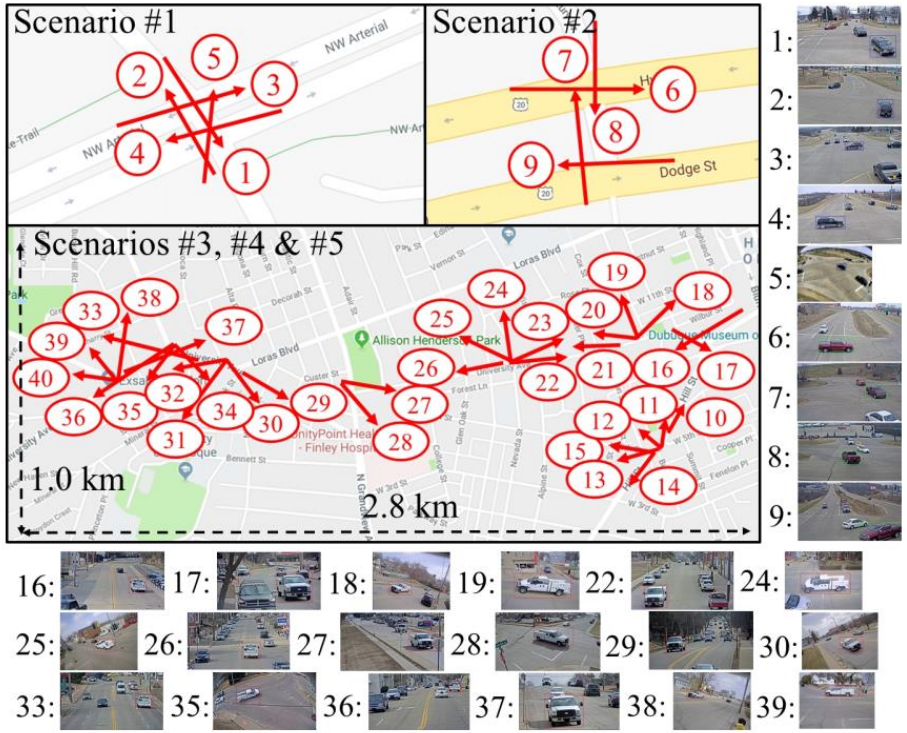


Dataset	VehicleID	VeRI-776	VERI-Wild
Images	221,763	49,360	**416,314**
Identities	26,267	776	**40,671**
Cameras	12	18	**174**
Capture Time	N/A	18h	**125,280h**
Views	2	6	**Unconstrained**
Spatio-temporal Relation Annotation	×	✓	✓
Tracks Across Cameras	×	×	✓
Camera ID	×	×	✓
Timestamp	×	×	✓
Occlusion	×	×	✓
Complex Background	×	×	✓
Morning	✓	×	✓
Afternoon	✓	✓	✓
Night	×	×	✓
Rainy Weather	×	×	✓
Foggy Weather	×	×	✓

Yihang Lou, Yan Bai, Jun Liu, Shiqi Wang, Lingyu Duan: VERI-Wild: A Large Dataset and a New Method for Vehicle Re-Identification in the Wild. CVPR 2019: 3235-3243

Datasets

- CityFlow [Tang, CVPR19]



Cameras	Boxes	Boxes/ID	Identities
40	229,680	**344.9**	666

Challenge Track 1: City-Scale Multi-Camera Vehicle Tracking

Challenge Track 2: City-Scale Multi-Camera Vehicle Re-Identification

Challenge Track 3: Traffic Anomaly Detection

Zheng Tang, Milind Naphade, Ming-Yu Liu, Xiaodong Yang, Stan Birchfield, Shuo Wang, Ratnesh Kumar, David C. Anastasiu, Jenq-Neng Hwang: CityFlow: A City-Scale Benchmark for Multi-Target Multi-Camera Vehicle Tracking and Re-Identification. CVPR 2019: 8797-8806

Datasets

Benchmark	Year	Cameras	Boxes	Boxes/ID	Identities	Video	Geom.	Multi-view	License Plate
VeRi-776	2016	20	49,357	63.6	776	X	√	√	√
PKU-VD1&2	2017	-	846,358	6.0	**141,756**	X	X	X	X
Vehicle-1M	2018	**-**	**936,051**	16.8	55,527	X	X	X	X
VeRi-Wild	2019	**174**	406,314	10	40,671	X	√	√	X
CityFlow	2019	40	229,680	**344.9**	666	√	√	√	X

Datasets

- MVP Dataset [Liu, ACM MM 20]

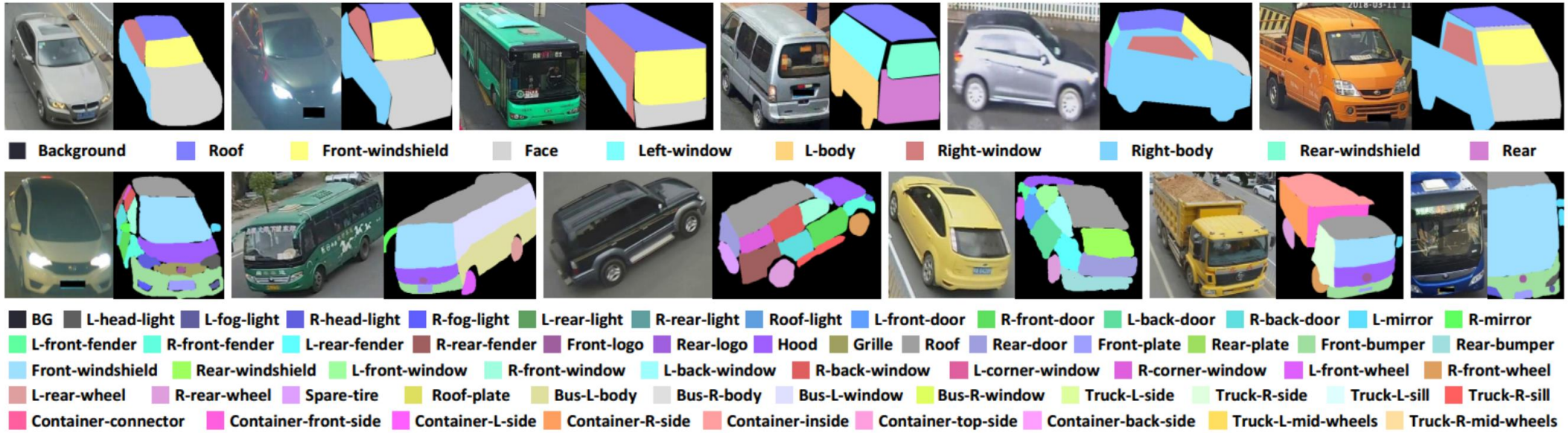


Table 1: Comparison of public datasets for vehicle parsing.

Dataset	Class #	Image #	Surveillance?
3D Class Dataset-Car [26]	6	960	✗
Pascal-Part-Car [3]	14	1,805	✗
Pascal-Part-Bus [3]	14	501	✗
MVP-coarse	10	21,000	✓
MVP-fine	59	3,000	✓

Xinchen Liu, Wu Liu, Jinkai Zheng, Chenggang Yan, Tao Mei : Beyond the Parts: Learning Multi-view Cross-part Correlation for Vehicle. Re-identification.. ACM MM 2020

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2 Methods

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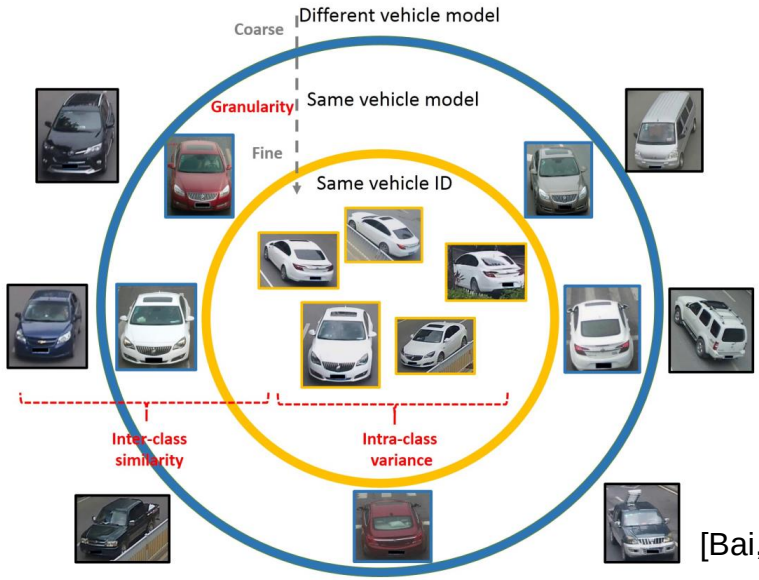
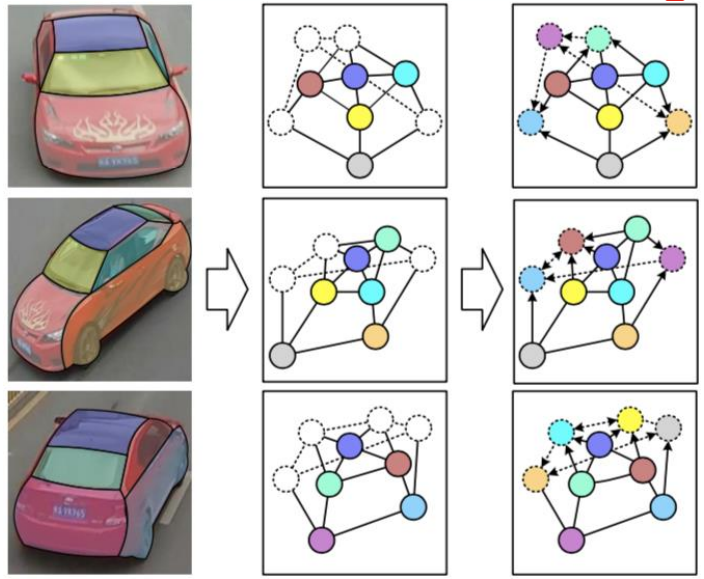
Methods

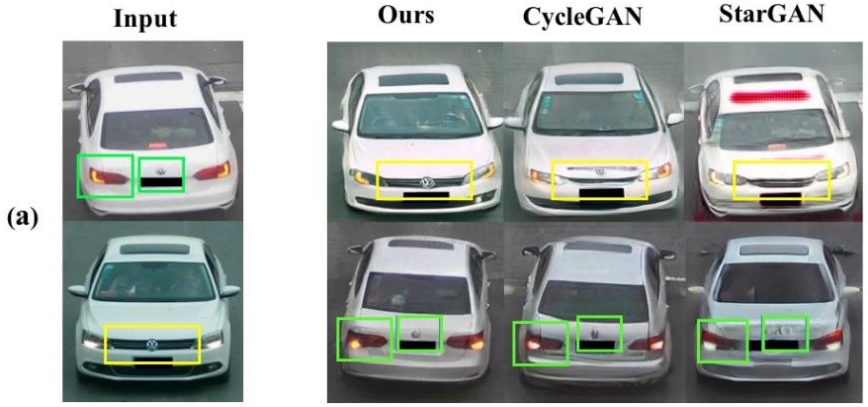


[Bai, TMM2018]

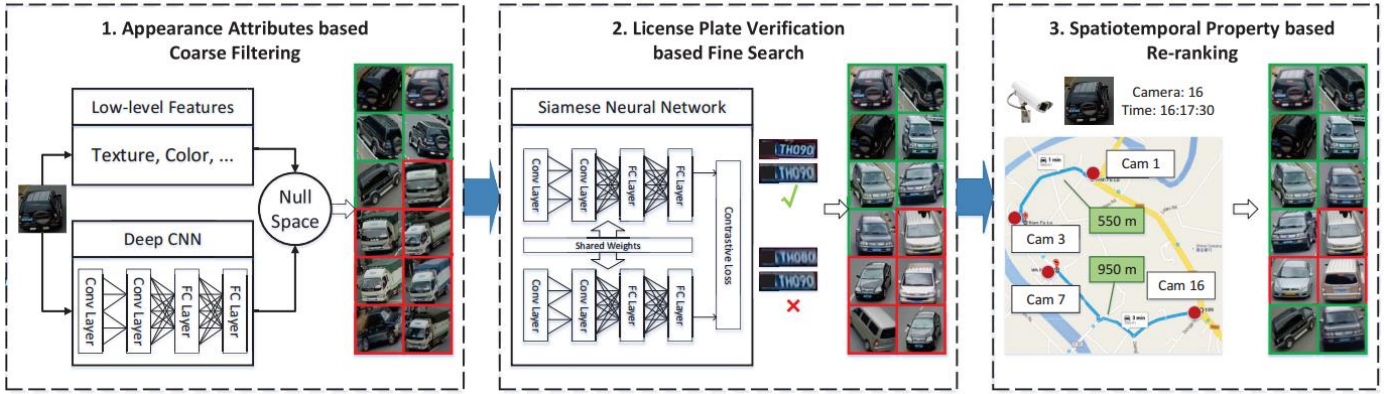
1. Attribute Recognition + Metric Learning



2. Detail-aware Attentive Multi-view Inference



3. GAN-based



4. Multi-modality data-based methods

Methods

1. Attribute Recognition + Metric Learning

- Xinchen Liu, Wu Liu, Huadong Ma, Huiyuan Fu, "Large-Scale Vehicle Re-Identification in Urban Surveillance Videos", IEEE ICME, 2016, pp.1-6
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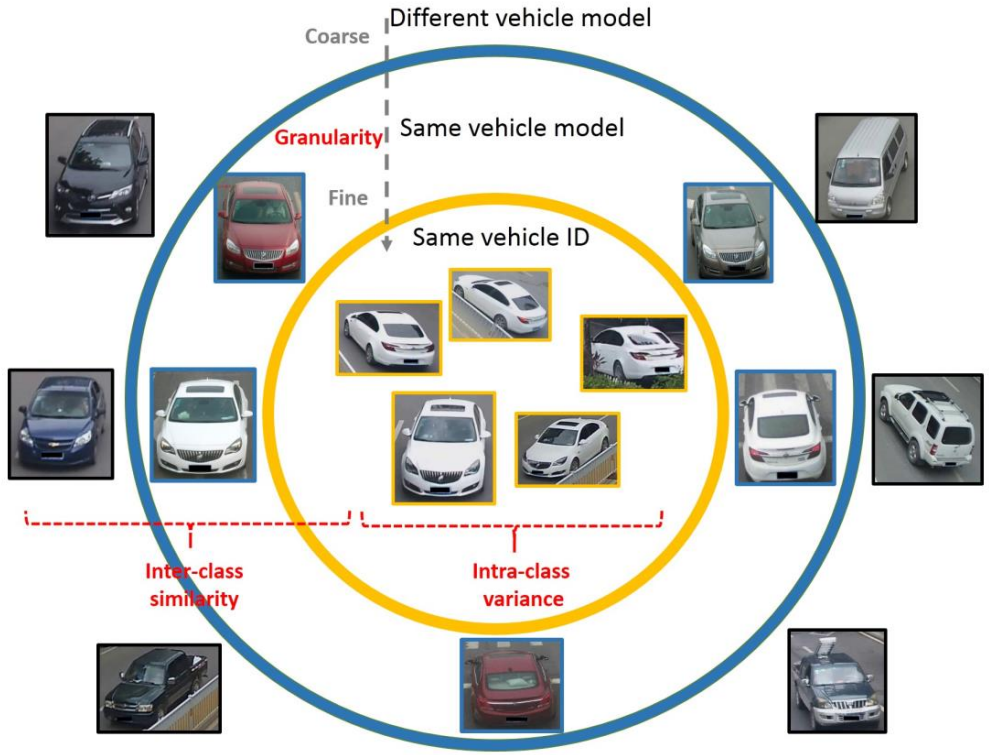
- Yan Bai, Yihang Lou, Feng Gao, Shiqi Wang, Yuwei Wu, Ling-Yu Duan: Group-Sensitive Triplet Embedding for Vehicle Reidentification. IEEE Trans. Multimedia 20(9): 2385-2399 (2018)
- Jianqing Zhu, Huanqiang Zeng, Jingchang Huang, Shengcai Liao, Zhen Lei, Canhui Cai, Lixin Zheng: Vehicle Re-identification Using Quadruple Directional Deep Learning Features. IEEE TITS (2020)



