Revisiting Dead Leaves Model: Training with Synthetic Data

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Introduction

- Supervised deep neural networks - superior performance across many tasks image classification, object detection etc.
- Model generalizability - require large labeled datasets for training.
- Synthetic data - easy to obtain but may lack sufficient realism.

Challenges

- Large scale collection of real world data with labels is expensive and time consuming
- Stereo datasets - require synchronised capture of images and 3D scene model, followed by a careful registration.
- Lack of large scale datasets with dense ground truth disparity and content diversity.

Goal

Generating synthetic data using natural image statistics for model training, and evaluate model generalizability on real world data.

Dead Leaves Model

- 3D dead leaves space - colored spheres with radii sampled from $f(r) = Kr^{-3}$
- Stereo image data - projection of 3D dead leaves space on parallel camera planes, and disparity d at pixel (x, y) can be calculated as $d(x,y) = \frac{fb}{D(x,y)}$
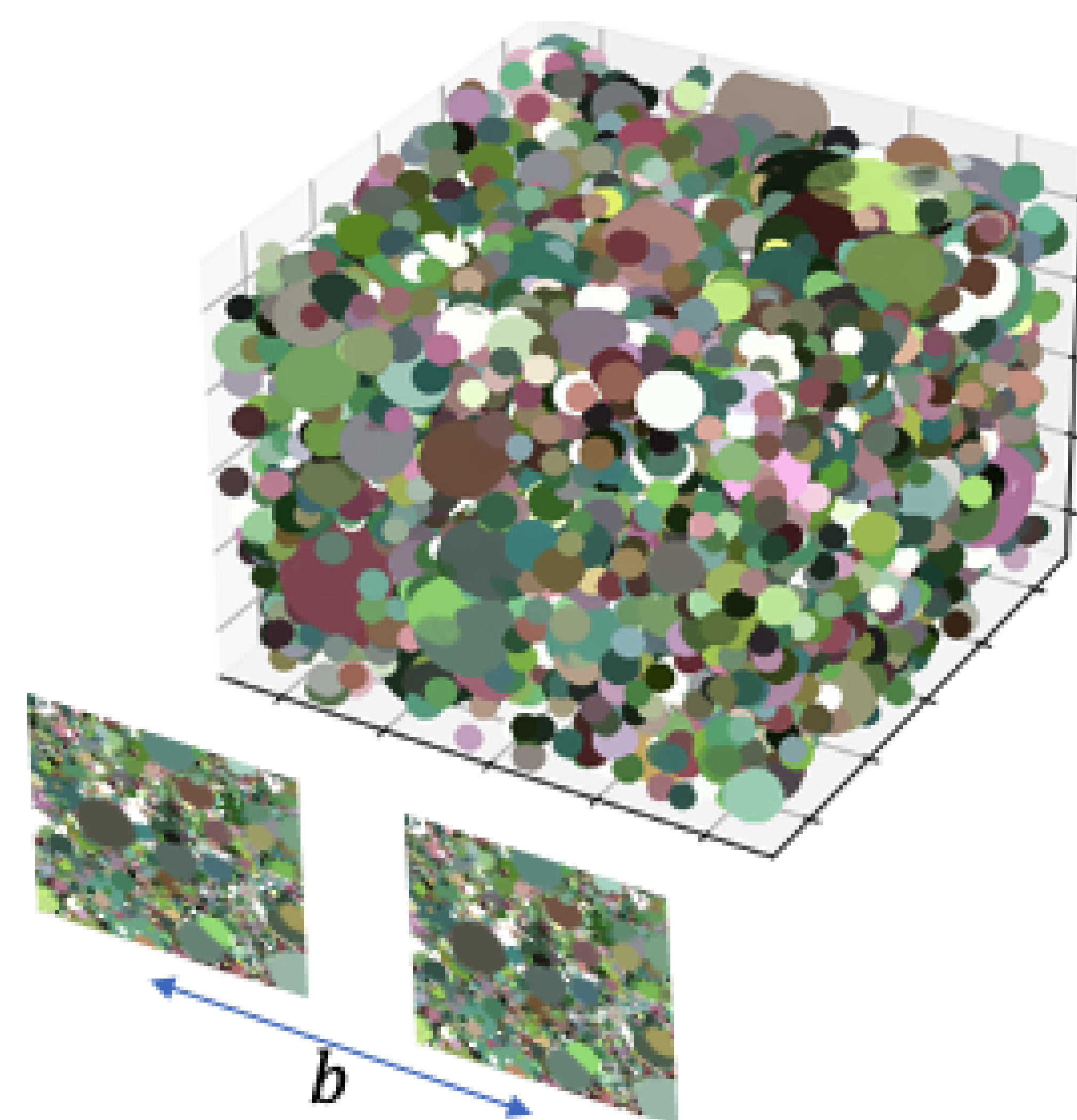- Texture addition - more closer to natural image statistics

