

# L2D2: Learnable Line Detector and Descriptor

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## Goal and Applications

*Detect* and *match* repeatable line segments

A repeatable line is a line which can be detected on **multiple images**

- ❖ Many handcrafted/deep features were proposed for keypoints, only a **few methods** exist for line segments detection and matching
- ❖ Line segments are commonly found in **man-made environments**, in particular **urban scene**
- ❖ No solution **focuses** on **line-based** camera pose estimation and tracking using **repeatable** lines.

Contributes to:

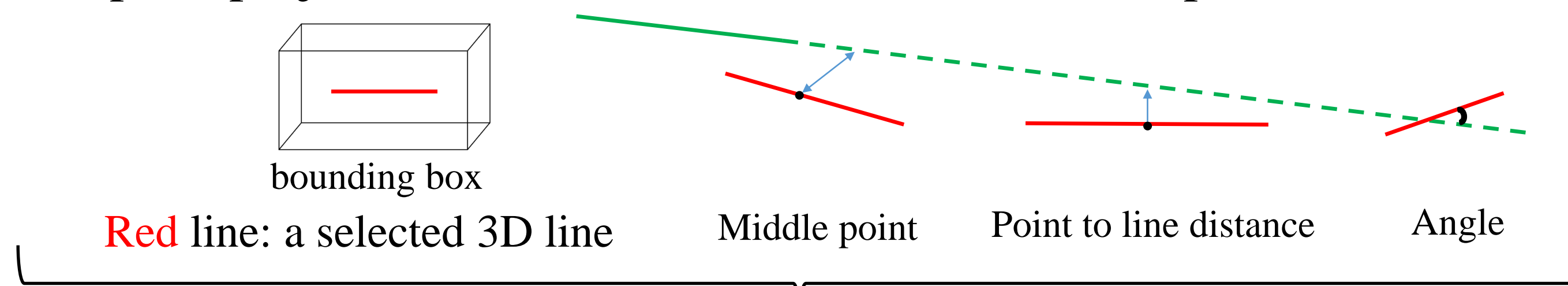
- Navigation
- Localization
- Visual Odometry
- Pose estimation and tracking

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## Automatic Training Data Generation

We proposed a novel fully automatic procedure to generate **training data** from datasets with 2D images and 3D point cloud

1. Detect lines on all 2D images (length  $\geq 48$  pixels)
2. Project 2D lines (in all images) into the 3D point cloud using the **ground truth pose**
3. Group the projected 3D lines then fit a line to their 3D points.



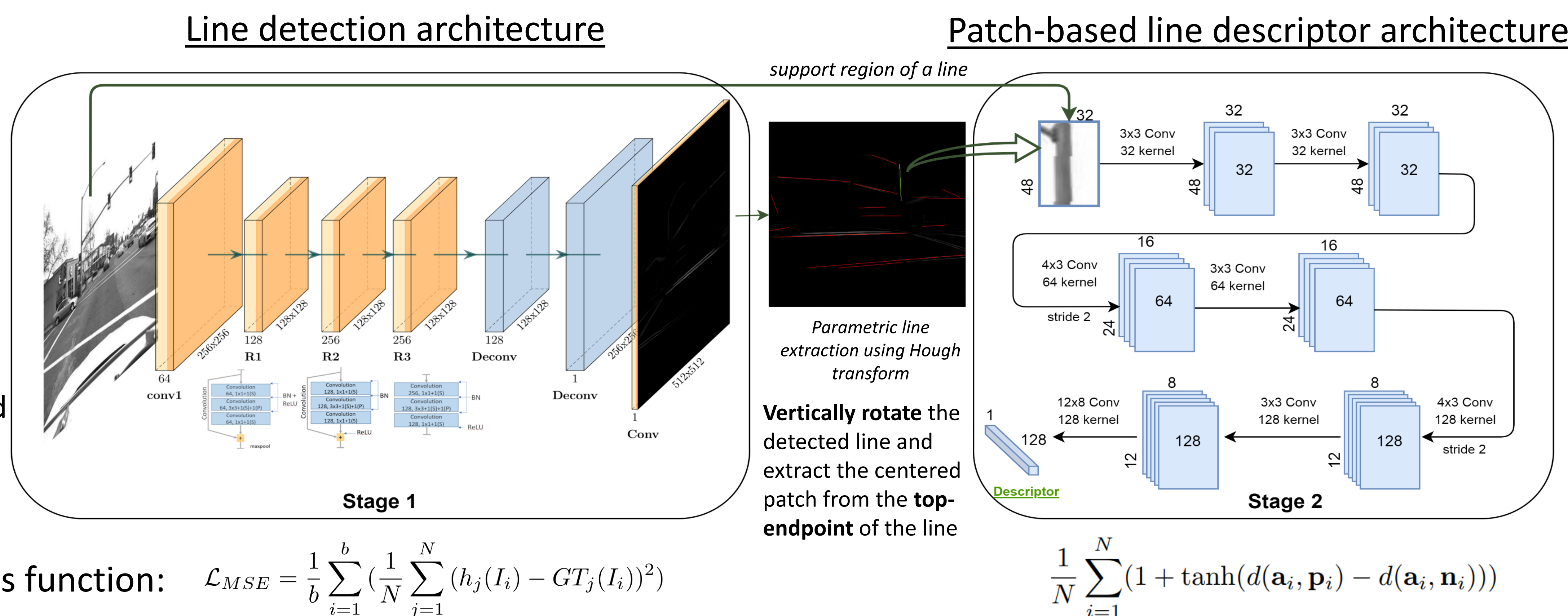
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## Proposed Solution: A 2-stage Network Named L2D2

