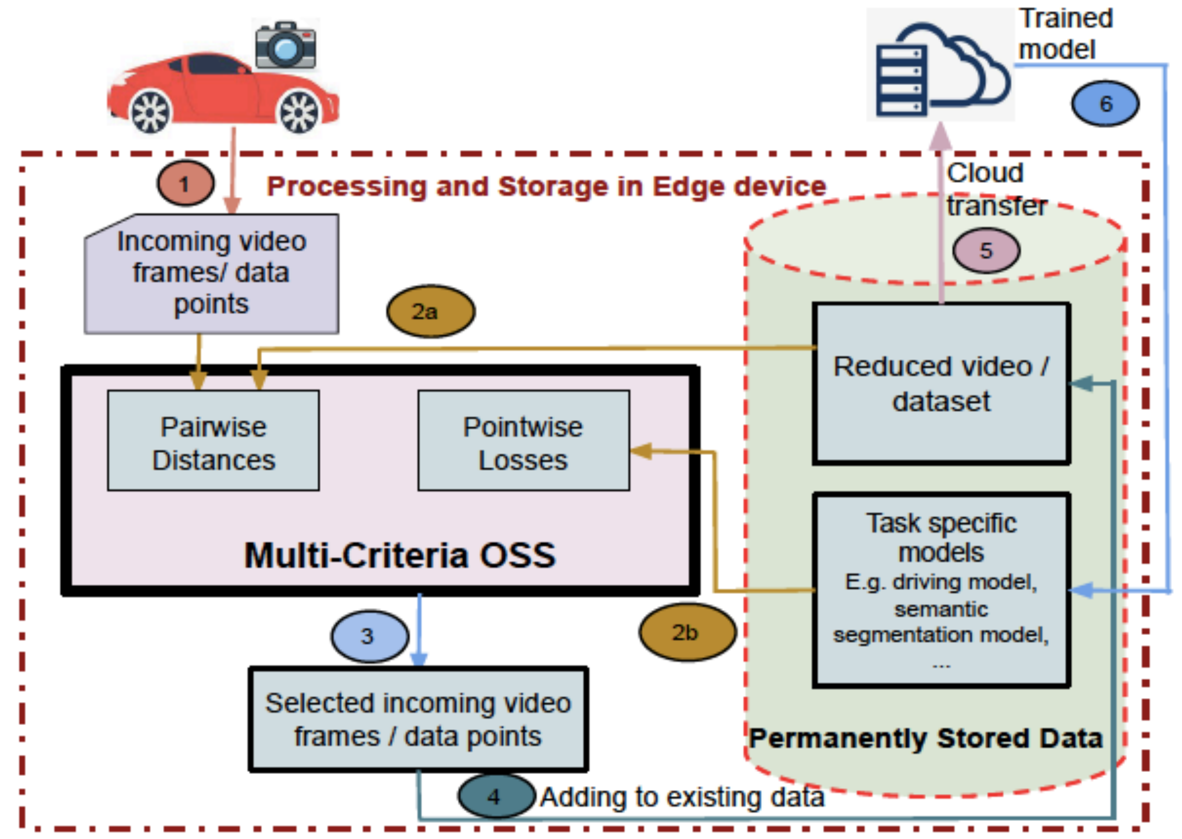
Hewlett Packard Enterprise

2021 ICCV OCTOBER 11-17 VIRTUAL

TMCOSS: Thresholded Multi-Criteria Online Subset Selection for Data-Efficient Autonomous Driving

Soumi Das, Harikrishna Patibandla, Suparna Bhattacharya, Kshounis Bera, Niloy Ganguly, Sourangshu Bhattacharya

Setting

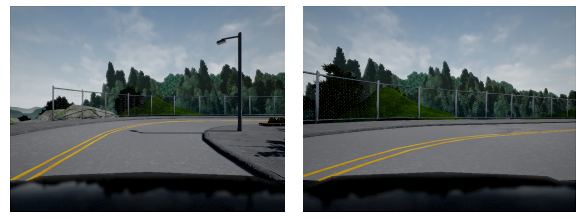


Idea: Developing a **thresholded multi-criteria online subset selection** (**TMCOSS**) algorithm that can select the most informative video frames.

Aim

- Data-efficient training of autonomous driving systems.
- In the context of an edge-device deployment, **multi-criteria online video frame subset selection** is an appropriate technique for developing frameworks to remove redundant data.

Straight road frames
REDUNDANT



Turning point frames
INFORMATIVE

Challenge

Subset selection on autonomous driving is challenging since failing to select informative frames can lead to abysmal performance like incomplete episodes while driving at turns.

Baseline Methods (100:20 compression)	Train One-Turn	Test One-turn
Uniform Skip	3/10	5/10
OSS[1]	7/10	6/10

TMCOSS: Thresholded Multi-Criteria OSS

$$\min_{z^o_{ij},z^n_{ij}} \mathscr{G}(z^o_{ij}, z^n_{ij}) s.t. \sum_{j=1}^{|R_t|} z^o_{i,j} + \sum_{j=1}^{m} z^n_{i,j} = 1; z^n_{i,j}, z^o_{i,j} \in [0,1]; \sum_{j=1}^{m} \|[z^n_{1,j} \ldots z^n_{m,j}]\|_p \leq frac * m$$

