Upgrading Optical Flow to 3D Scene Flow through Optical Expansion

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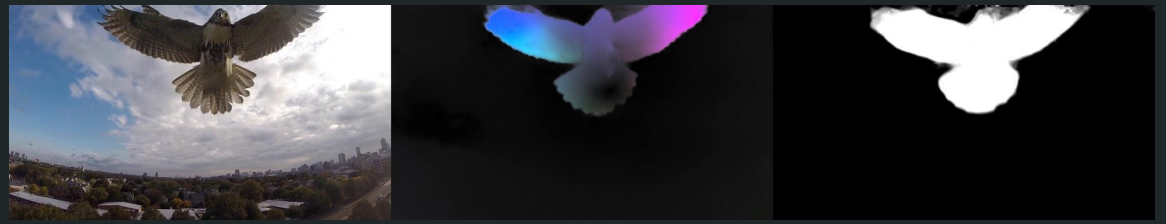


Input from a drone | Optical flow | Optical expansion

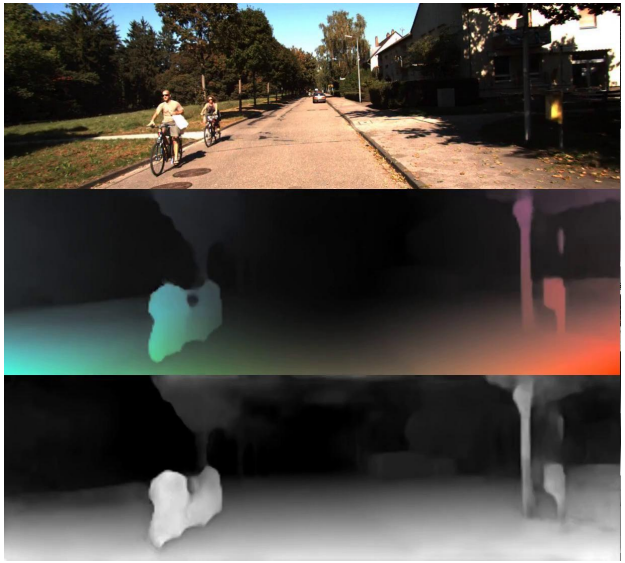
"Red-Tailed Hawk vs. Drone. Hawk Wins." Video from The New York Times.

CVPR 2020

Monocular 3D Scene Motion Estimation

Problem: Estimate the 3D motion of dynamic scene elements using a monocular camera.

Input (drone) Optical flow Optical expansion



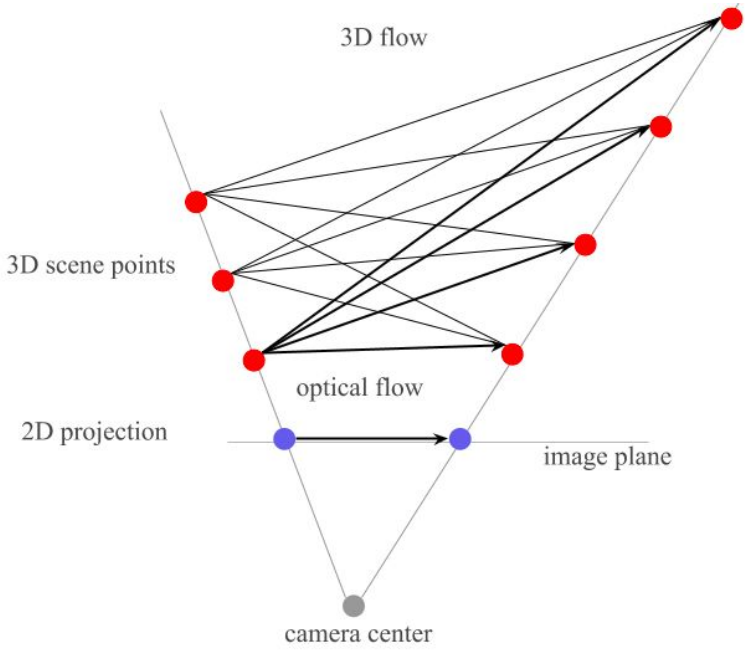
Input (car)