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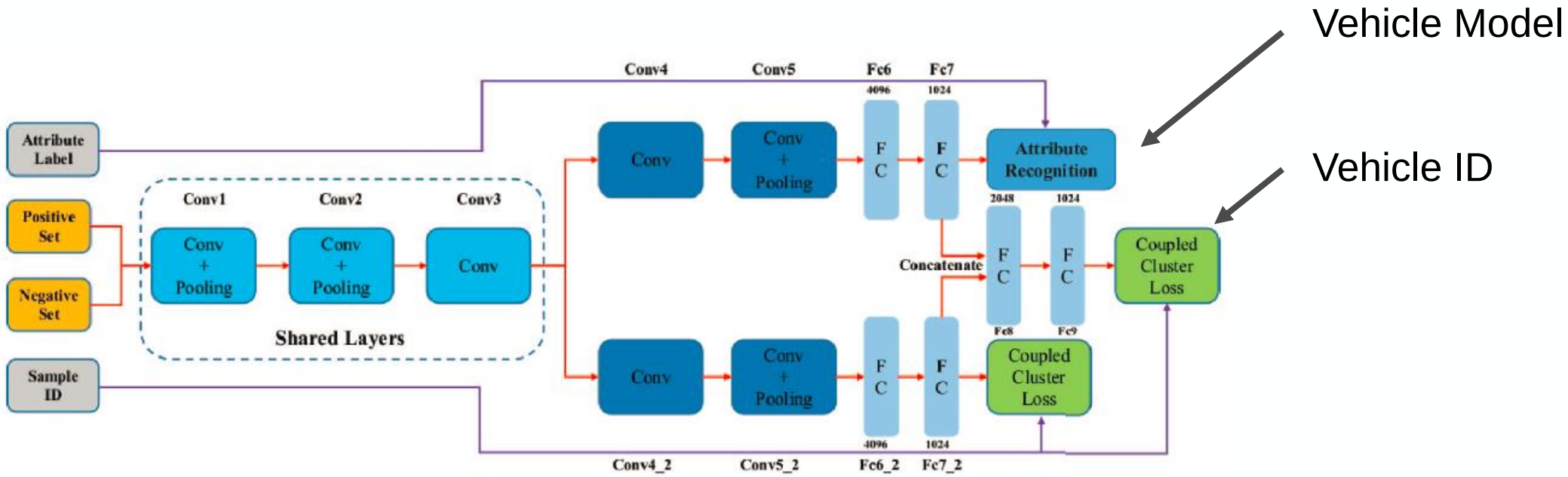

Multi-task learning: Attribute Recognition + Metric Learning

Dataset: VehicleID

Attribute Recognition + Metric Learning

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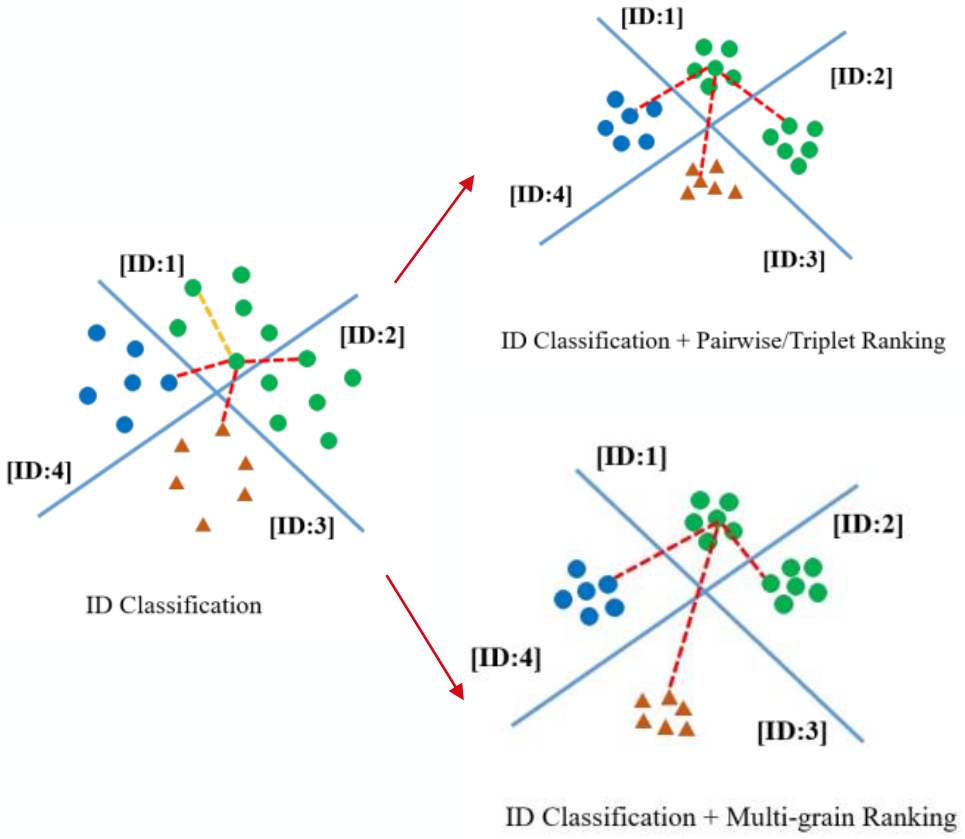
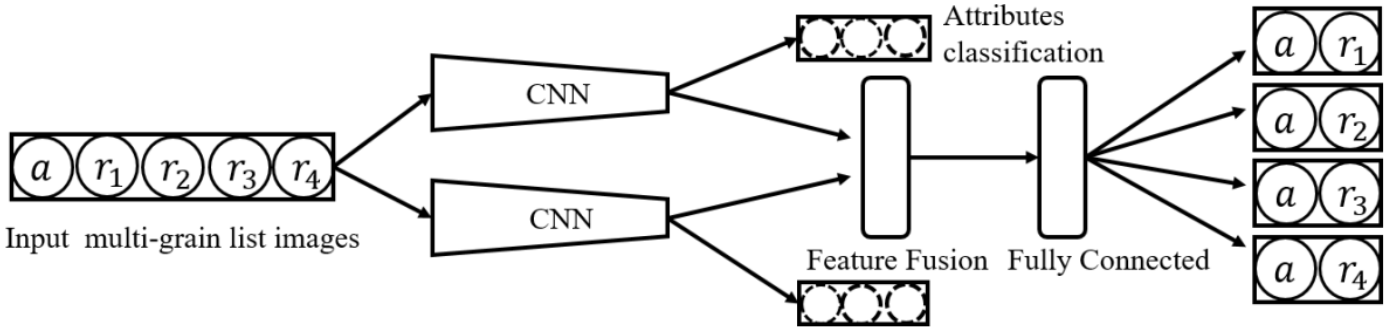
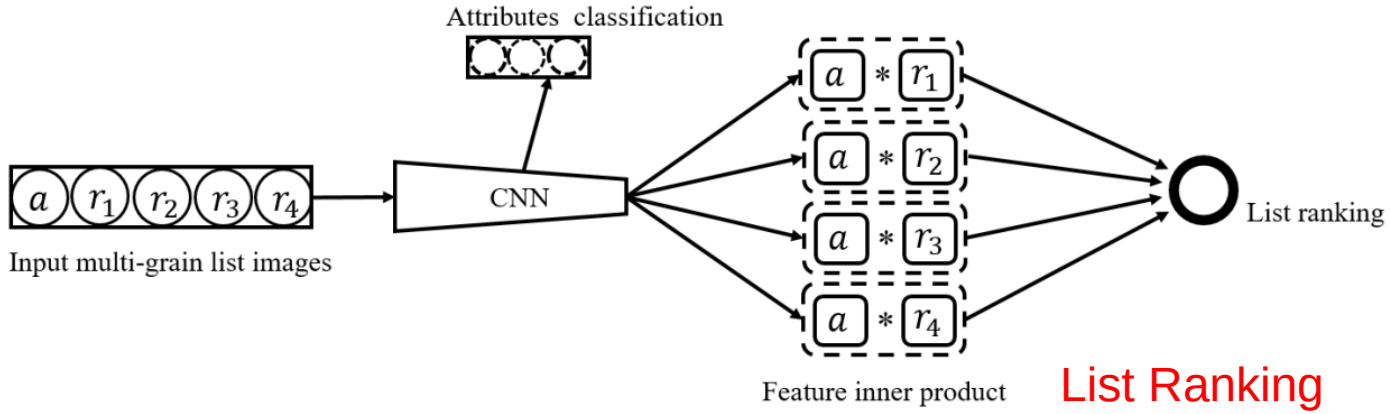


Vehicle ID, model and color

Pairwise Ranking





List Ranking

Dataset: PKU-VD1&2

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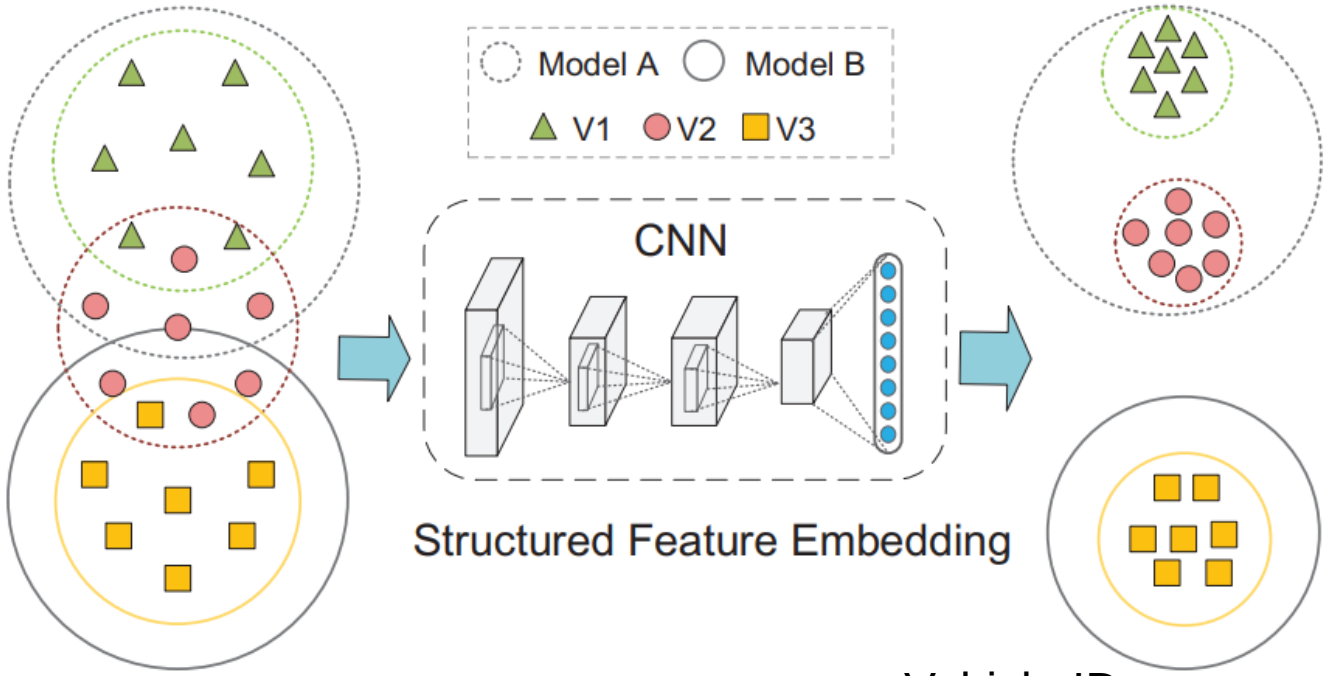


Dataset: Vehicle-1M

Vehicle Model
Classification loss term

$$C = \frac{1}{N}\sum_{i=1}^{N} -log p_{m_i},$$

Vehicle Model
Coarse-grained ranking loss term

$$R_c = \frac{1}{\mathcal{Z}_c}\sum_{i=1}^{N}\sum_{(i,j)\in\mathcal{N}_v}\sum_{(i,k)\in\mathcal{N}_m}[D(i,j) - D(i,k) + \mathcal{M}_c]_+,$$

models

Vehicle ID
Fine-grained ranking loss term

$$R_f = \frac{1}{\mathcal{Z}_f}\sum_{i=1}^{N}\sum_{(i,l)\in\mathcal{P}}\sum_{(i,j)\in\mathcal{N}_v}[D(i,l) - D(i,j) + \mathcal{M}_f]_+,$$