A **lightweight** architecture inspired from the wireframe network

**Input:** 512x512 grayscale image

Trained with ground truth images that contains **repeatable** lines



An adaptation of the RAL-Net architecture

**Output:** L2 normalized 128D descriptor

Trained with triplet-based loss, using batches of anchor, positive and negative 2D lines

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## Experimental Validation

### Evaluation of the Detector Only

**Top part of the table** is the detected line segments with each SotA methods and how many unique infinite lines they belong to

Statistics/Detector	L2D2	SOLD2	EDLines
detected line segments	<b>73,063</b>	70,836	66,887
unique infinite detected lines	<b>59,395</b>	53,381	44,485
percentage	<b>81.29%</b>	75.36%	66.51%
validated line segments	10,685	13,552	<b>17,771</b>
unique infinite validated lines	9,785	11,771	<b>13,762</b>
percentage	<b>91.58%</b>	86.86%	77.44%

In the second part of the table, we have the validated line segments which are repeatable lines supported by the point cloud

**EDLines** detects more lines but, **L2D2** detects the longest line segments and has the highest ratio of detected individual repeatable infinite lines, that are more useful for real applications like pose estimation

### Evaluation of the Descriptor Only

#### Pairwise Matching

Matching ratio on 45000 image pairs

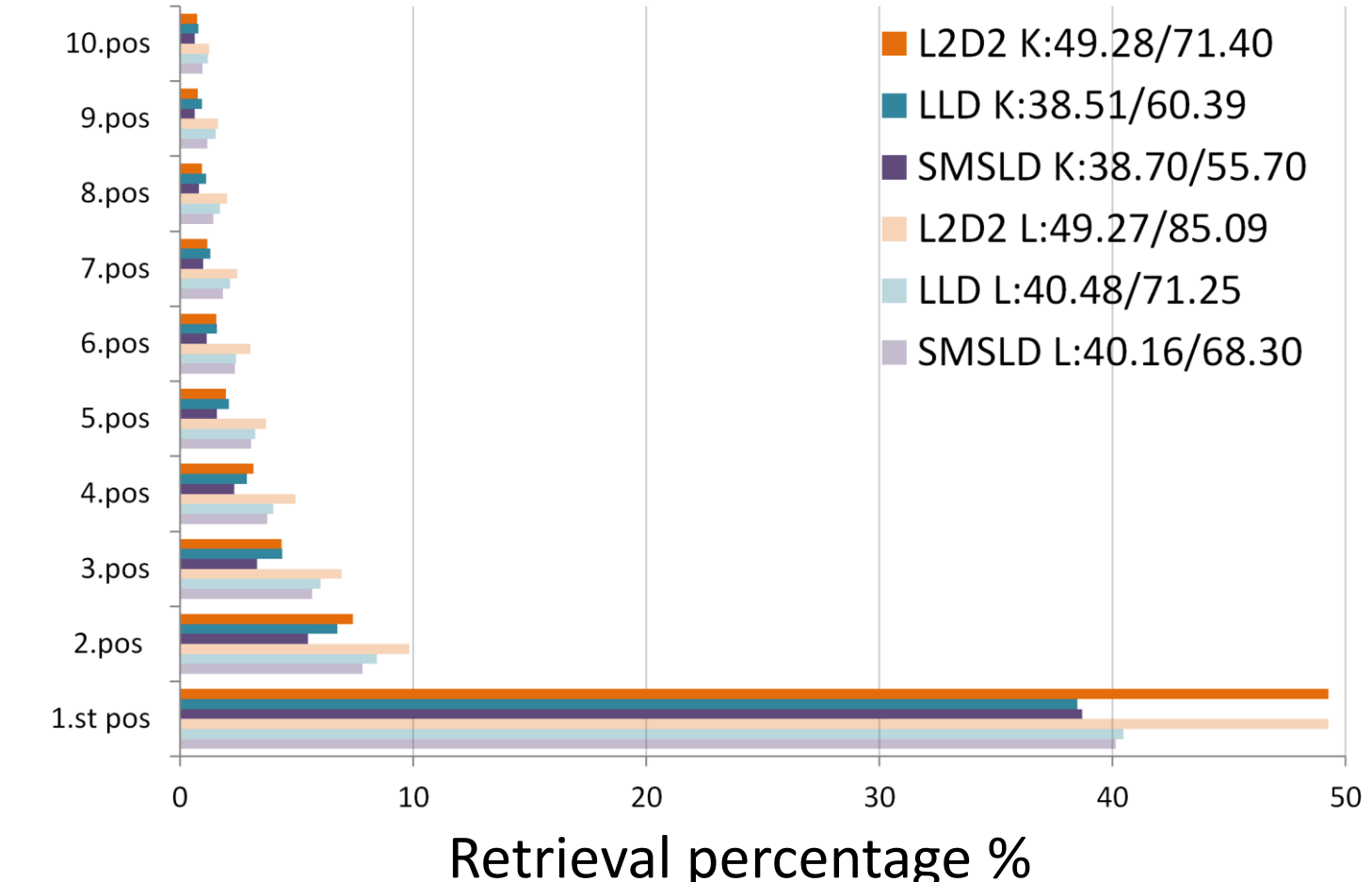
	Matching %	Matching % With $\tau$
<b>L2D2</b>	<b>79.92%</b>	<b>93.17%</b>
<b>SMSLD</b>	74.40%	87.69%
<b>LLD</b>	73.75%	78.27%
<b>SOLD2</b>	73.05%	73.05%

Number of correct matches found over the number of true line- pairs in an image pair

$\tau$  threshold value set to drop maximum 10% of the correct matches

#### Retrieval from a large image dataset

##### Global matching performance



First position percentage / first 10 position percentage %

K: KITTI dataset

L: Lyft dataset

### Full Detector-Descriptor performance

Compared **L2D2** with :