Optical flow

Optical expansion

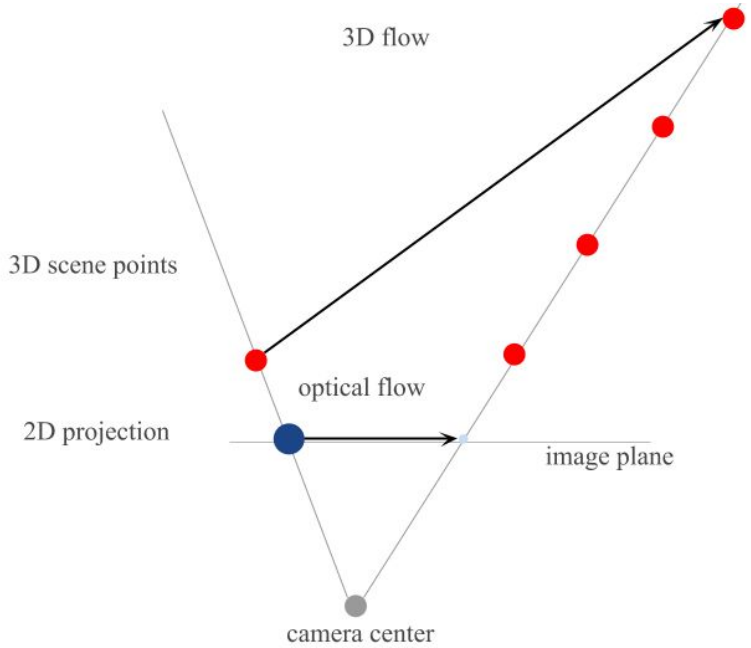
Monocular 3D Scene Motion Estimation

Challenge: Infinite pairs of 3D points correspond to the 2D flow observation.



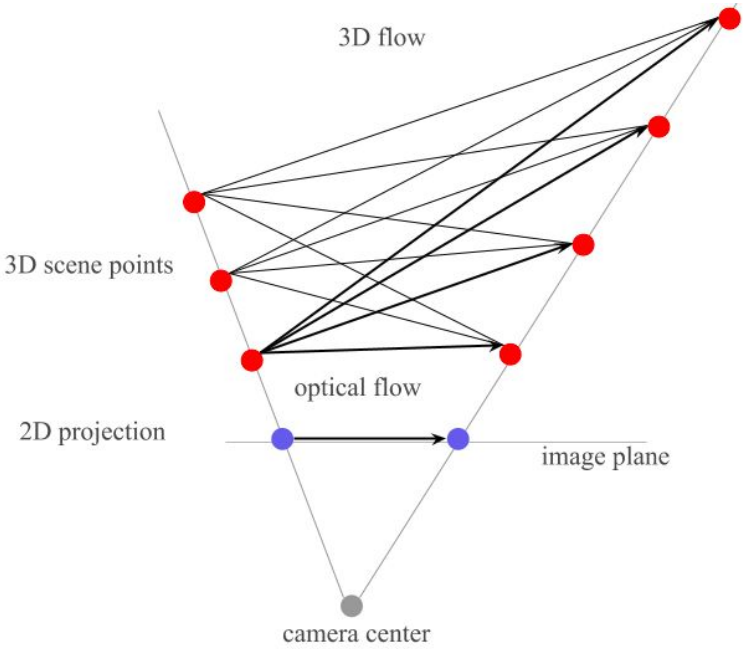
Optical Expansion and Motion-in-depth

Change of perceptual size corresponds to change of physical depth.