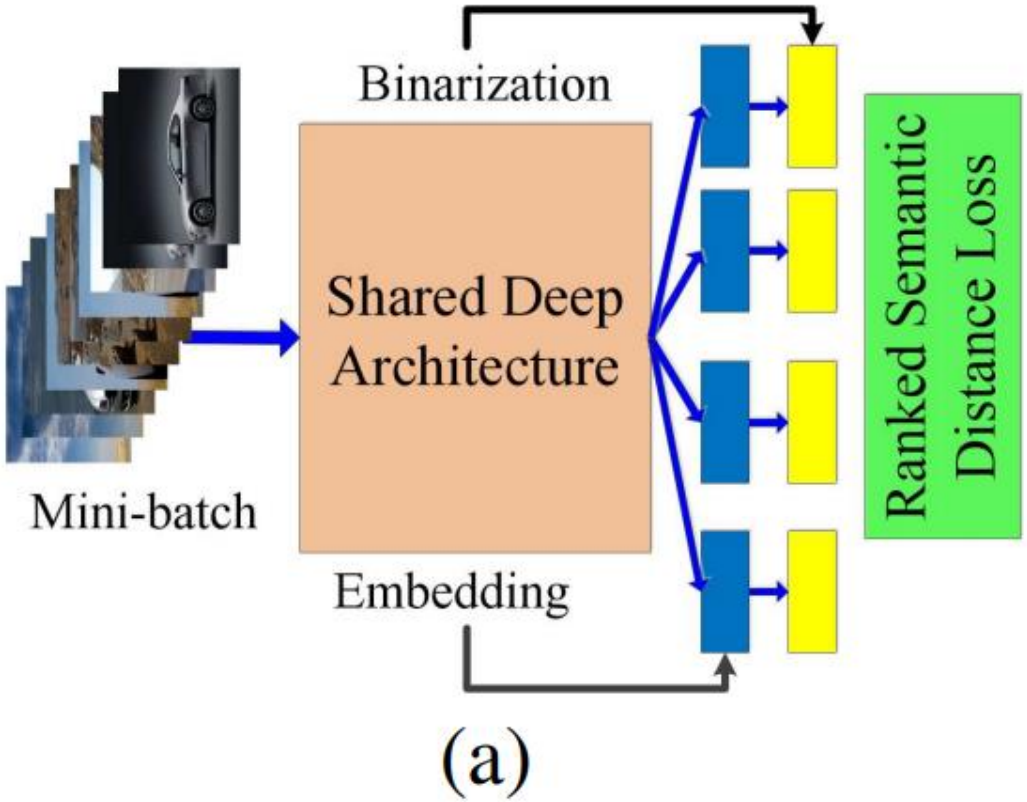
Vehicle ID
Pairwise loss term

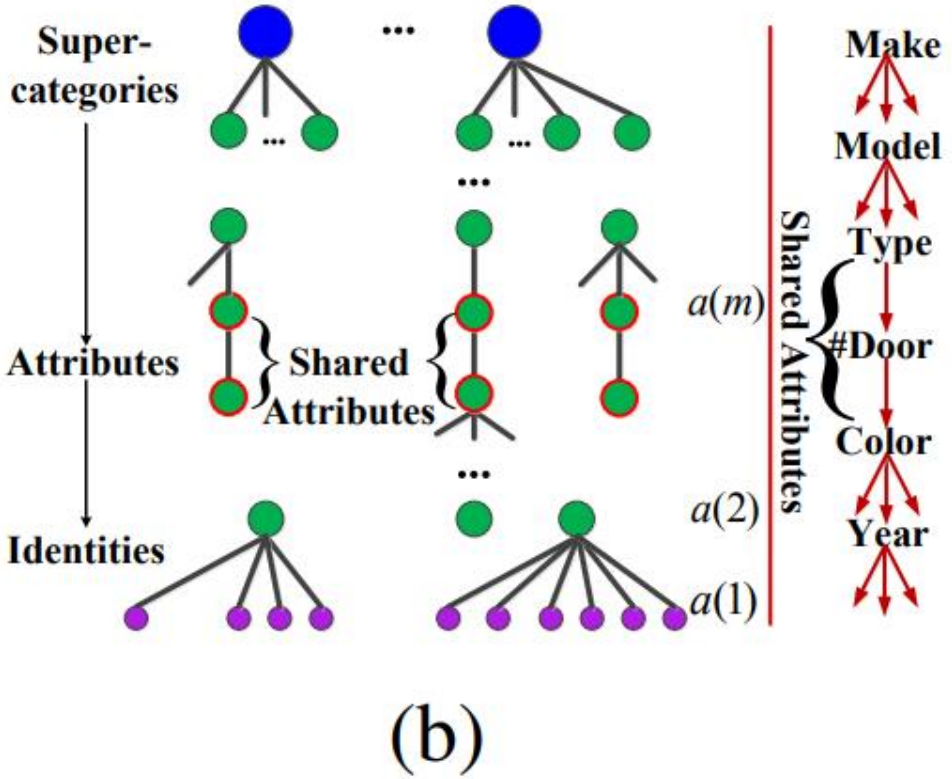
$$P = \frac{1}{\mathcal{Z}_p}\sum_{i=1}^{N}\sum_{(i,l)\in\mathcal{P}} D(i,l),$$

ID

Attribute Recognition + Metric Learning

- Feng Zheng, Xin Miao, Heng Huang: Fast Vehicle Identification in Surveillance via Ranked Semantic Sampling Based Embedding. IJCAI 2018: 3697-3703





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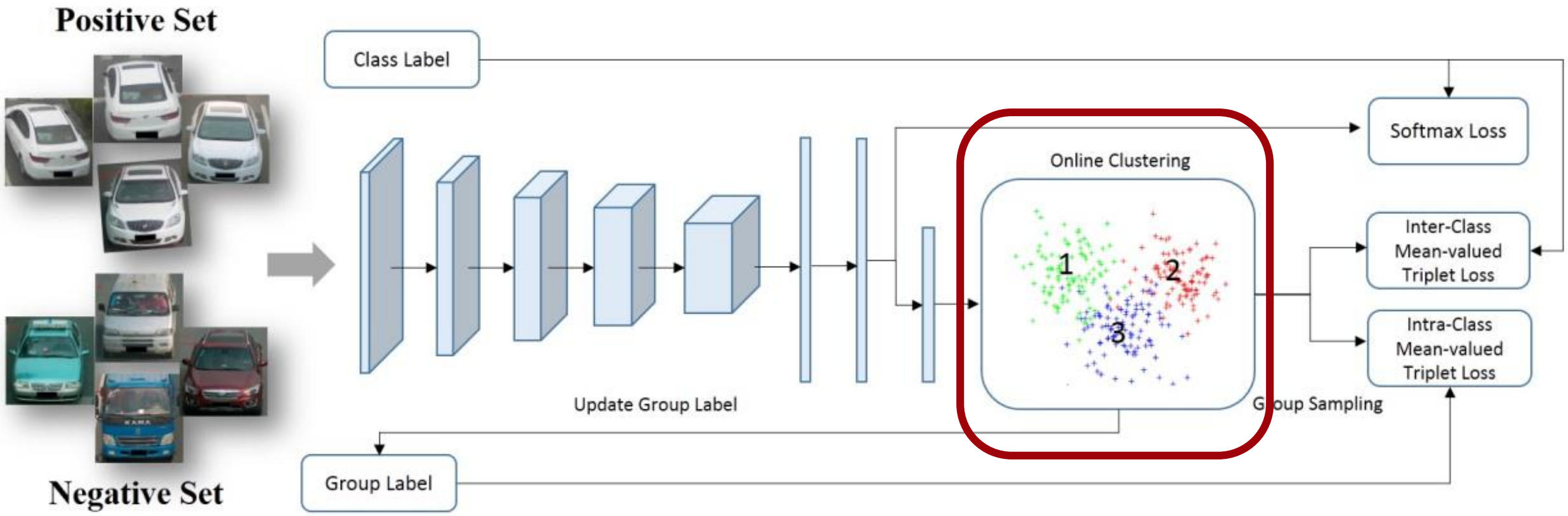
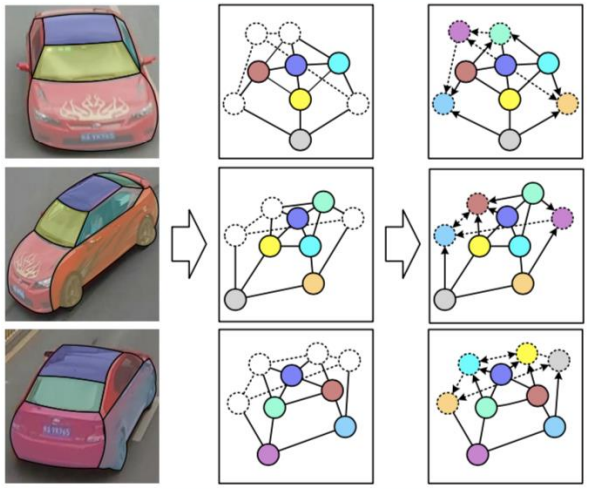


Methods

2. Detail-aware Attentive Multi-view Inference

- Zhongdao Wang, Luming Tang, Xihui Liu, Zhuliang Yao, Shuai Yi, Jing Shao, Junjie Yan, Shengjin Wang, Hongsheng Li, Xiaogang Wang: Orientation Invariant Feature Embedding and Spatial Temporal Regularization for Vehicle Re-identification. ICCV 2017: 379-387
- Zhou, Yi, Li Liu, and Ling Shao. "Vehicle re-identification by deep hidden multi-view inference." IEEE TIP 27.7 (2018): 3275-3287.
- Bing He, Jia Li, Yifan Zhao, Yonghong Tian: Part-Regularized Near-Duplicate Vehicle Re-Identification. CVPR 2019: 3997-4005
- Pirazh Khorramshahi, Amit Kumar, Neehar Peri, Sai Saketh Rambhatla, Jun-Cheng Chen, Rama Chellappa: A Dual-Path Model With Adaptive Attention for Vehicle Re-Identification. ICCV 2019: 6131-6140
- Zheng Tang, Milind Naphade, Stan Birchfield, Jonathan Tremblay, William Hodge, Ratnesh Kumar, Shuo Wang, Xiaodong Yang: PAMTRI: Pose-Aware Multi-Task Learning for Vehicle Re-Identification Using Highly Randomized Synthetic Data. ICCV 2019: 211-220
- Ruihang Chu, Yifan Sun, Yadong Li, Zheng Liu, Chi Zhang, Yichen Wei: Vehicle Re-Identification With Viewpoint-Aware Metric Learning. ICCV 2019: 8281-8290
- Xiaobin Liu, Shiliang Zhang, Xiaoyu Wang, Richang Hong, Qi Tian: Group-Group Loss-Based Global-Regional Feature Learning for Vehicle Re-Identification. IEEE Trans. Image Process. 29: 2638-2652 (2020)
- Dechao Meng, Liang Li, Xuejing Liu, Yadong Li, Shijie Yang, Zheng-Jun Zha, Xingyu Gao, Shuhui Wang, Qingming Huang: Parsing-Based View-Aware Embedding Network for Vehicle Re-Identification. CVPR 2020: 7101-7110
- Tsai-Shien Chen, Chih-Ting Liu, Chih-Wei Wu, Shao-Yi Chien: Orientation-aware Vehicle Re-identification with Semantics-guided Part Attention Network. ECCV 2020
- Pirazh Khorramshahi, Neehar Peri, Jun-Cheng Chen, Rama Chellappa: The Devil is in the Details: Self-Supervised Attention for Vehicle Re-Identification. ECCV 2020
- Xinchen Liu, Wu Liu, Jinkai Zheng, Chenggang Yan, Tao Mei: Beyond the Parts: Learning Multi-view Cross-part Correlation for Vehicle Re-identification, ACM MM 2020

[CVPR 2019]



[ACMMM 2020]

Multi-view Inference

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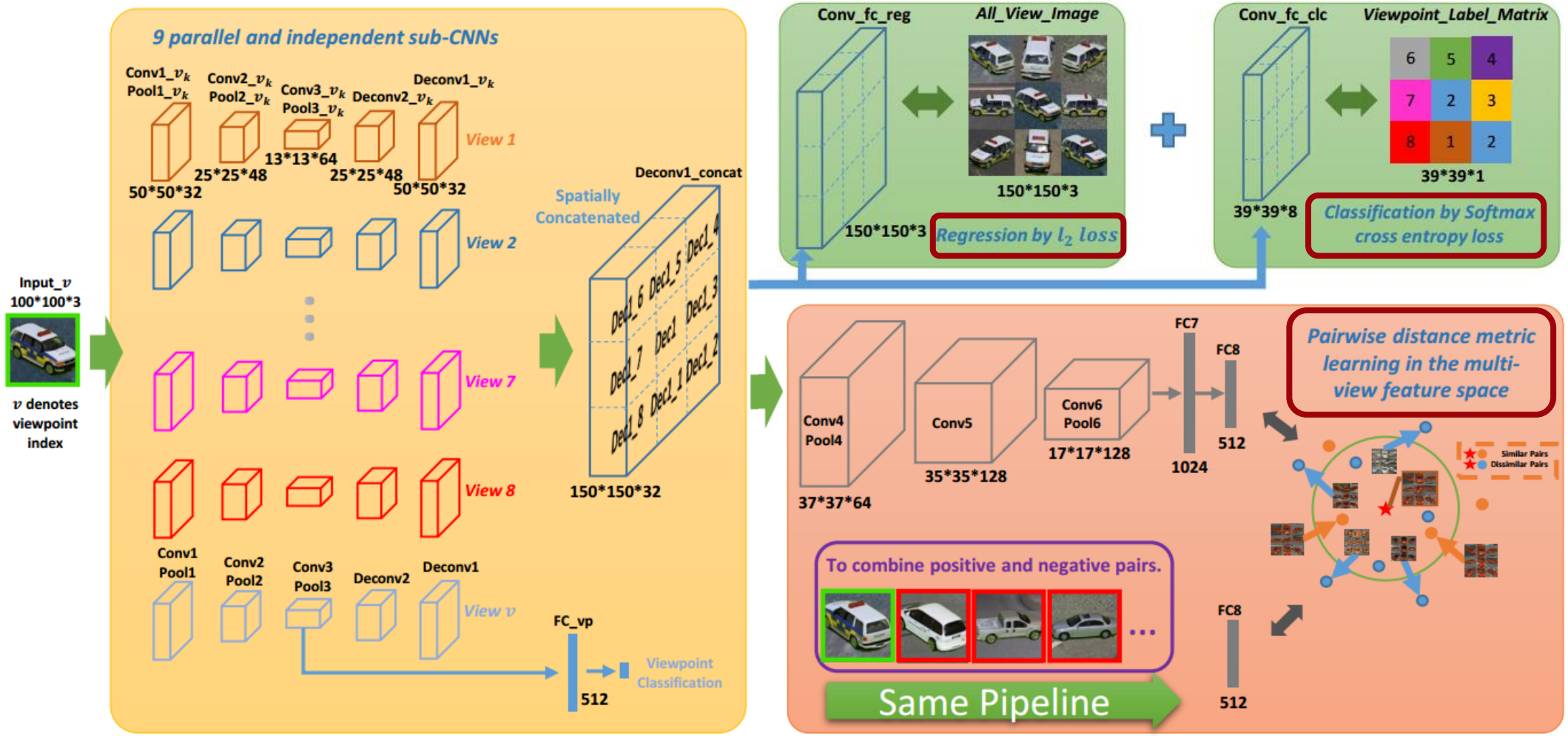

