Grid-wise Normalization for Local Feature Detection in Thermal-Infrared Image

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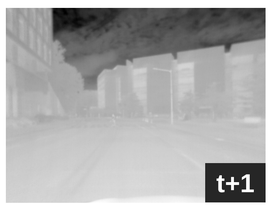
Motivation

Local feature detector is one of the essential modules in Visual SLAM.

- Feature Tracking (visual odometry), Feature Aggregation (vocabulary-based place recognition)

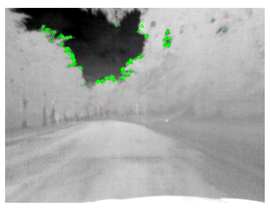
Why is it difficult to apply RGB feature detector to TIR (Thermal-Infrared) images?

- TIR image is 14-bit → contrast decreases when converting it into 8-bit via min/max normalization.
- Hot objects (cars, pedestrians, and sun) drastically decrease the contrast of whole image.
- Features are detected only on regions with high thermal contrast (hot objects and skylines).



Hot object (car) drastically reduce contrast of whole image

Keypoints only on hot objects



Keypoints only on skylines

What aspects should good TIR image feature detection module have?

- **Detect rich features in low-contrast area** (e.g. urban road with signs and texts).
- **Hinder hot objects from breaking average contrast level** of TIR images.

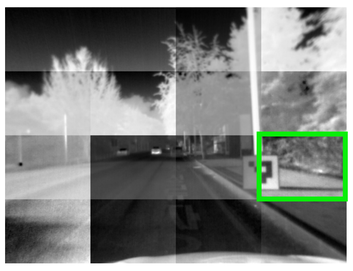
Method: Grid-wise Normalization

Since receptive fields of local feature detector are restricted to small areas,

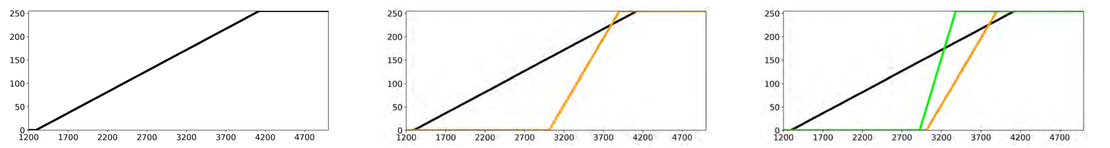
- min/max normalization for whole image is not efficient in perspective of feature detection.
- We thereby **divide TIR image into local grids (2x2, 4x4, e.g.)**
- and **use min/max value of local grid to normalize each grid**.
- Grid always has narrower min/max range than whole image → contrast of each grid is enhanced.
- Hot objects in one grid do not affect other grids → overall contrast level is preserved.

Whole-image Min/Max Normalization

2x2 Grid-wise Min/Max Normalization



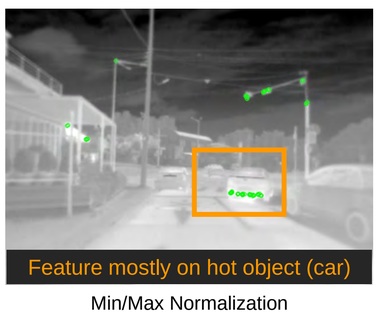
4x4 Grid-wise Min/Max Normalization



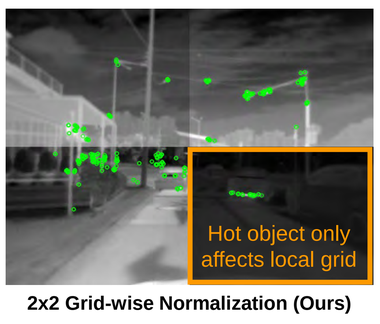
14-bit to 8-bit (linear) mapping function of min/max normalization. Grid-wise normalization shows narrower range and steeper slope.