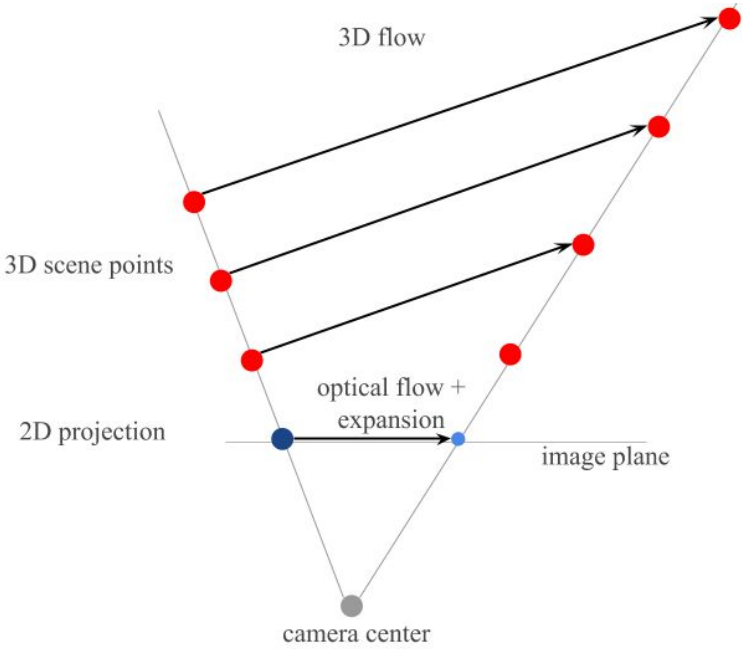


Swanston, Michael T., and Walter C. Gogel. "Perceived size and motion in depth from optical expansion." *Perception & psychophysics* 39.5 (1986): 309-326.