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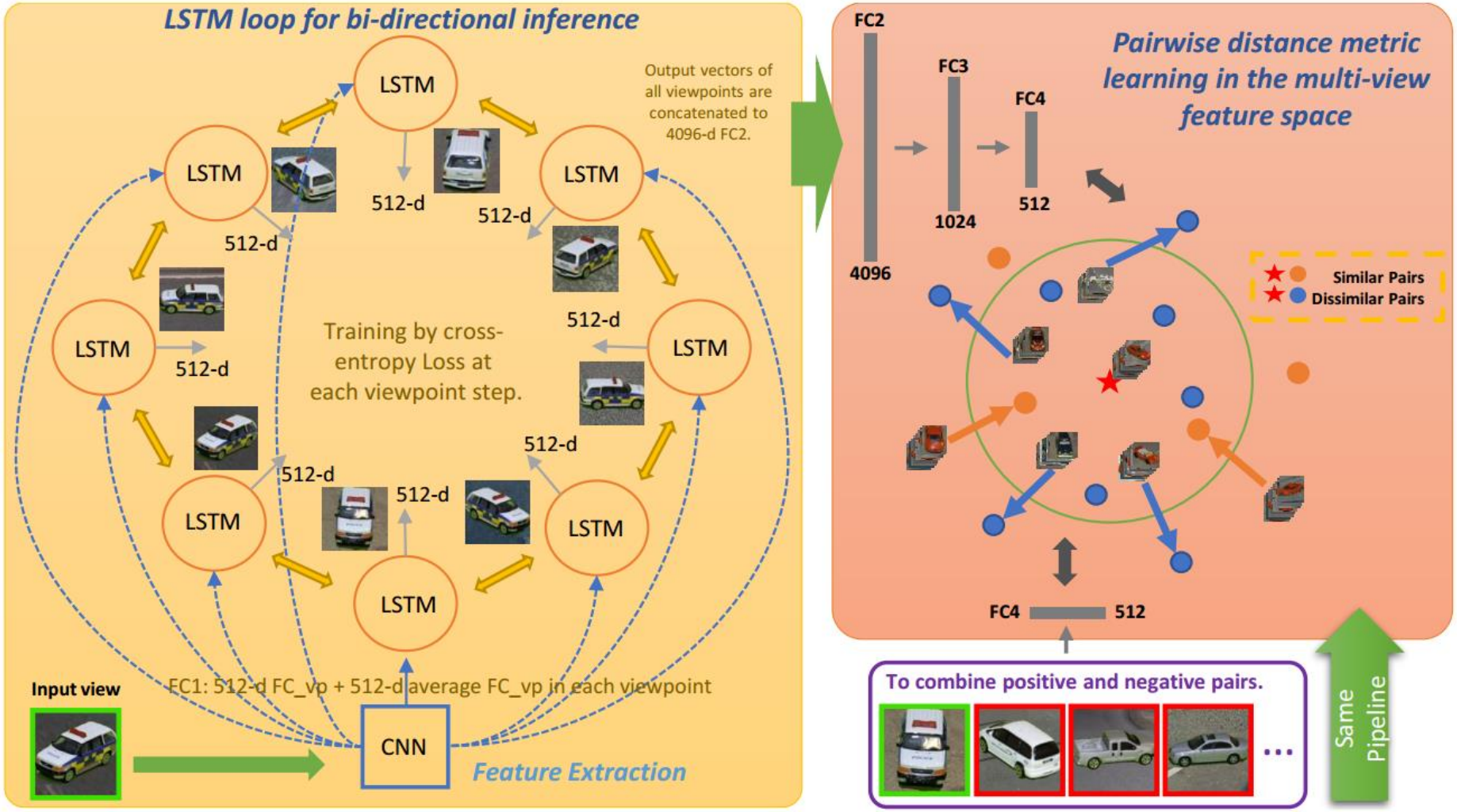

Global and Local Paths

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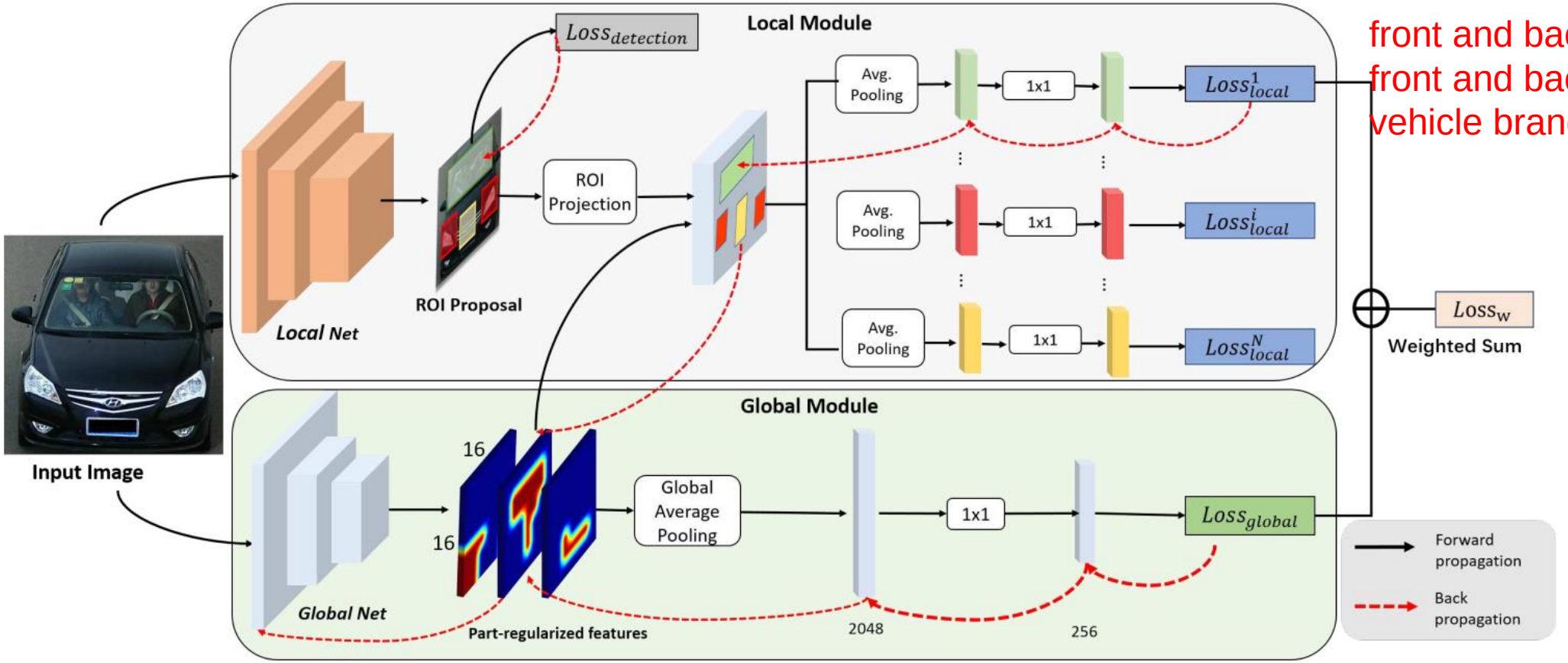

front and back light;
front and back window;
vehicle brand.

This framework consist of two modules, a local module which focuses on the part features to distinguish the subtle discrepancy in visual features and a global module, which is regularized by the part attentions in the local module.

Global and Local Paths

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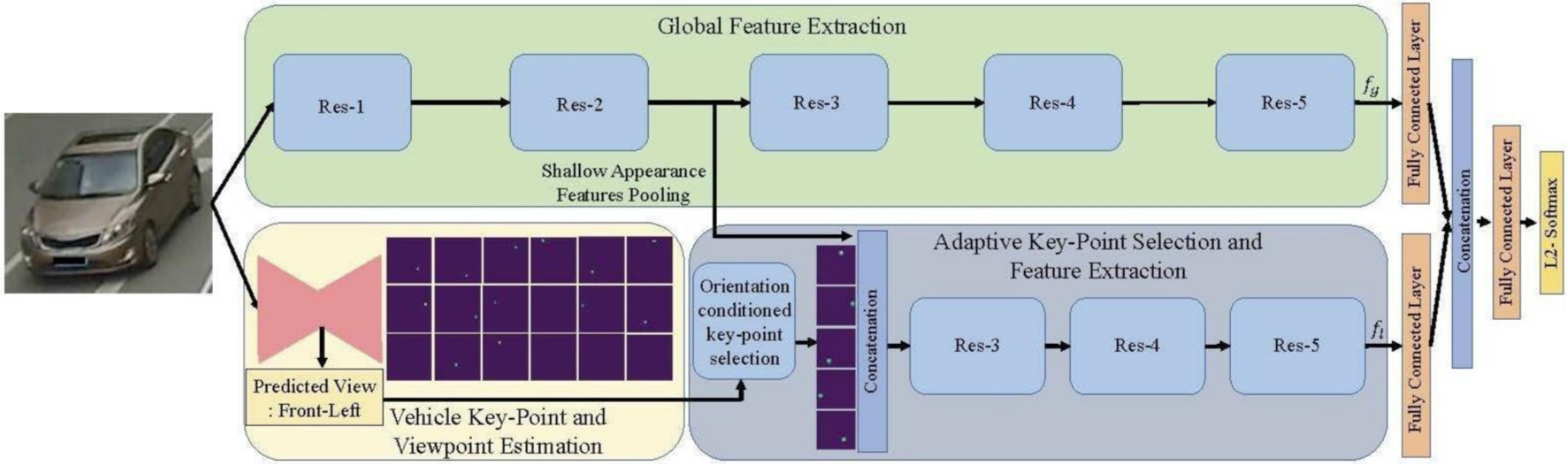

Orientation conditioned key-point selection and localized feature extraction modules is used in parallel to supplement the features from the global path.

Global and Local Paths

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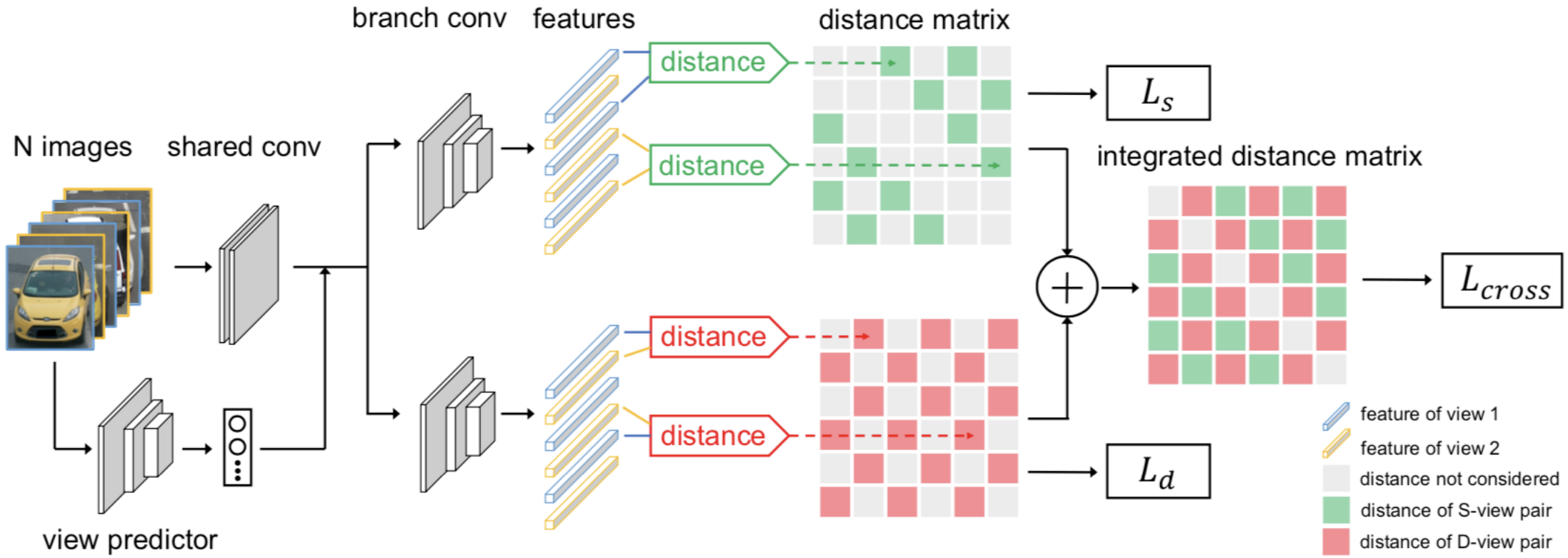
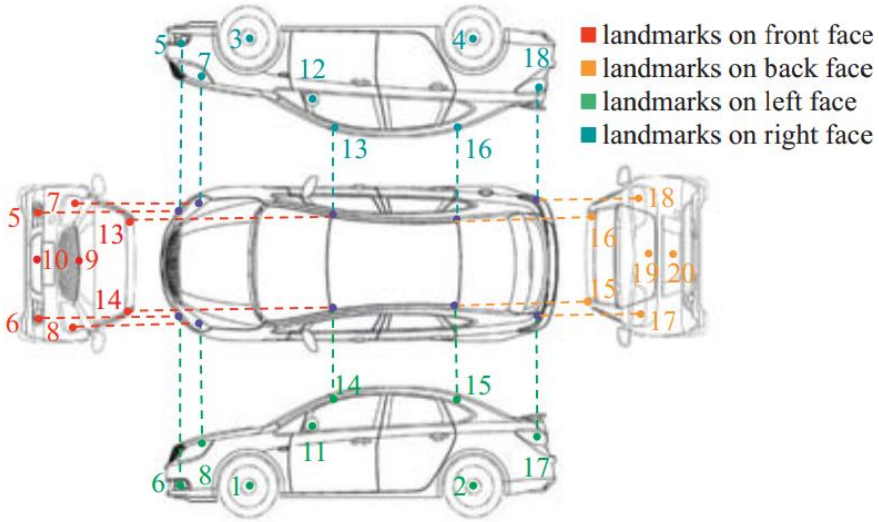
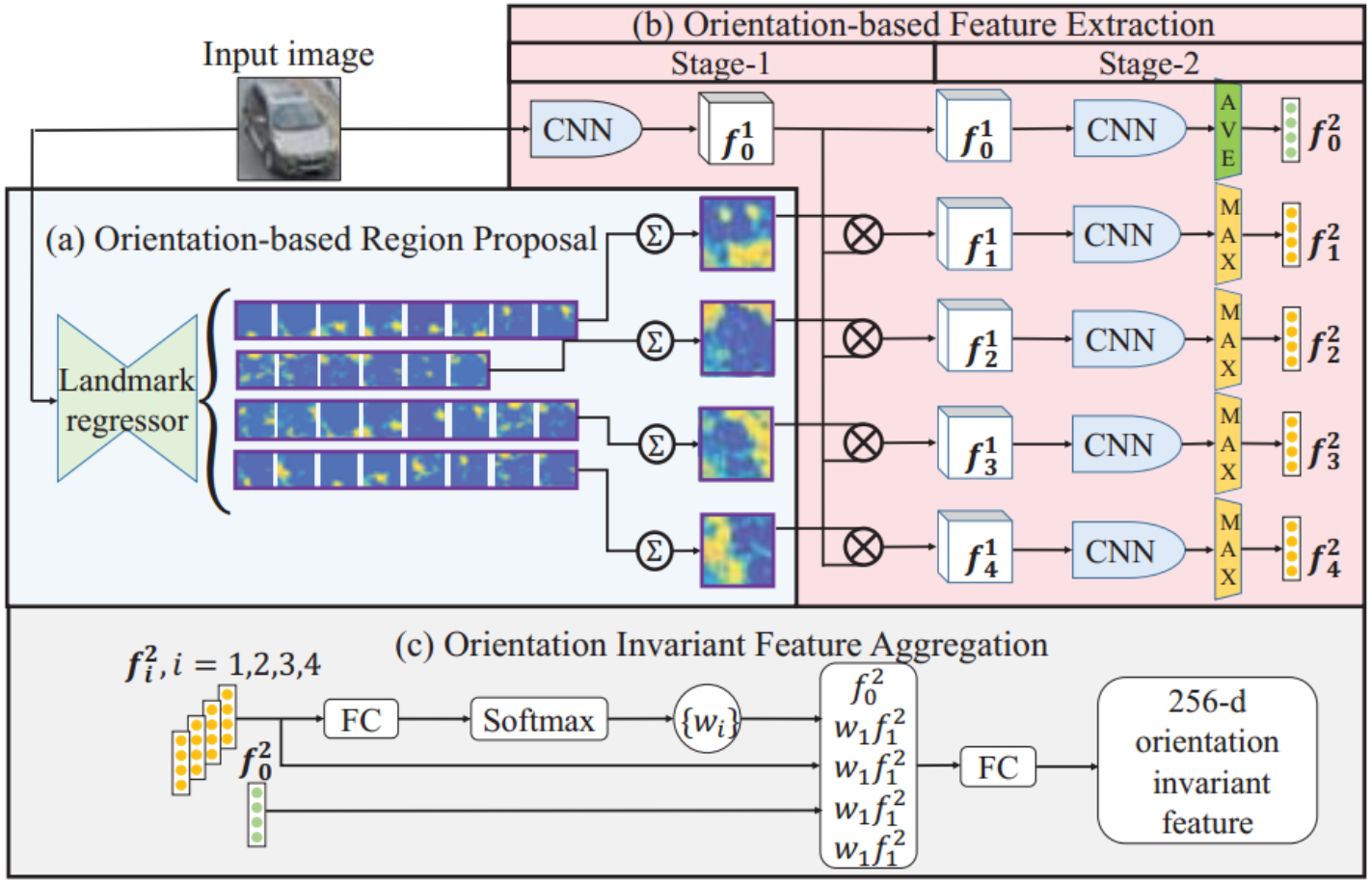