Figure: Illustration of the setup employed for obtaining stereo images from 3D Dead Leaves space.
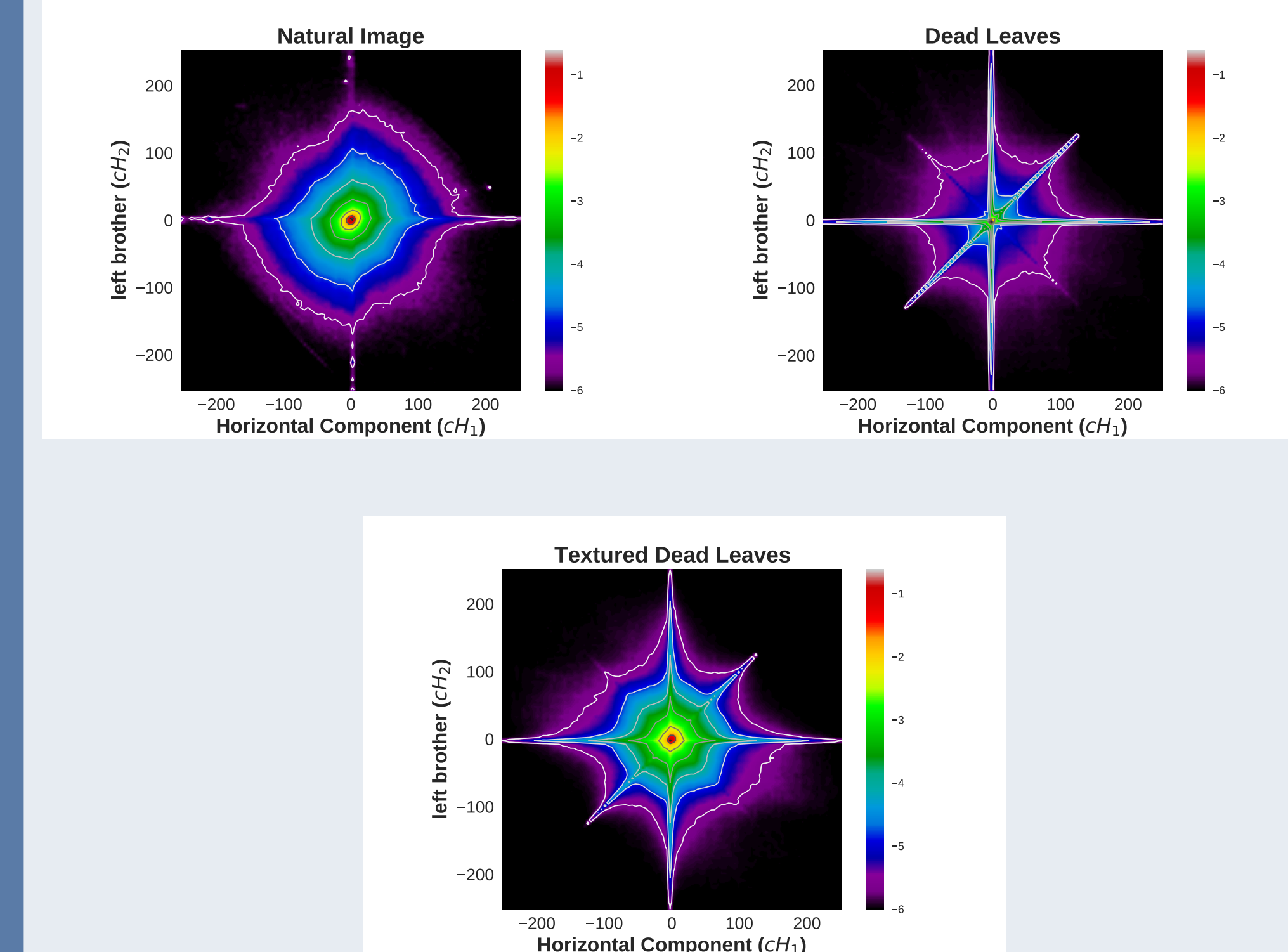
Image Statistics

Figure: Comparison of joint statistics (derivative) of natural and dead leaves images. Plots show the $\log(\text{probability})$ distributions for different neighboring coefficients.

