RMS-FlowNet: Efficient and Robust Multi-Scale Scene Flow Estimation for Large-Scale Point Clouds

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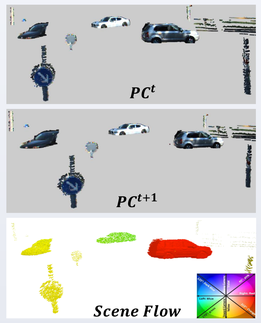
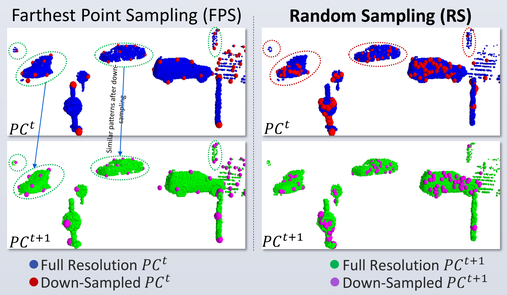
What is Scene Flow?

- 3D Motion field estimation.
- Perception of dynamic changes.
- LiDAR-based / Point-based Solutions.
  - Advantages:
    - Impressive Results.
    - Strong Generalization.
  - Disadvantages:
    - Low Efficiency.
    - Less Density.



Challenges:

- RS is much efficient, however:
  - Over-representation for locally dense regions.
  - Unevenly distribution.
  - Dissimilar patterns.

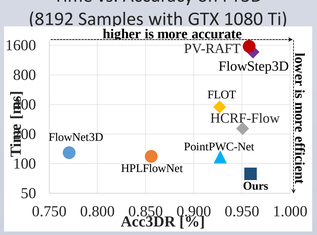


Overview:

RMS-FlowNet is a fully supervised network for scene flow estimation with high efficiency for large-scale point clouds.

Advantages:

- Hierarchical End-to-End Prediction.
- Efficient Point-based Architecture.
- Random Sampling (RS).
- Attention Technique [RandLA-Net].
- Novel Flow Embedding.



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[HPLFlowNet] Gu et al.: "HPLFlowNet: Hierarchical Permutohedral Lattice FlowNet for Scene Flow Estimation on Large-scale Point Clouds". In *Computer Vision and Pattern Recognition (CVPR), 2019.*

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[HALFlow] Wang et al.: "Hierarchical attention learning of scene flow in 3d point clouds". In *Transactions on Image Processing (TIP)*, 2021.

[FLOT] Puy et al.: "FLOT: Scene Flow on Point Clouds Guided by Optimal Transport". In *European Conference on Computer Vision (ECCV), 2020.*

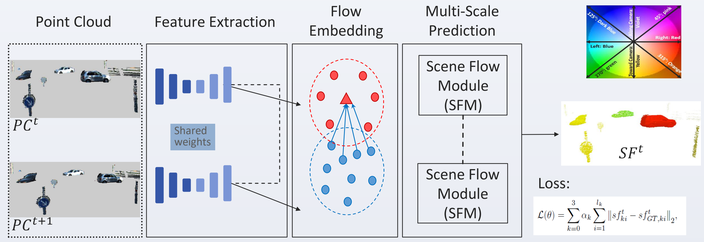
[FlowStep3D] Kittenplon et al.: "FlowStep3D: Model Unrolling for Self-Supervised Scene Flow Estimation". In *Computer Vision and Pattern Recognition. (CVPR), 2021.*

[PV-RAFT] Wei et al.: "PV-RAFT: Point-Voxel Correlation Fields for Scene Flow Estimation of Point Clouds". In *Computer Vision and Pattern Recognition. (CVPR), 2021.*

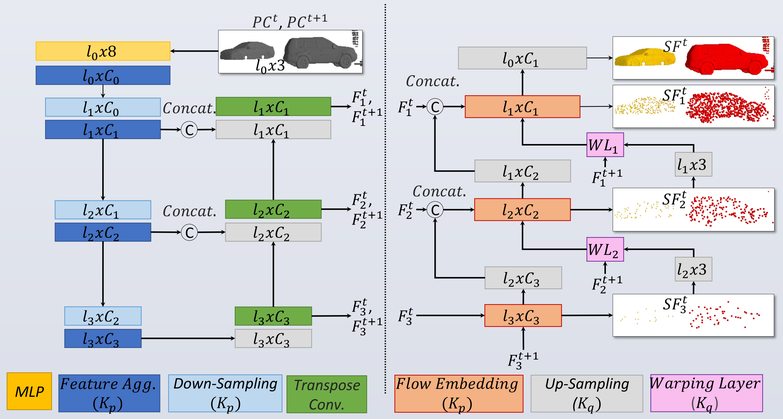
[WSLR] Gojcic et al.: "Weakly Supervised Learning of Rigid 3D Scene Flow". In *Computer Vision and Pattern Recognition (CVPR), 2021.*