Keypoints-based

- Zhongdao Wang, Luming Tang, Xihui Liu, Zhuliang Yao, Shuai Yi, Jing Shao, Junjie Yan, Shengjin Wang, Hongsheng Li, Xiaogang Wang: Orientation Invariant Feature Embedding and Spatial Temporal Regularization for Vehicle Re-identification. ICCV 2017: 379-387



20 selected vehicle key points,
clustered into four set,
Each set shares the same visibility



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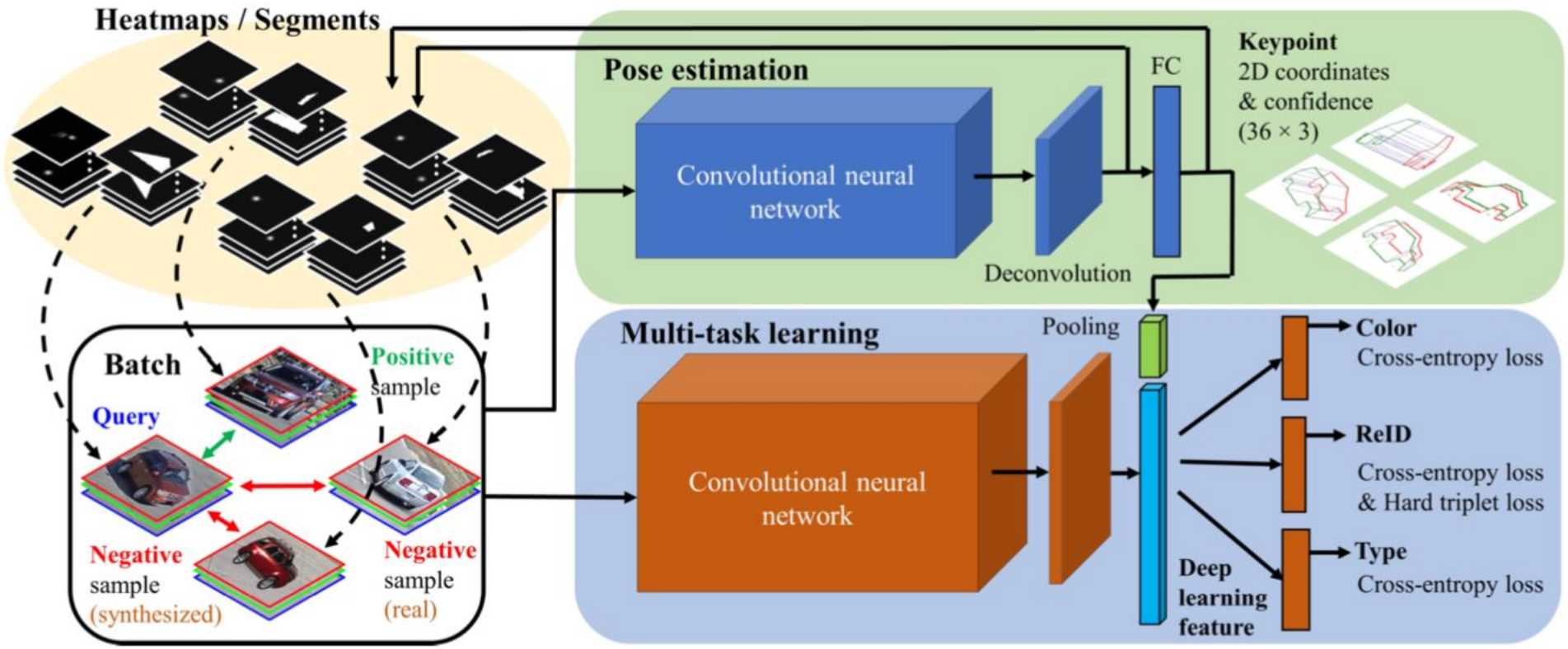
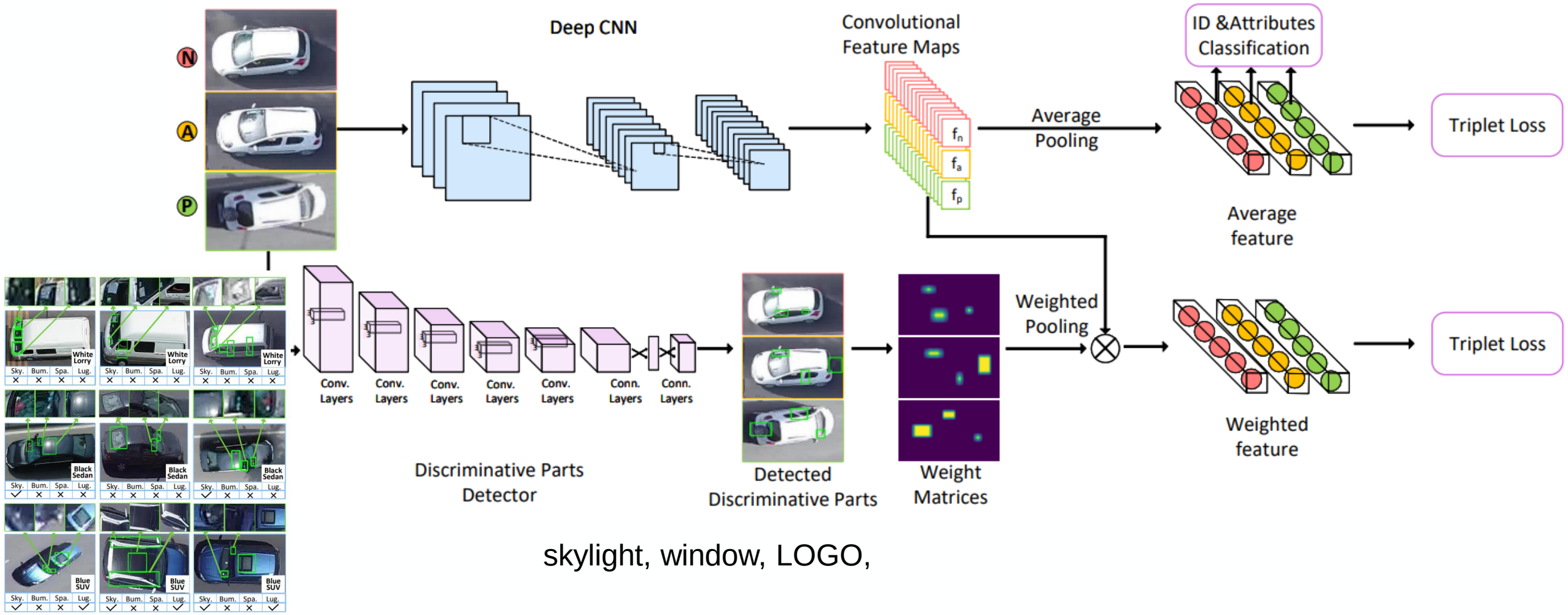


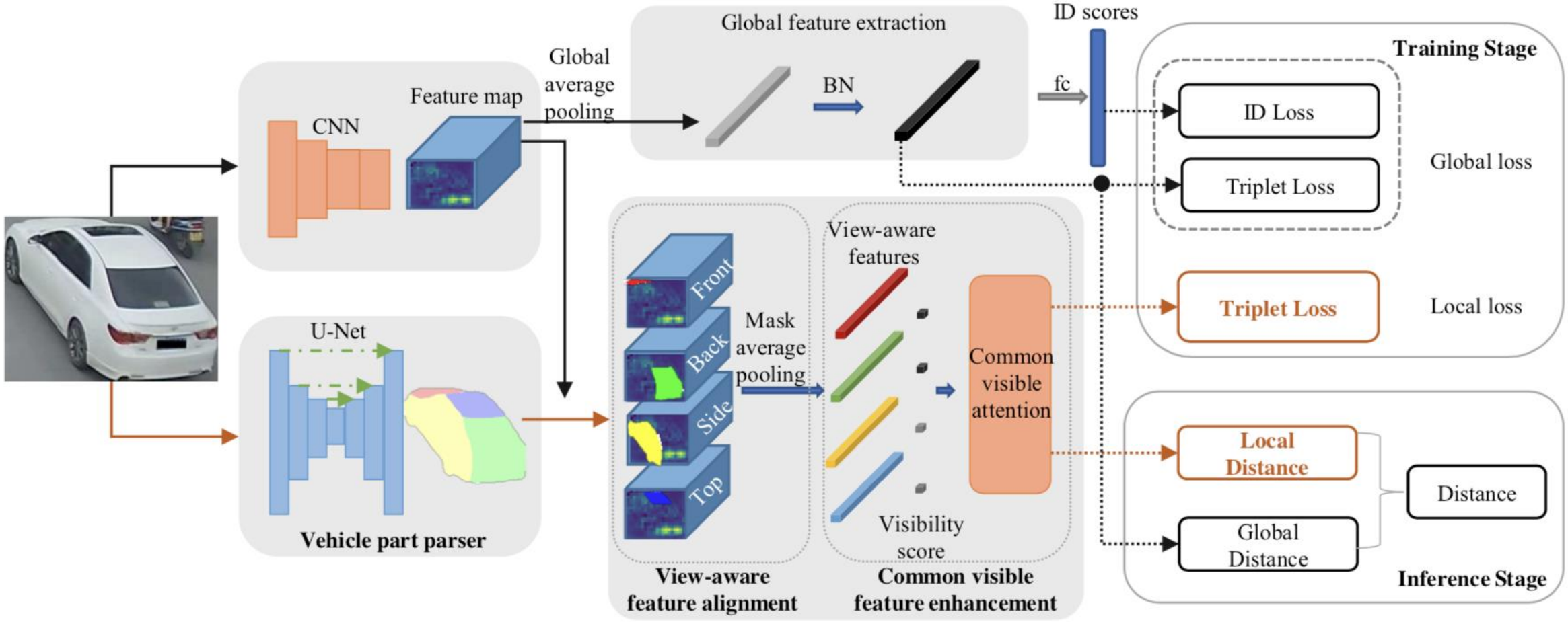
Keypoints-based

- Peng Wang, Bingliang Jiao, Lu Yang, Yifei Yang, Shizhou Zhang, Wei Wei, Yanning Zhang: Vehicle Re-Identification in Aerial Imagery: Dataset and Approach. ICCV 2019: 460-469



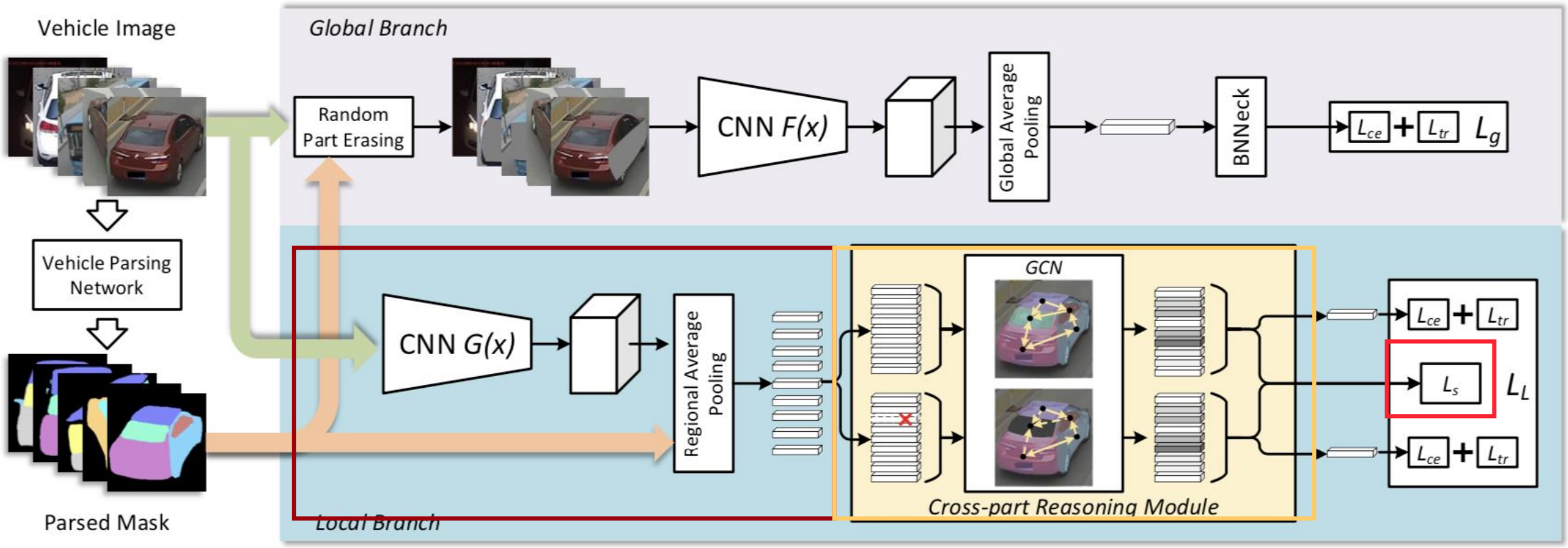
Parsing-based

- Dechao Meng, Liang Li, Xuejing Liu, Yadong Li, Shijie Yang, Zheng-Jun Zha, Xingyu Gao, Shuhui Wang, Qingming Huang: Parsing-Based View-Aware Embedding Network for Vehicle Re-Identification. CVPR 2020: 7101-7110