Figure: Sample dead leaves stereo data

left image   right image   disparity map

Results

- Disparity prediction is evaluated in terms of End Point Error

$$EPE = \frac{1}{M} \sum_{i=1}^{M} |disp_{pred}^i - disp_{GT}^i|$$

- Addition of textures leads to smoother and noise-free estimates boosting performance in terms of EPE values.
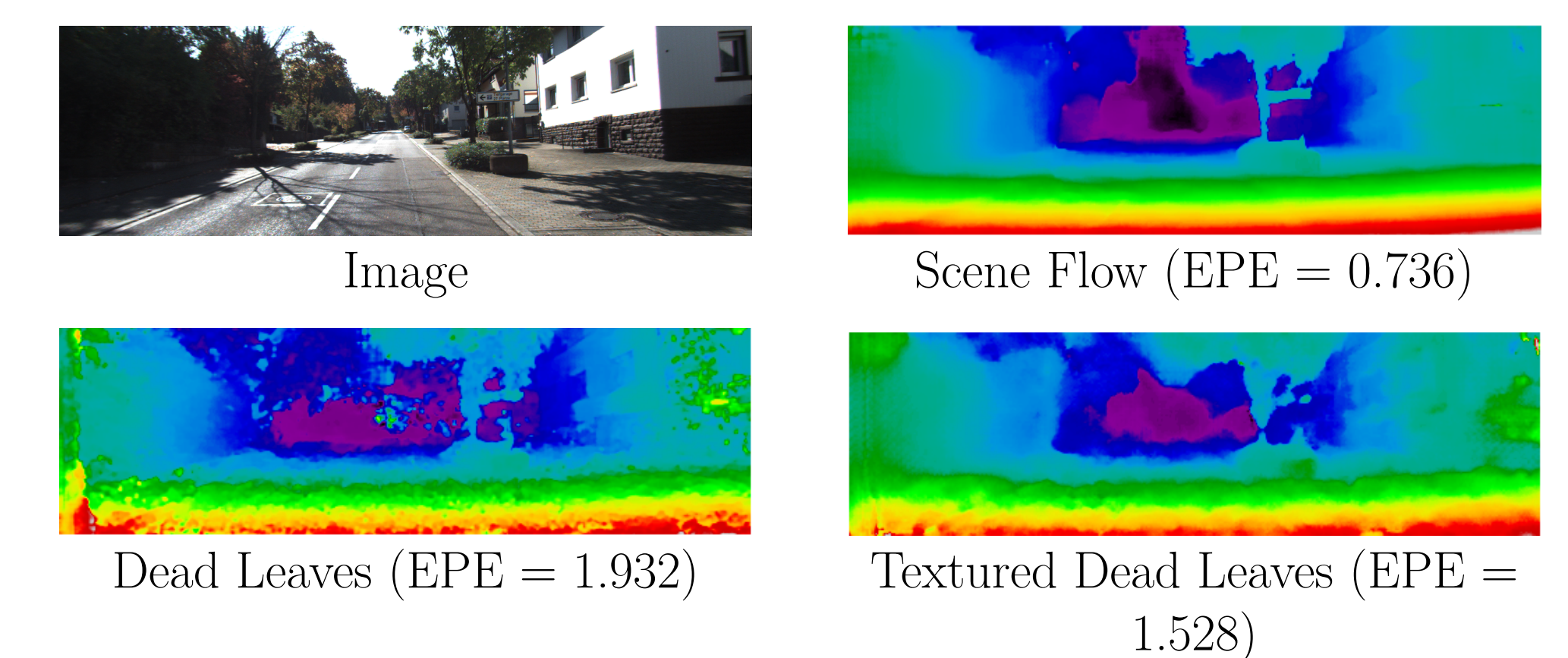

Image   Scene Flow (EPE = 0.736)

Dead Leaves (EPE = 1.932)   Textured Dead Leaves (EPE = 1.528)

Figure: Visual comparison of disparity predictions across different datasets.

Training Dataset	KITTI 2012	KITTI 2015	Scene Flow	
			Train	Test
Scene Flow	1.35	1.83	-	1.09
Dead Leaves	3.01	3.14	13.26	11.52
Textured Dead Leaves	3.38	2.29	9.97	8.3

Table: Objective comparison of disparity predictions in terms of EPE across different datasets.

Paper citation

[1] P. C. Madhusudana, Seok-Jun Lee and Hamid R. Sheikh, "Revisiting Dead Leaves Model: Training with Synthetic Data", in IEEE Signal Processing Letters, vol. 29, pp. 209-213, 2022.