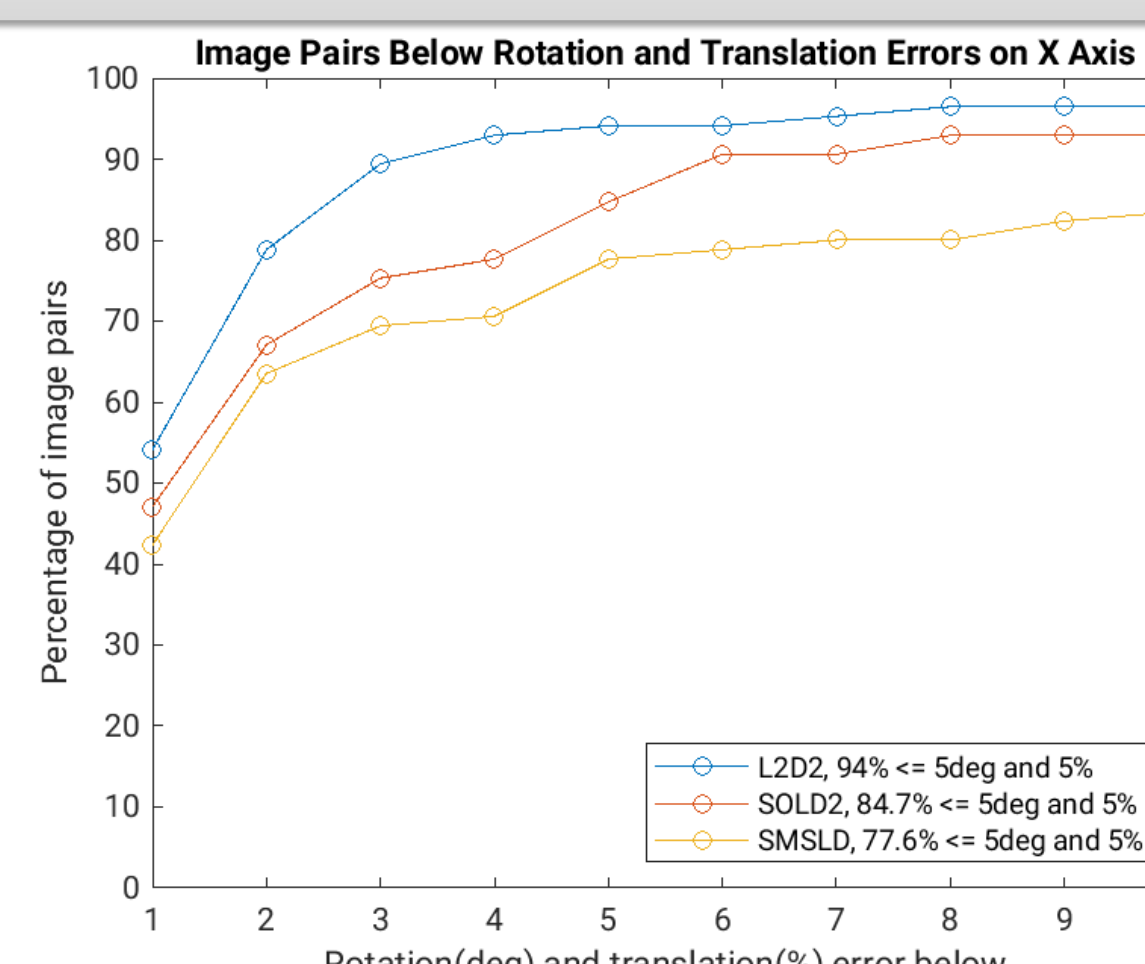
- SotA full pipeline detector-descriptor: **SOLD2**
- **EDLines** detector combined with **SMSLD** descriptor

Detector-Descriptor	Line Matching %
<b>L2D2</b>	<b>84.08%</b> (5398 / 6420)
<b>SOLD2</b>	70.15% (5685 / 8103)
<b>EDLines with SMSLD</b>	74.78% (8667 / 11590)

Line matching percentage % (correctly matched lines/total matched lines)