Parsing-based

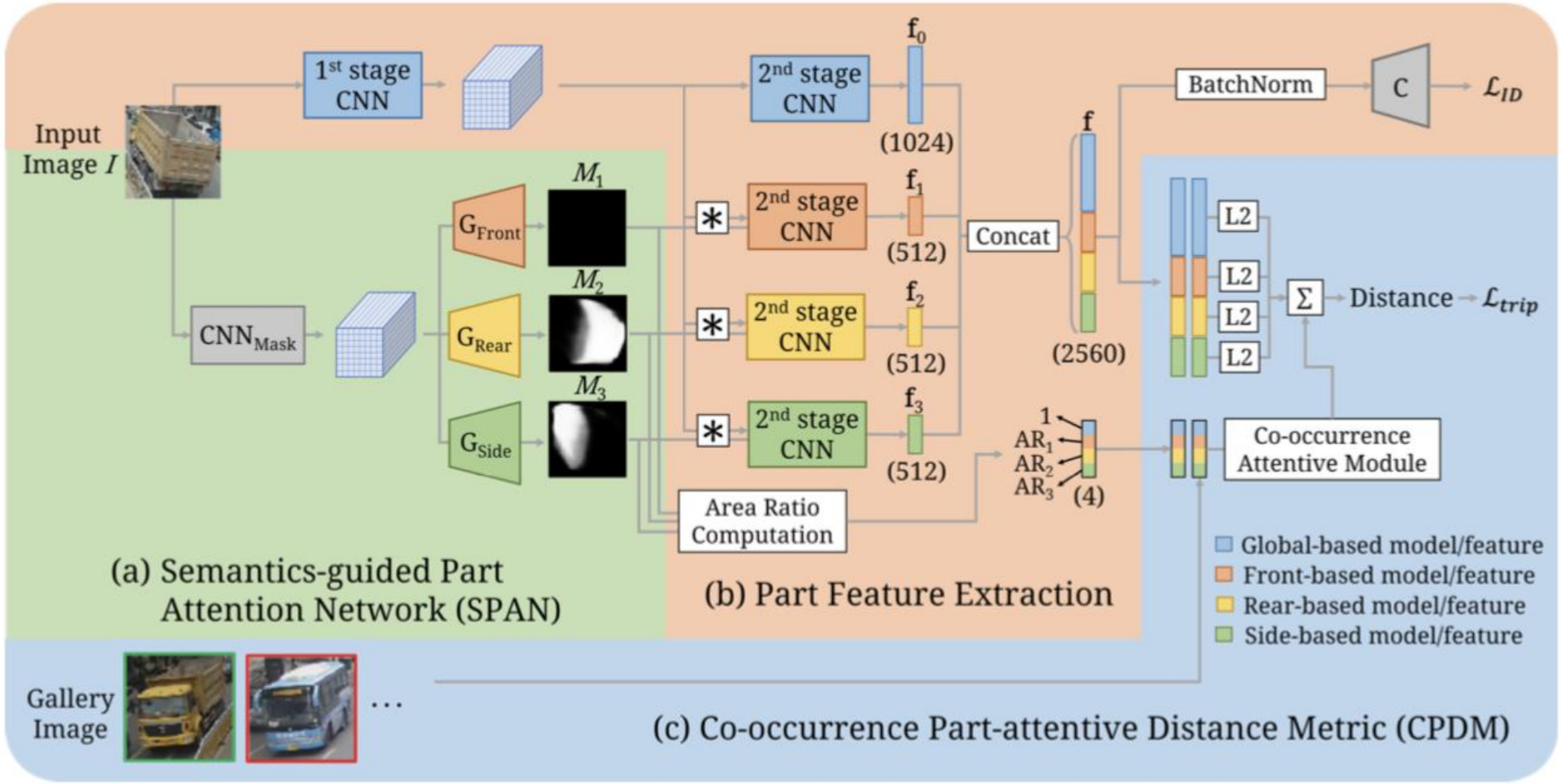
- Xinchen Liu, Wu Liu, Jinkai Zheng, Chenggang Yan, Tao Mei: Beyond the Parts: Learning Multi-view Cross-part Correlation for Vehicle Re-identification, ACM MM 2020



Parsing-guided Cross-part Reasoning network (PCRNet)

Segmentation-based

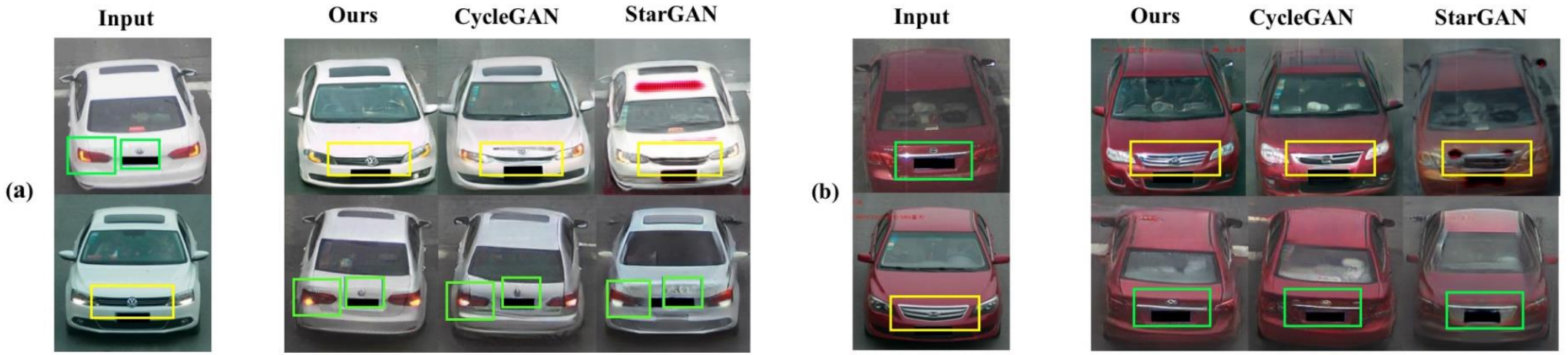
- Tsai-Shien Chen, Chih-Ting Liu, Chih-Wei Wu, Shao-Yi Chien: Orientation-aware Vehicle Re-identification with Semantics-guided Part Attention Network. ECCV 2020



Methods

3. GAN

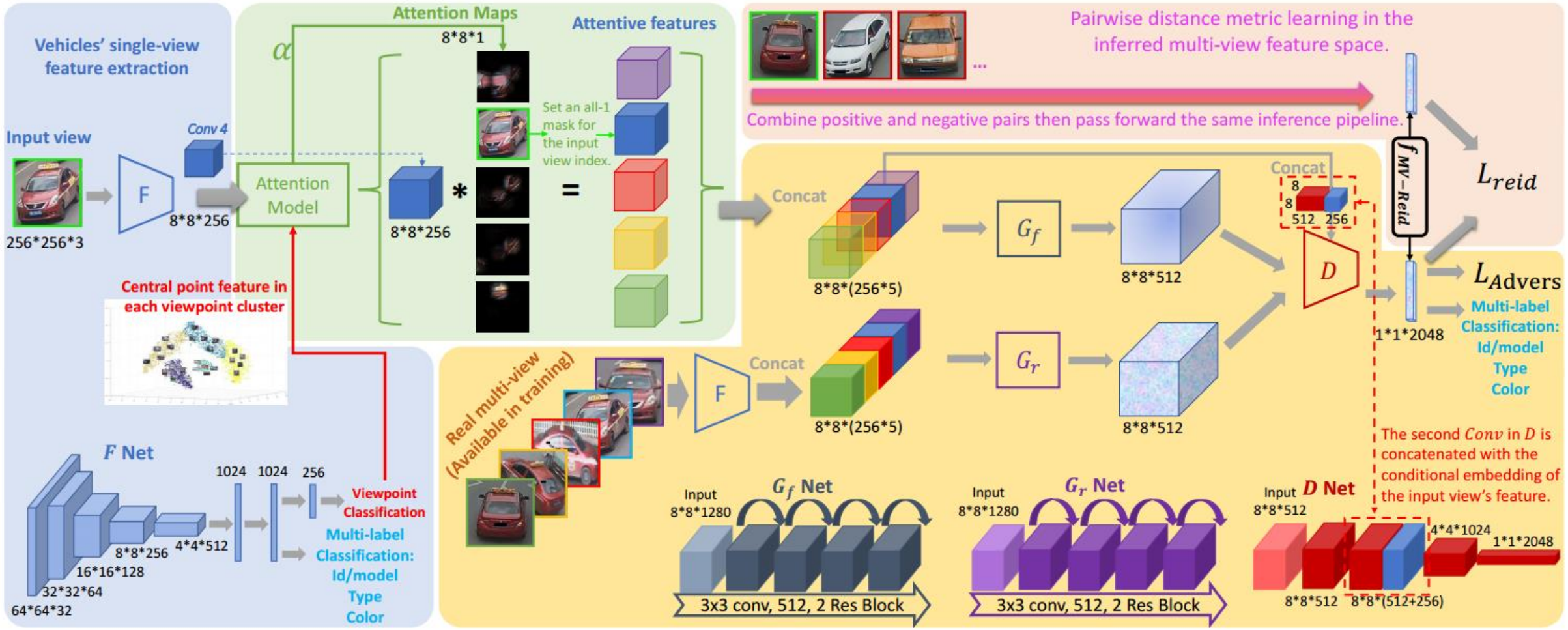
- Yi Zhou, Ling Shao: Viewpoint-Aware Attentive Multi-View Inference for Vehicle Re-Identification. CVPR 2018: 6489-6498
- Yihang Lou, Yan Bai, Jun Liu, Shiqi Wang, Lingyu Duan: VERI-Wild: A Large Dataset and a New Method for Vehicle Re-Identification in the Wild. CVPR 2019: 3235-3243
- Yihang Lou, Yan Bai, Jun Liu, Shiqi Wang, Ling-Yu Duan: Embedding Adversarial Learning for Vehicle Re-Identification. IEEE Trans. Image Process. 28(8): 3794-3807 (2019)
- Pirazh Khorramshahi, Neehar Peri, Jun-Cheng Chen, Rama Chellappa: The Devil is in the Details: Self-Supervised Attention for Vehicle Re-Identification. ECCV 2020



IEEE TIP (2019)

GAN

- Yi Zhou, Ling Shao: Viewpoint-Aware Attentive Multi-View Inference for Vehicle Re-Identification. CVPR 2018: 6489-6498



GAN

- Yihang Lou, Yan Bai, Jun Liu, Shiqi Wang, Lingyu Duan: VERI-Wild: A Large Dataset and a New Method for Vehicle Re-Identification in the Wild. CVPR 2019: 3235-3243
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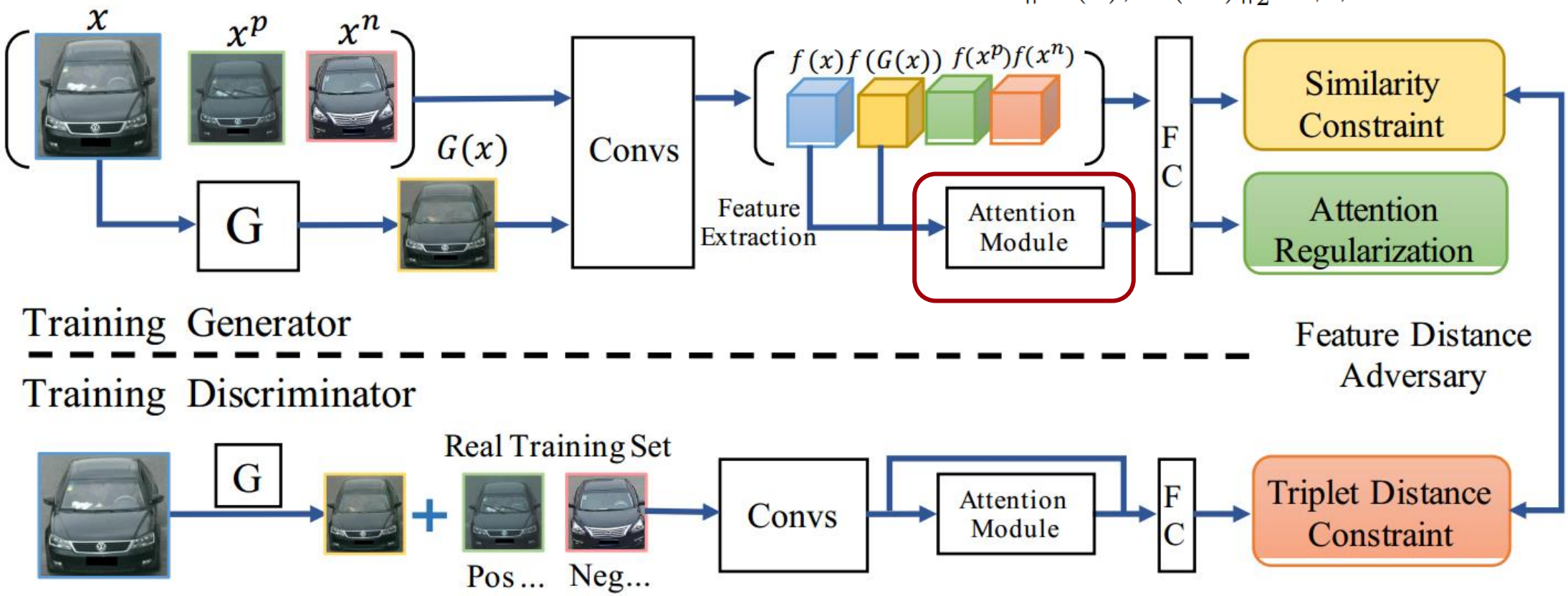
$$\|H(x), H(x^p)\|_2^2 + \beta \leq \|H(x), H(G(x))\|_2^2 \leq \|H(x), H(x^n)\|_2^2 - \beta,$$



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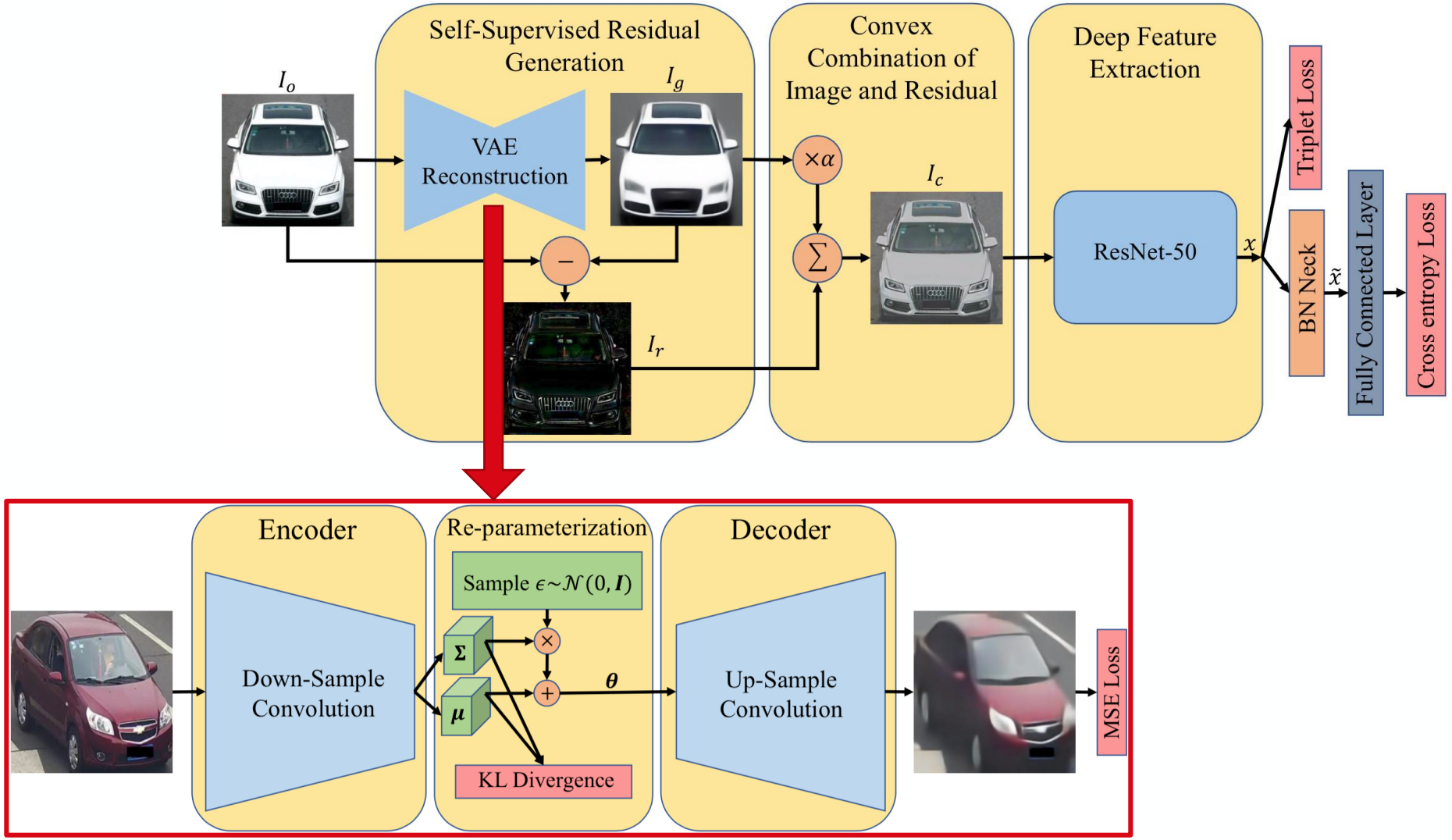
- Pirazh Khorramshahi, Neehar Peri, Jun-Cheng Chen, Rama Chellappa: The Devil is in the Details: Self-Supervised Attention for Vehicle Re-Identification. ECCV 2020