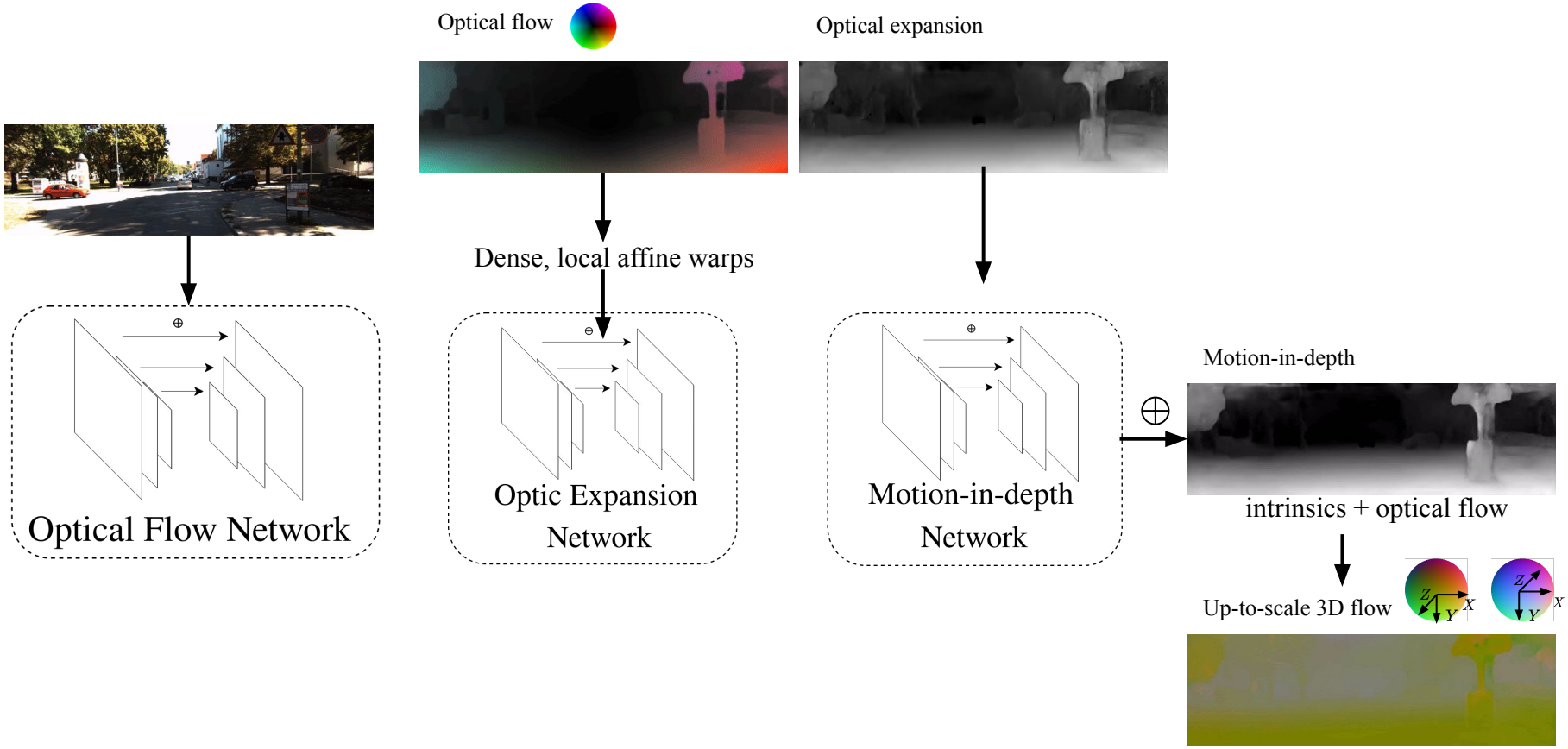
Upgrading to 3D Scene Flow



(a) with optical flow



(b) optical flow + expansion


Optical flow
Optical expansion
Dense, local affine warps
Optical Flow Network
Optic Expansion Network
Motion-in-depth Network
Motion-in-depth
intrinsics + optical flow
Up-to-scale 3D flow

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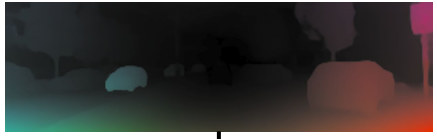
Gengshan Yang, Deva Ramanan. CVPR 2020.

Optical Flow Network

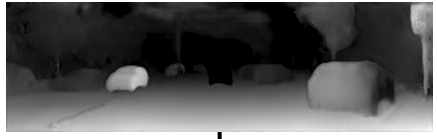
Optical flow



Dense, local affine warps

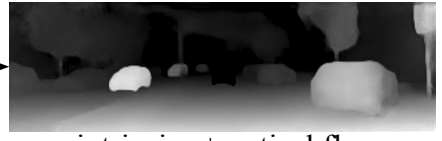
Optic Expansion Network

Optical expansion



Motion-in-depth Network

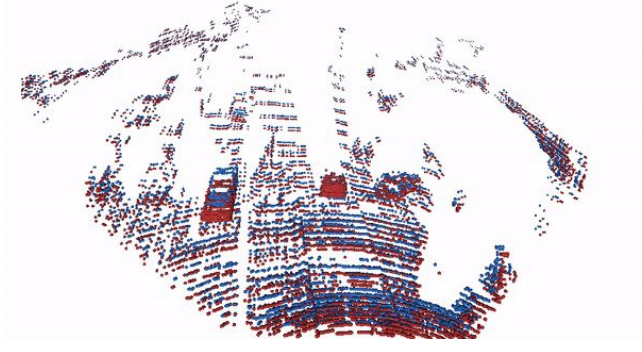
Motion-in-depth



intrinsics + optical flow

Up-to-scale 3D flow

3D scene flow $\mathbf{t} = Z\hat{\mathbf{t}}$



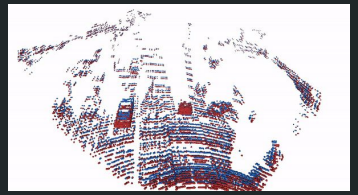
Application: Monocular Scene Flow

Input frame pair

Optical Flow Estimation

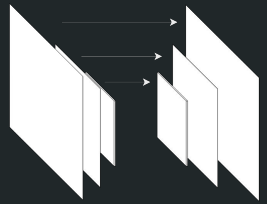
Optical Expansion Estimation

Motion-in-depth Correction



Output 3D scene flow

1st frame



Off-the-shelf monocular depth network

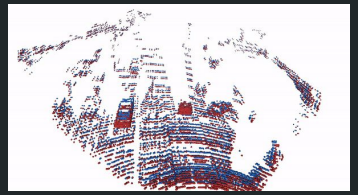
Application: Stereo Scene Flow

Input frame pair

Optical Flow Estimation

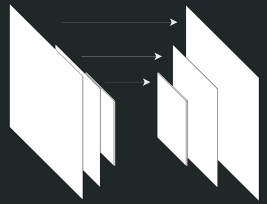
Optical Expansion Estimation

Motion-in-depth Correction



Output 3D scene flow

1st stereo pair



Off-the-shelf stereo matching network

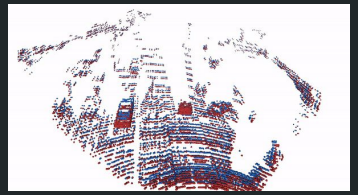
Application: LiDAR Scene Flow

Input frame pair

Optical Flow Estimation

Optical Expansion Estimation

Motion-in-depth Correction



Output 3D scene flow

1st frame LiDAR

Monocular / Stereo Scene Flow

Input

Relative depth change
(motion-in-depth)