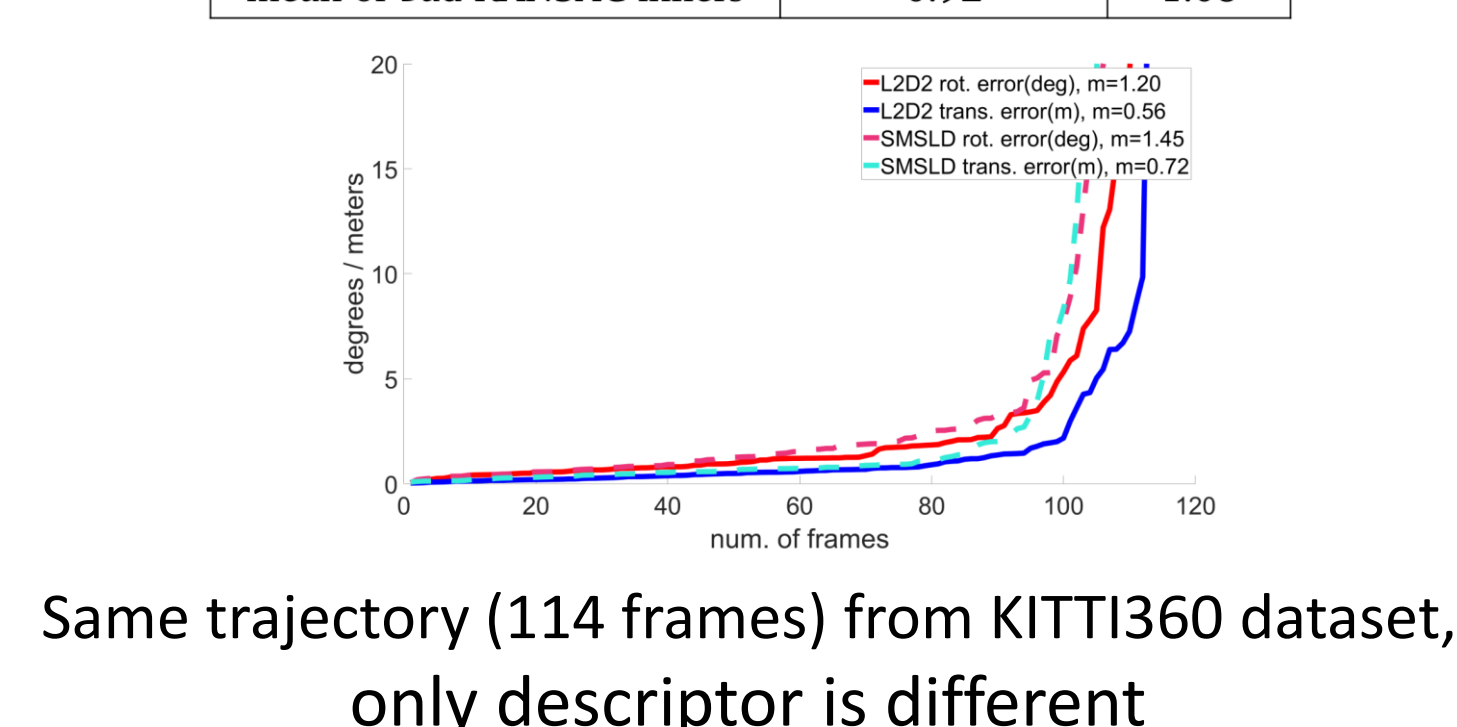
**L2D2** detects repeatable lines that are robustly matched

### Pose Estimation and Pose Tracking



Comparison on the same 85 image pairs from KITTI dataset

	L2D2 descriptor	SMSLD
% of good poses	69.3%	59.65%
% of bad poses	3.3%	10.53%
mean of good matches	8.87	10.49
mean of bad matches	3.3	7.17
mean of good RANSAC inliers	5.96	6.93
mean of bad RANSAC inliers	0.92	1.08



Wireframe: Kun Huang *et al.*, CVPR2018.

RAL-Net: Xu *et al.*, ACCV2019.

EDLines: C. Akinlar and C. Topal, ICIP2011.

SMSLD: Verhagen *et al.*, WACV2014.

LLD: Vakhtitov and Lempitsky, IEEE2019.

SOLD2: Pautrat *et al.*, CVPR2021.

KITTI: A. Geiger *et al.*, CVPR2012.

KITTI360: Yiyi Liao *et al.*, 2021.

Lyft: R. Kesten *et al.*, 2019.

## Conclusion

**Proposed** a novel 2-stage CNN  
Stage1: Repeatable line **detector**  
Stage2: Robust line **descriptor**

**Proposed** an automatic training data generation that provides **2D-3D line pairs**, the **algorithm** can be adapted to other datasets.

**Improved** and **outperformed** the State-of-the-Art in terms of

- Repeatable line detection and matching
- Line matching on image pairs and line retrieval from a database
- **Especially** in the line-based pose estimation and tracking

#### Acknowledgements:

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