Methods

Multimodal data-based methods

1. Spatial-temporal

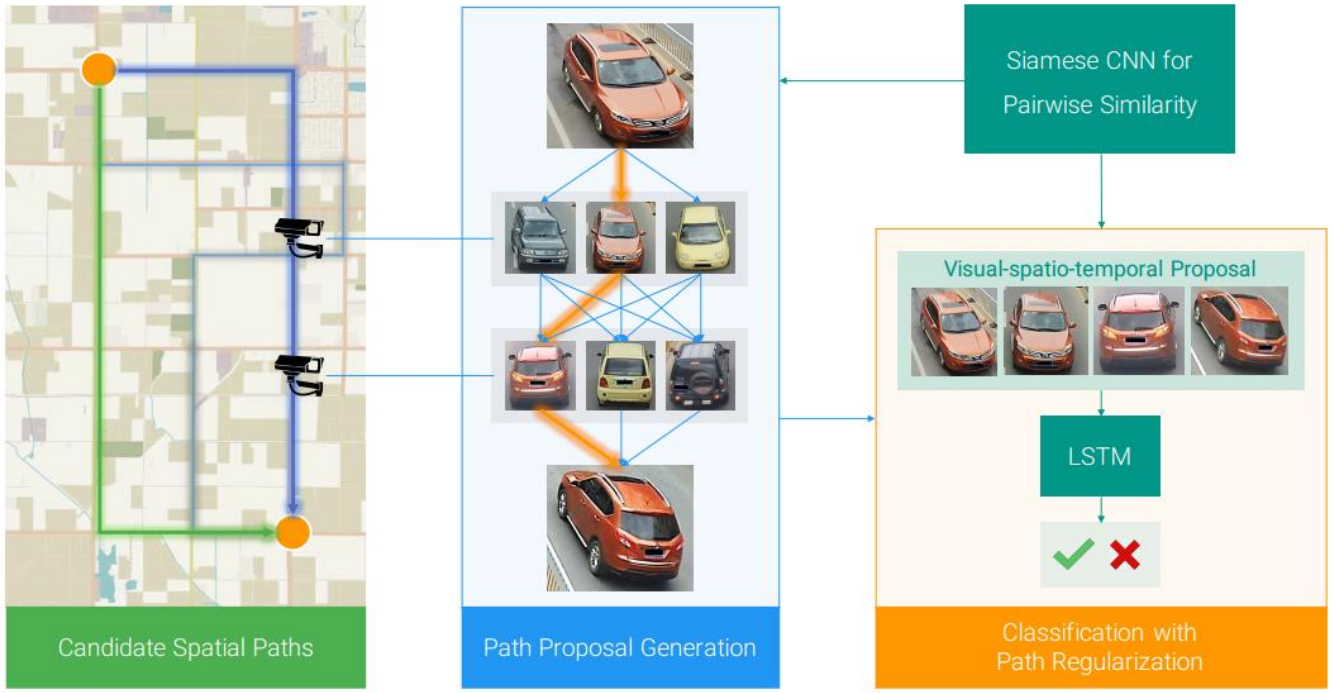
- Zhongdao Wang, Luming Tang, Xihui Liu, Zhuliang Yao, Shuai Yi, Jing Shao, Junjie Yan, Shengjin Wang, Hongsheng Li, Xiaogang Wang: Orientation Invariant Feature Embedding and Spatial Temporal Regularization for Vehicle Re-identification. ICCV 2017: 379-387

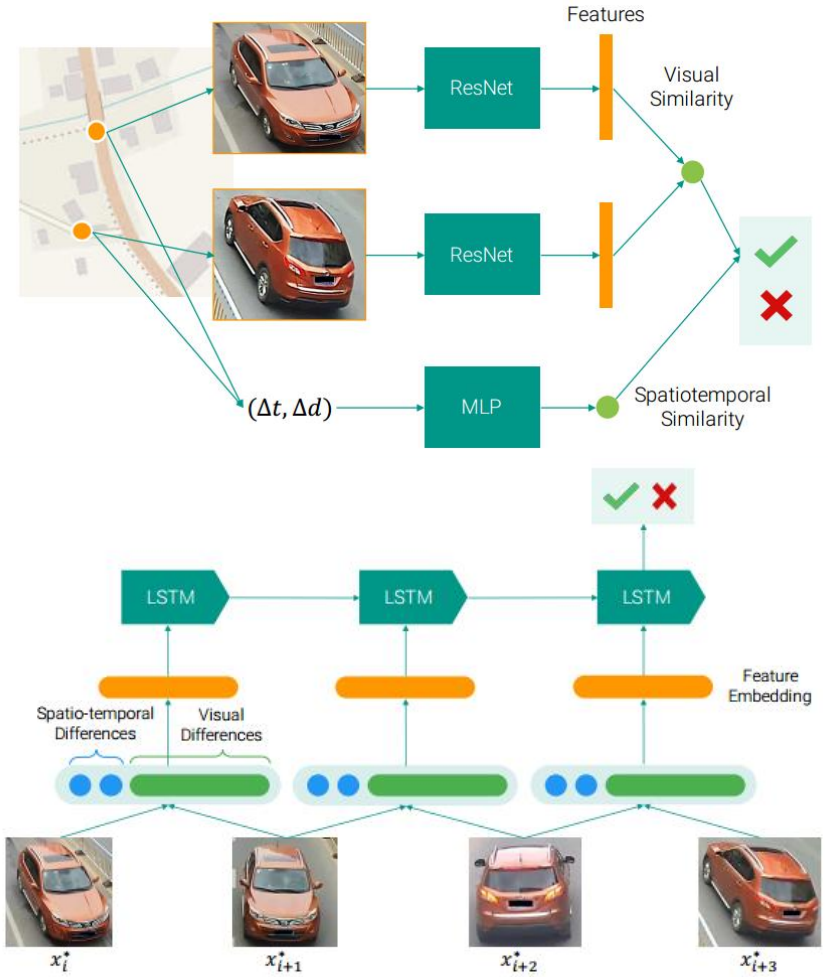
2. License Plate + Spatial-temporal

- Wu Liu, Xinchen Liu, Huadong Ma, Peng Cheng: Beyond Human-level License Plate Super-resolution with Progressive Vehicle Search and Domain Priori GAN. ACM Multimedia 2017: 1618-1626
- Xinchen Liu, Wu Liu, Tao Mei, Huadong Ma: PROVID: Progressive and Multimodal Vehicle Reidentification for Large-Scale Urban Surveillance. IEEE Trans. Multimedia 20(3): 645-658 (2018)

Spatial-temporal

- Zhongdao Wang, Luming Tang, Xihui Liu, Zhuliang Yao, Shuai Yi, Jing Shao, Junjie Yan, Shengjin Wang, Hongsheng Li, Xiaogang Wang: Orientation Invariant Feature Embedding and Spatial Temporal Regularization for Vehicle Re-identification. ICCV 2017: 379-387





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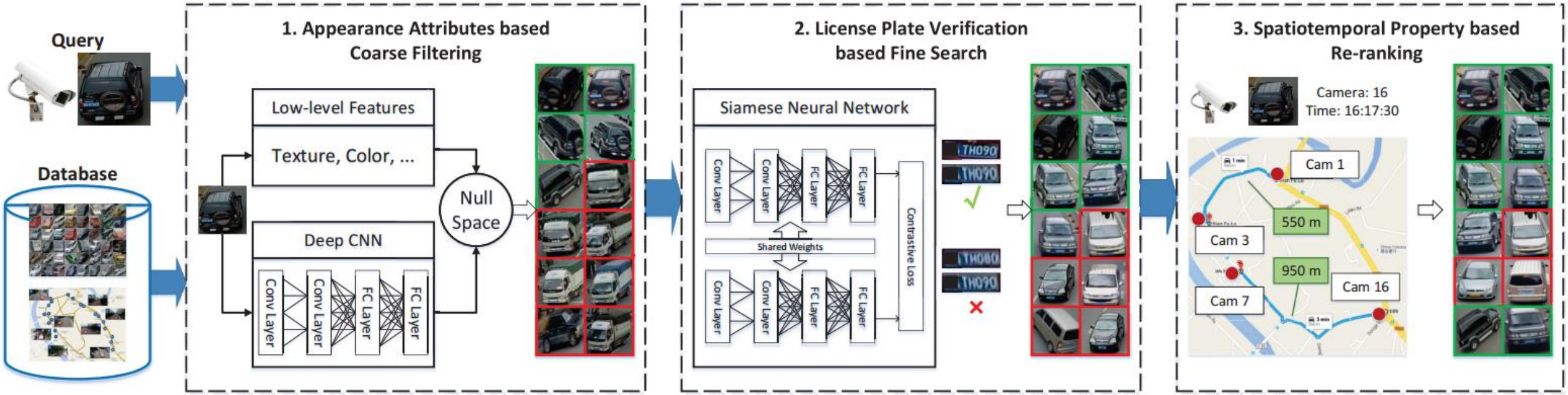

Fig. 3: The architecture of the PROVID framework.

License Plate + Spatial-temporal

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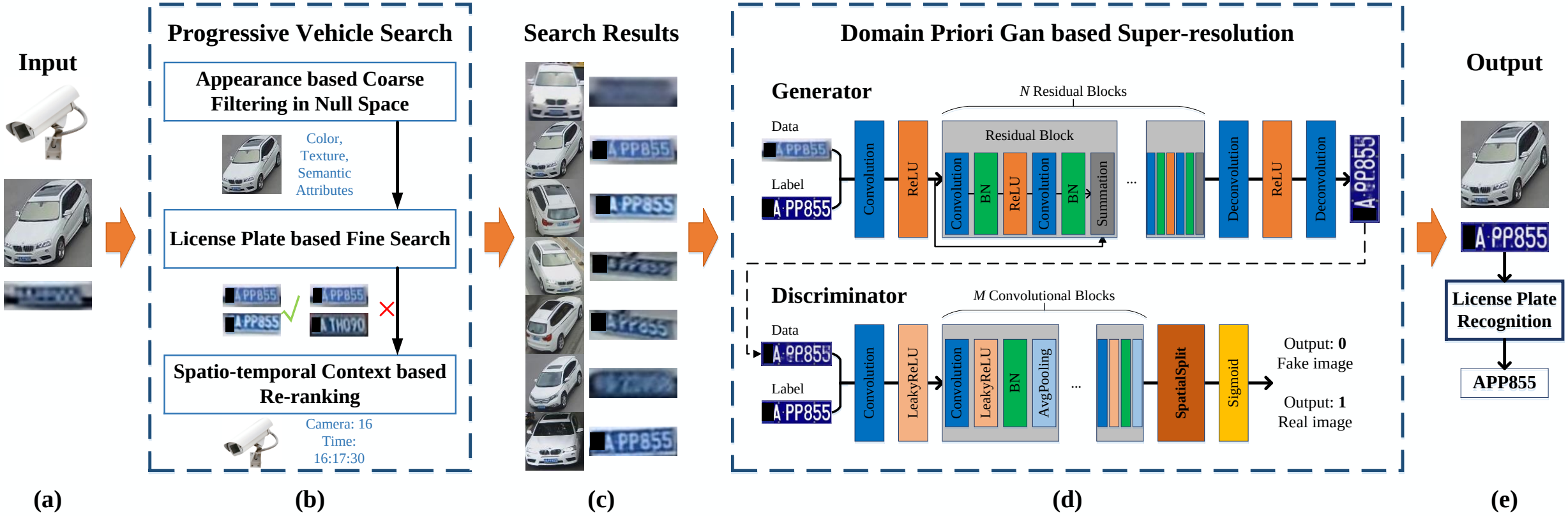


JDAI
京东人工智能

1 Datasets

2 Methods

3 Discussion

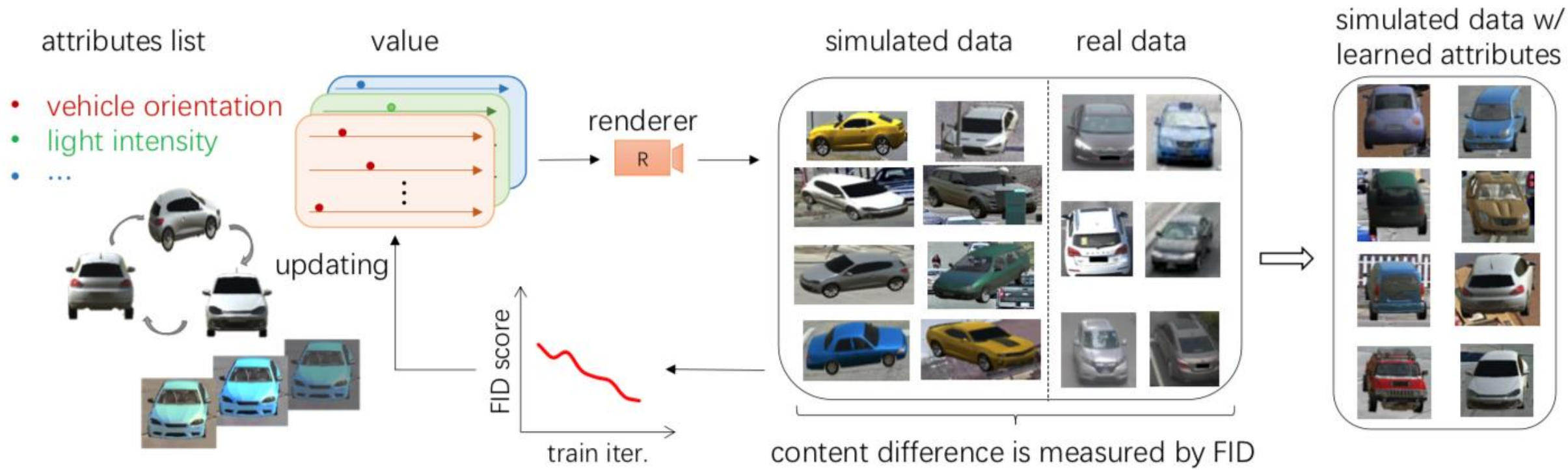
Discussion

JDAI 京东人工智能

1. Cross-domain/Generalizable Vehicle Re-ID
2. Un-supervised/Self-supervised Vehicle Re-ID
3. Synthetic Data Generation for Vehicle Re-ID
4. Vehicle Re-ID with 3D models
5. Real-world Applications