Objective function — Representative — Domain — Compression Ratio

Constraints

$$\mathscr{G}(z^o_{ij}, z^n_{ij}) = \rho\underbrace{\Big(\sum_{i=1}^{m}\sum_{j=1}^{|R_t|} z^o_{ij} d^o_{ij}(t) + \sum_{i,j=1}^{m} z^n_{ij} d^n_{ij}(t)\Big)}_{\text{Pairwise Dissimilarity}} - (1-\rho)\underbrace{\Big(\sum_{j=1}^{|R_t|} S^o_j * L^o_j + \sum_{j=1}^{m} S^n_j * L^n_j\Big)}_{\text{Pointwise Loss}}$$

$$where, \underbrace{S^o_j = \frac{1}{\epsilon}\min(\epsilon, \sum_{i=1}^{m} z^o_{ij}), S^n_j = \frac{1}{\epsilon}\min(\epsilon, \sum_{i=1}^{m} z^n_{ij})}_{\text{Representative power of element j thresholded by } \epsilon}$$

Variants of TMCOSS

Driving requires several cues/affordances for taking the next move. We use Conditional Affordance Learning [3] model as the driving model. In order to complete an episode involving turns, **relative angle is a vital signal.** We introduce 2 variants of TMCOSS:

TMCOSS-TL

Total Loss of affordances like red light, hazard stop, relative angle etc as point wise metric

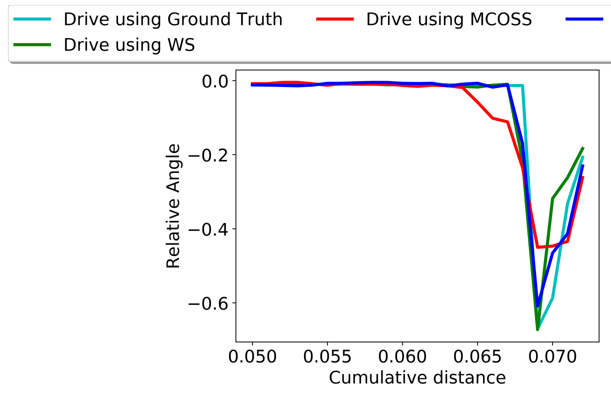
TMCOSS-BL

Bucket specific Loss of relative angle and combined loss of other affordances as point wise metric

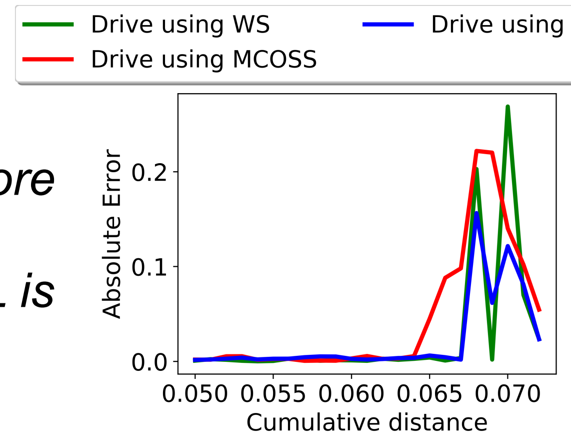
Episode completion using CARLA simulator(100:7 compression)

Method	Train One-turn	Test One-Turn
Whole Set	10/10	10/10
MCOSS[2]	5/10	4/10
TMCOSS-TL	**7/10**	**9/10**
TMCOSS-BL	**8/10**	**9/10**

Analysis:Failed episode by MCOSS but completed by TMCOSS-BL

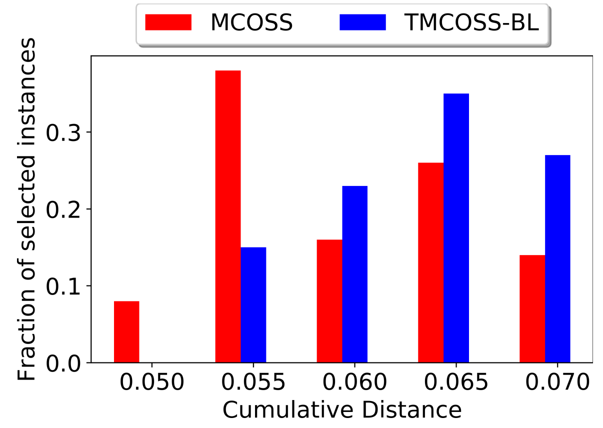


MCOSS deviates before the turn. TMCOSS-BL is more stable.



MCOSS has higher error in relative angle prediction due to deviation.

MCOSS selects more instances on straight road bucket. TMCOSS-BL selects informative frames in required buckets.



Semantic segmentation(IoU)using DeepLabV3+ [4] on Cityscapes

Method	Road	Sidewalk	Person	Car
Whole Set	98.0	83.0	81.0	94.0
MCOSS[2]	96.0	75.0	74.0	90.0
TMCOSS	**98.0**	**82.0**	**79.0**	**93.0**

References

1. Elhamifar, Ehsan, and M. Clara De Paolis Kaluza. "Online summarization via submodular and convex optimization." *CVPR*. 2017
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3. Sauer, Axel, Nikolay Savinov, and Andreas Geiger. "Conditional affordance learning for driving in urban environments." Conference on Robot Learning. PMLR, 2018.
4. Liang-Chieh Chen, Yukun Zhu, George Papandreou, Florian Schroff, Hartwig Adam, "Encoder-decoder with atrous separable convolution for semantic image segmentation." *ECCV*. 2018

Acknowledgment

We thank Hewlett Packard Labs for the funding and constant guidance and valuable suggestions.

Contact Information

Soumi Das, IIT Kharagpur; soumi_das@iitkgp.ac.in; @soumi_das0407