[HCRF-Flow] Ruibo et al.: "HCFF-Flow: Scene Flow from Point Clouds with Continuous High-order CRFS and Position-aware Flow Embedding". In *Computer Vision and Pattern Recognition. (CVPR), 2021.*

RMS-FlowNet Network:

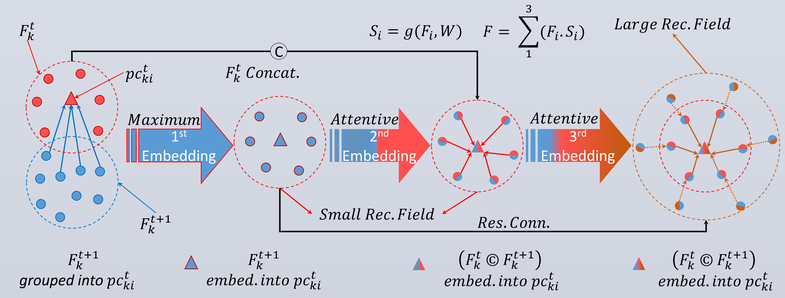


Multi-Scale Predictions:



Hierarchical Feature Extraction and Hierarchical Scene Flow Prediction.

Novel Flow Embedding:



Patch-to-Dilated Patch flow embedding module is inspired by [RandLA-Net]

More Details in our Paper:

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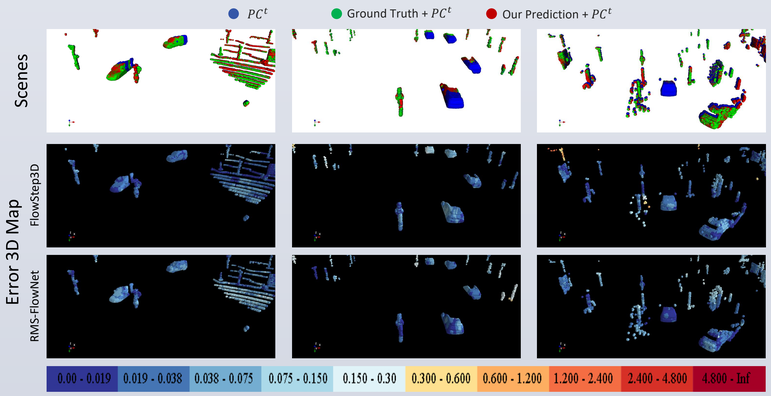
Results:

Quantitative Results: *8192 Samples with GTX 1080 Ti.*

	Model	Sampling	EPE3D [m]	KEO3D [%]	ACC3DS [%]	ACC3DR [%]	Time [ms]	GPU [GB]
FT3D (Trained Domain)	FlowNet3D	FPS	0.114	0.602	0.413	0.771	132	10.85
	HPLFlowNet	_	0.080	0.428	0.616	0.856	119	1.58
	PointPWC-Net	FPS	0.059	0.342	0.738	0.928	117	2.86
	HALFlow	FPS	0.049	0.308	0.785	0.947	_	_
	FLOT	_	0.052	0.357	0.732	0.927	376	3.84
	FlowStep3D	FPS	0.046	0.217	0.816	0.961	1369	1.31
	PV-RAFT	_	0.046	0.292	0.817	0.957	1565	4.03
	WSLR	_	0.052	0.361	0.746	0.936	234	_
	HCRF-Flow	FPS	0.049	0.261	0.834	0.951	228	_
	RMS-FlowNet (Ours)	**RS**	0.051	0.309	0.800	0.956	77	1.39
	RMS-FlowNet (Ours)	FPS	0.051	0.322	0.791	0.955	134	10.60
KITTI (w/o Fine-tuning)	FlowNet3D	FPS	0.177	0.527	0.374	0.668	132	10.85
	HPLFlowNet	_	0.117	0.410	0.478	0.778	119	1.58
	PointPWC-Net	FPS	0.069	0.265	0.728	0.888	117	2.86
	HALFlow	FPS	0.062	0.249	0.765	0.903	_	_
	FLOT	_	0.054	0.244	0.764	0.915	376	3.84
	FlowStep3D	FPS	0.054	0.233	0.814	0.926	1369	1.31
	PV-RAFT	_	0.045	0.196	0.856	0.956	1565	4.03
	WSLR	_	0.042	0.208	0.849	0.959	234	_
	HCRF-Flow	FPS	0.053	0.180	0.863	0.944	228	_
	RMS-FlowNet (Ours)	**RS**	0.054	0.211	0.811	0.934	77	1.39
	RMS-FlowNet (Ours)	FPS	0.048	0.187	0.876	0.957	134	10.60

Qualitative Results: *8192 Samples with GTX 1080 Ti.*



Robustness with High Density: *Ours can operate on high dense (> 400K at once).*