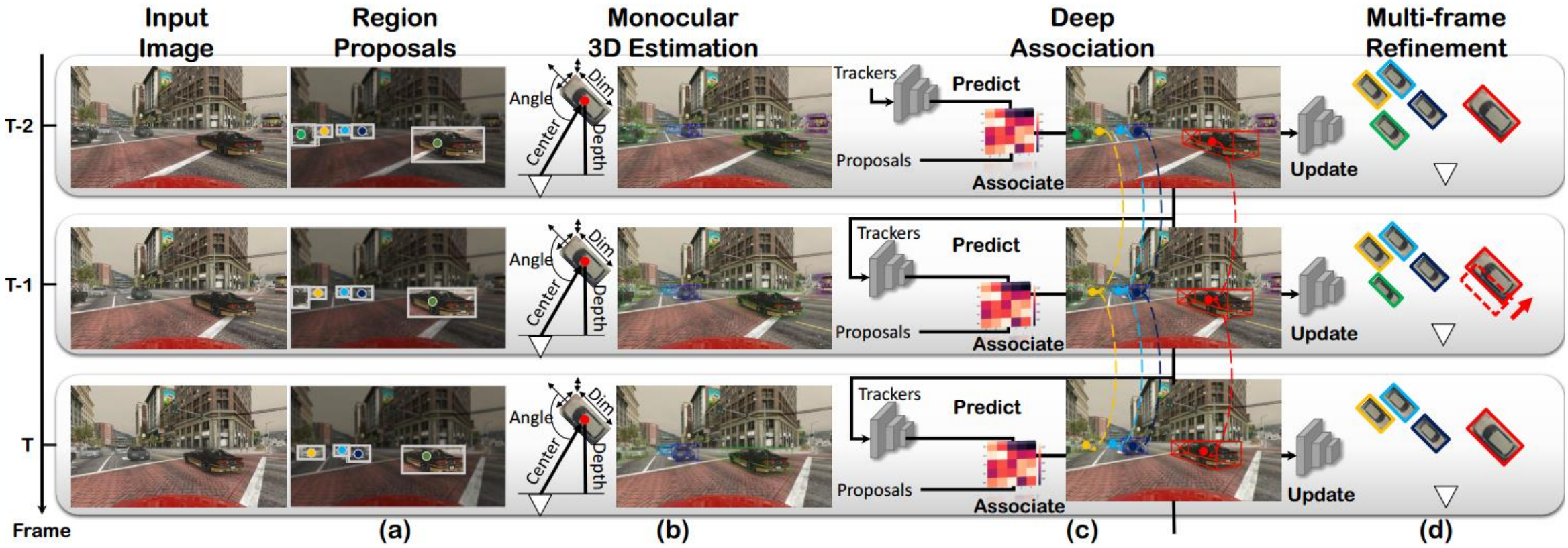
Synthetic Data Generation for Vehicle Re-ID

- Yue Yao, Liang Zheng, Xiaodong Yang, Milind Naphade, Tom Gedeon: Simulating Content Consistent Vehicle Datasets with Attribute Descent. ECCV (2020)



3D Vehicle Analysis

- Hou-Ning Hu, Qi-Zhi Cai, Dequan Wang, Ji Lin, Min Sun, Philipp Krähenbühl, Trevor Darrell, Fisher Yu: Joint Monocular 3D Vehicle Detection and Tracking. ICCV 2019: 5389-5398



Discussion

JDAI 京东人工智能

1. Cross-domain/Generalizable Vehicle Re-ID
2. Un-supervised/Self-supervised Vehicle Re-ID
3. Synthetic Data Generation for Vehicle Re-ID
4. Vehicle Re-ID with 3D models
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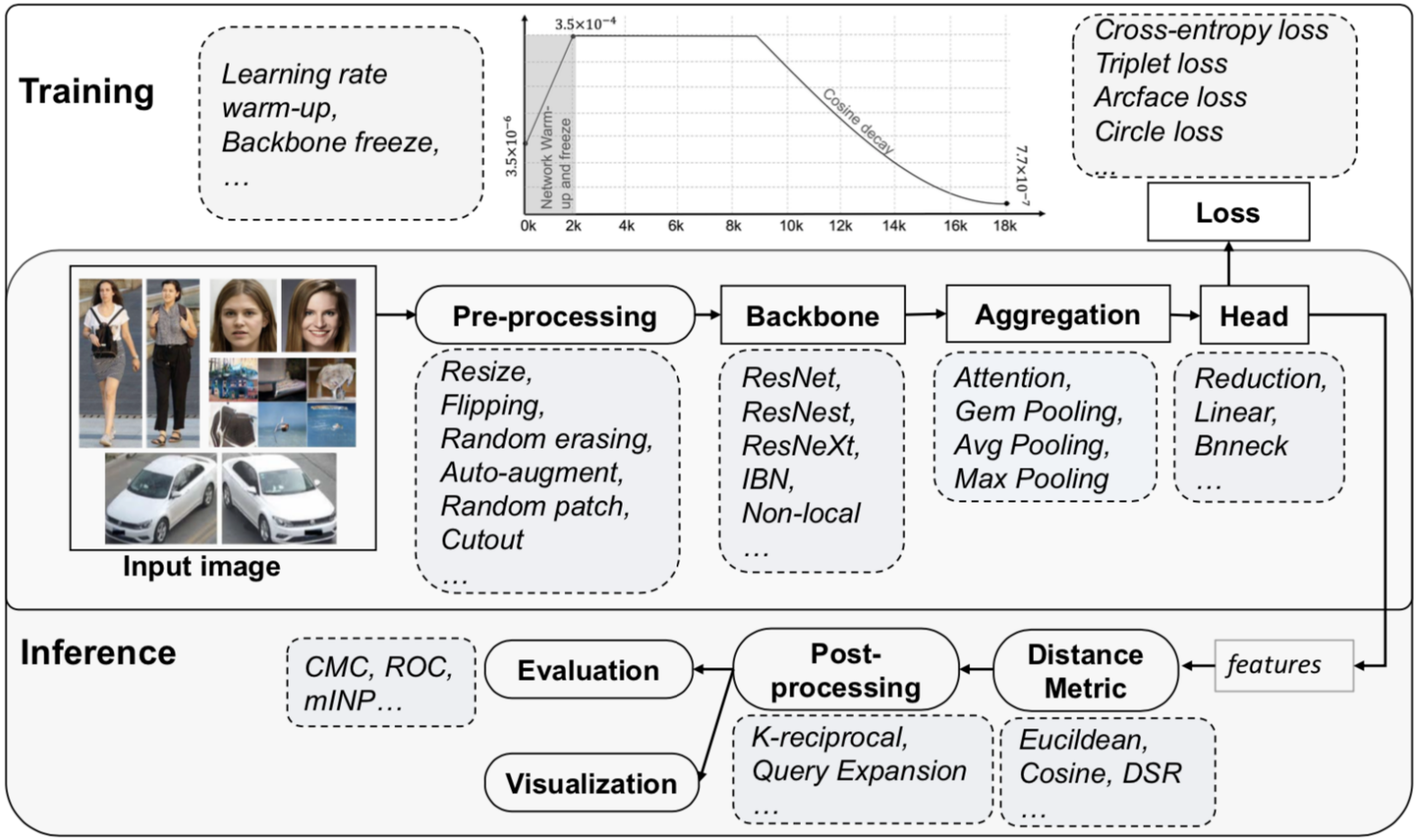
Real-world Applications

FastReID: A Pytorch Toolbox for General Instance Re-identification

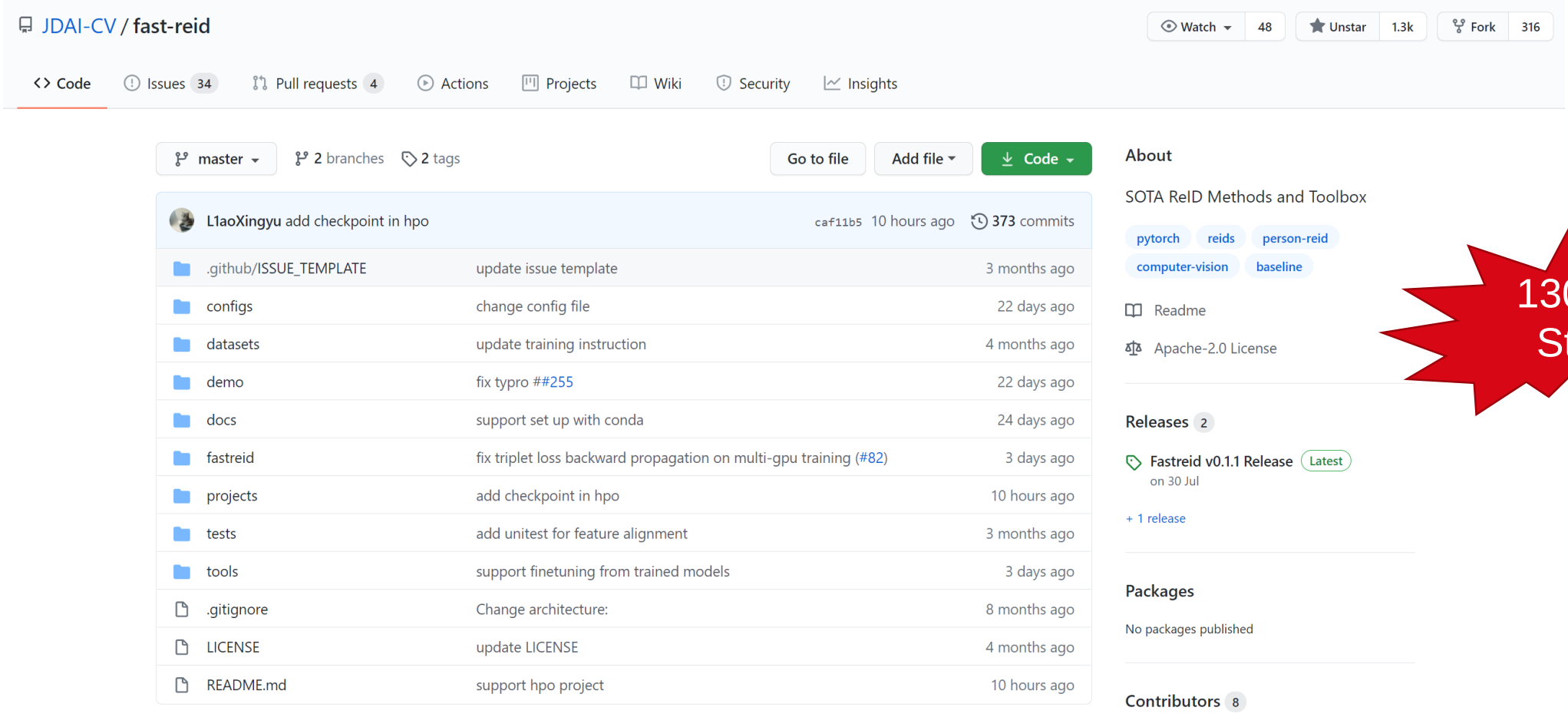


- ✓ **Modular and extensible design**
- ✓ **Manageable system configuration**
- ✓ **Richer evaluation system**
- ✓ **Richer evaluation system**
- ✓ **State-of-the-art pre-trained models**

- Lingxiao He, Xingyu Liao, Wu Liu, Xinchen Liu, Peng Cheng, Tao Mei: FastReID: A Pytorch Toolbox for General Instance Re-identification. CoRR abs/2006.02631 (2020) https://github.com/JDAI-CV/fast-reid

Real-world Applications

FastReID: A Pytorch Toolbox for General Instance Re-identification



1300+ Star

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Real-world Applications

JDAI 京东人工智能

Results on VeRi

Methods	mAP (%)	R-1 (%)	R-5 (%)
LOMO [33] (CVPR'15)	9.6	25.3	46.5
BOW-CN [92] (CVPR'15)	12.2	33.91	53.69
GoogLeNet [80] (CVPR'15)	17.9	52.3	72.2
FACT [39] (ICME'16)	18.8	52.2	72.9
Siamese-CNN [55] (ICCV'17)	54.2	79.3	88.9
NuFACT [40] (TMM'18)	48.5	76.9	91.4
RAM [41] (ICME'18)	61.5	88.6	94.0
FDA-Net [42] (CVPR'19)	55.5	84.3	92.4
OIFE+ST [73] (ICCV'17)	51.4	92.4	-
Siamese-CNN+ST [55] (ICCV'17)	58.3	83.5	90.0
PROVID [40] (TMM'18)	53.4	81.6	95.1
OIFE [73](ICCV'17)	48.0	89.4	-
VAMI [100] (CVPR'18)	50.1	77.0	90.8
EALN [43] (TIP'19)	57.4	84.4	94.1
AAVER [28] (ICCV'19)	61.2	89.0	94.7
PRN [18] (CVPR'19)	70.2	92.2	97.9
PAMTRI [66](ICCV'19)	71.8	92.9	97.0
PRN [18] (CVPR'19)	74.3	94.3	98.9
FastReID	**81.9**	**97.0**	**99.0**

Results on VehicleID

Methods	Small		Medium		Large	
	R-1	R-5	R-1	R-5	R-1	R-5
DRDL [36]	48.9	73.5	42.8	66.8	38.2	61.6
NuFACT [40]	48.9	69.5	43.6	65.3	38.6	60.7
VAMI [100]	63.1	83.3	52.9	75.1	47.3	70.3
C2F [16]	61.1	81.7	56.2	76.2	51.4	72.2
FDA-Net [42]	-	-	59.8	77.1	55.5	74.7
AAVER [28]	74.7	93.8	68.6	90.0	63.5	85.6
MLSL [1]	74.2	88.4	69.2	81.5	66.6	78.7
OIFE [73]	-	-	-	-	67.0	82.9
PRN [18]	78.4	92.3	75.0	88.3	74.2	86.4
FastReID	**86.6**	**97.9**	**82.9**	**96.0**	**80.6**	**93.9**

Results on VeRi-Wild

Methods	Small		Medium		Large	
	mAP	R-1	mAP	R-1	mAP	R-1
GoogLeNet [80]	24.3	57.2	24.2	53.2	21.5	44.6
DRDL [36]	22.5	57.0	19.3	51.9	14.8	44.6
FDA-Net [42]	35.1	64.0	29.8	57.8	22.8	49.4
MLSL [1]	46.3	86.0	42.4	83.0	36.6	77.5
FastReID	**87.7**	**96.4**	**83.5**	**95.1**	**77.3**	**92.5**

- Lingxiao He, Xingyu Liao, Wu Liu, Xinchen Liu, Peng Cheng, Tao Mei: FastReID: A Pytorch Toolbox for General Instance Re-identification. CoRR abs/2006.02631 (2020) https://github.com/JDAI-CV/fast-reid

Thanks!

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FastReID

Computer Vision and Multimedia Lab
JD AI Research

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