Result

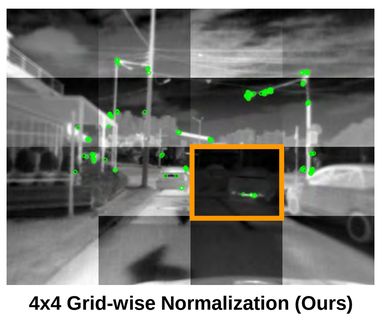
ORB Feature Detection



Min/Max Normalization



2x2 Grid-wise Normalization (Ours)



4x4 Grid-wise Normalization (Ours)

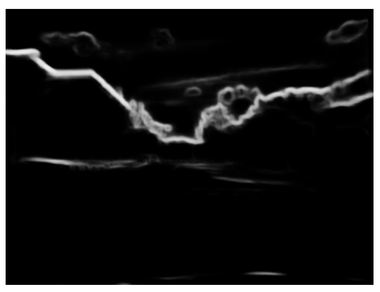
	Min/Max	2x2 Grid (Ours)	4x4 Grid (Ours)
KAIST 01 (morning)	131.8	**336.1**	**263.3**
KAIST 02 (afternoon)	178.2	**346.3**	**273.1**
KAIST 03 (night)	50.1	**188.1**	**231.6**

Table: Average number of detected ORB keypoints for each sequence in STheReO [1] dataset.

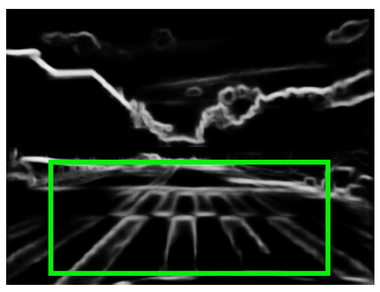
- Most features on min/max normalization lies on hot objects; but in our method, hot object only affects local grid and features in other grids are well detected.
- As a result, grid-wise normalization always detect more keypoints than min/max normalization.

Edge Detection

Original TIR Image



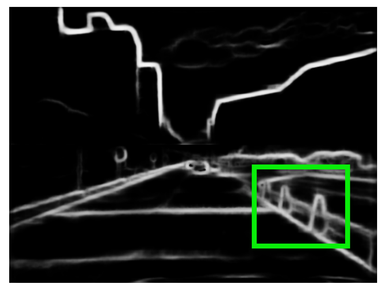
Min/Max Normalization



2x1 Grid-wise Normalization (Ours)

Original TIR Image

Min/Max Normalization

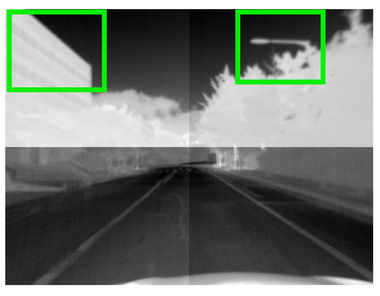


2x1 Grid-wise Normalization (Ours)

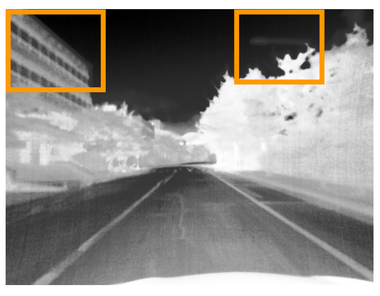
- While most edges of min/max normalized image were on the skyline, grid-wise normalization detects edges on lower contrast regions (road markers, lanes, and small objects).
- Grid-wise normalization can capture more valuable edges than original min/max normalization.

Comparison with Other Normalization Methods

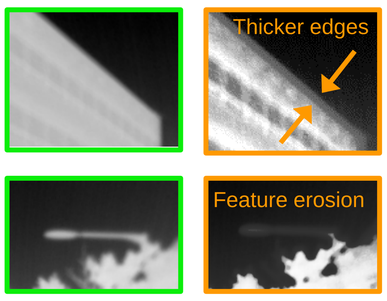
Histogram Equalization (HE)



2x2 Grid-wise Normalization (ours)



Histogram Equalization



‘Distorted’ edges in skyline

- Gradient of objects in skyline is overamplified → thicken the edges + erode thin objects.
- Grid-wise normalization is better at capturing rich features in skylines.

Contrast Limited Adaptive Histogram Equalization (CLAHE)

Sensitive to ‘clip limit’: small difference in value yields very different results

Fail to deal with hot object (sun)

- Sensitive to clip limit & Parameter-tuning is required for each sequence.
- Hot object affects whole image’s contrast: while grid-wise normalization does not.

Conclusion & Future Work

- In perspective of feature detection, grid-wise normalization outstands previous methods.
- Future work 1: Sophisticated grid division algorithm to minimize ‘blind spot’ for feature detection.
- Future work 2: Apply our module into feature tracking and aggregation of TIR SLAM pipeline.

Reference

[1] Yun, Seungsang, et al. "STheReO: Stereo Thermal Dataset for Research in Odometry and Mapping." *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2022.