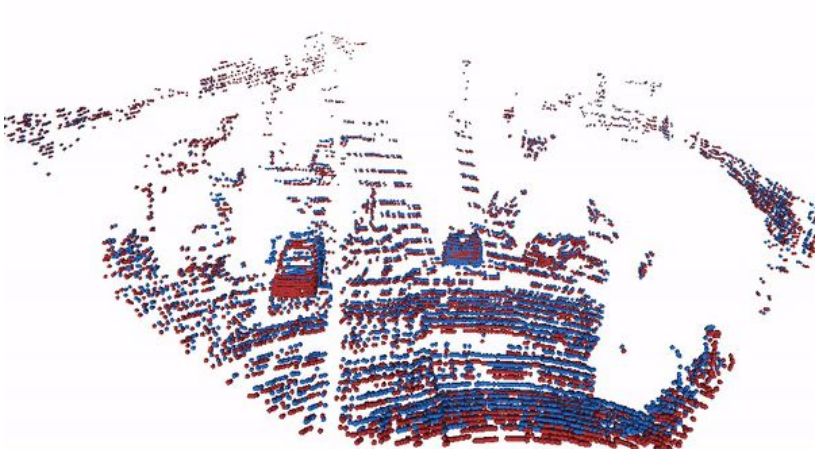
“Flow warping” [1]

FlowNet-3 [2]

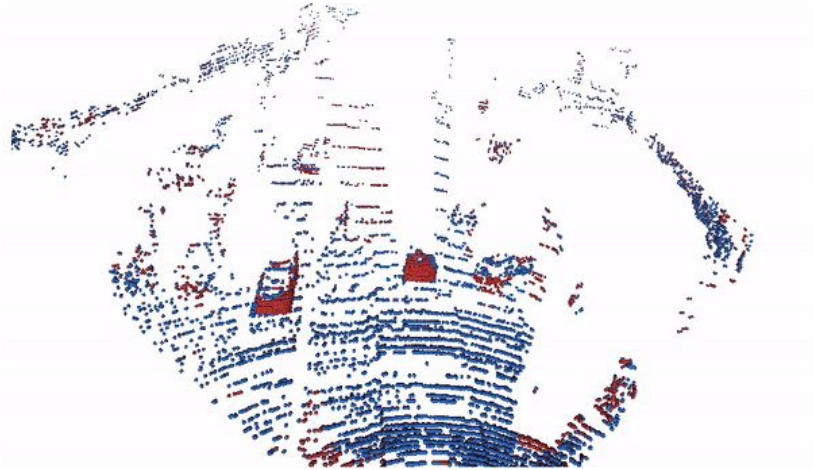
Ours

SOTA monocular and stereo scene flow performance on foreground objects of KITTI leaderboard.

[1] Schuster, René, et al. "Combining stereo disparity and optical flow for basic scene flow." Commercial Vehicle Technology 2018. Springer Vieweg, Wiesbaden, 2018. 90-101.
[2] Ilg, Eddy, et al. "Occlusions, motion and depth boundaries with a generic network for disparity, optical flow or scene flow estimation." ECCV. 2018.



Result of HPLFlowNet



Our result

- High-accuracy than state-of-the-art lidar-only methods
- Can be computed before the next LiDAR sweep is captured

Gu, Xiuye, et al. "HPLFlowNet: Hierarchical Permutohedral Lattice FlowNet for Scene Flow Estimation on Large-scale Point Clouds." CVPR. 2019.

Thanks! More in our paper ...

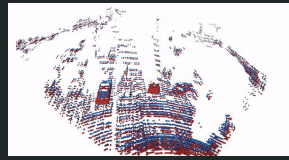
- Formalism for upgrading 2D optical flow to 3D scene flow

Input frame pair

Optical Flow

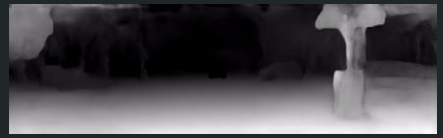
Expansion

Motion-in-depth



Output 3D scene flow

- Optical expansion is the crucial ingredient enabling the above



- If you are using optical-flow-for-X, consider using optical-expansion as well!