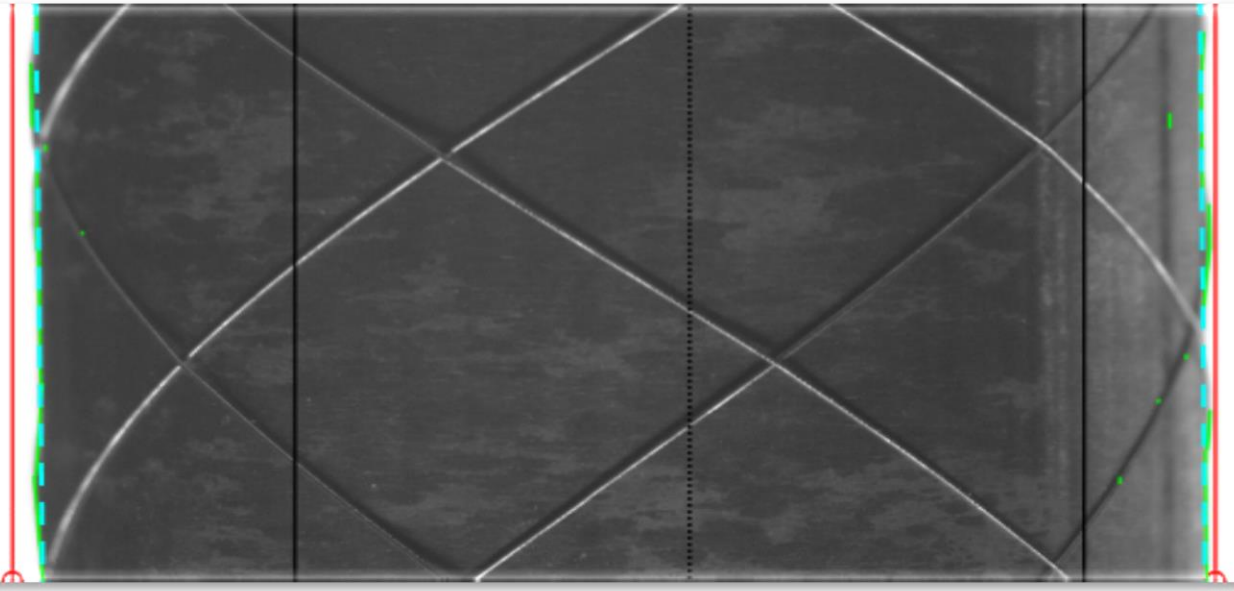
Institut für Technik der
Informationsverarbeitung

Directors
Prof. Dr.-Ing. Dr. h. c. J. Becker
Prof. Dr.-Ing. E. Sax
Prof. Dr. rer. nat. W. Stork
Supervising Tutors
Benedikt Haas

Master Thesis

Evaluation of Image-Based Approaches Extracting a Mandrel's Borders Using Machine Vision

cand. el. Dinggen Dai



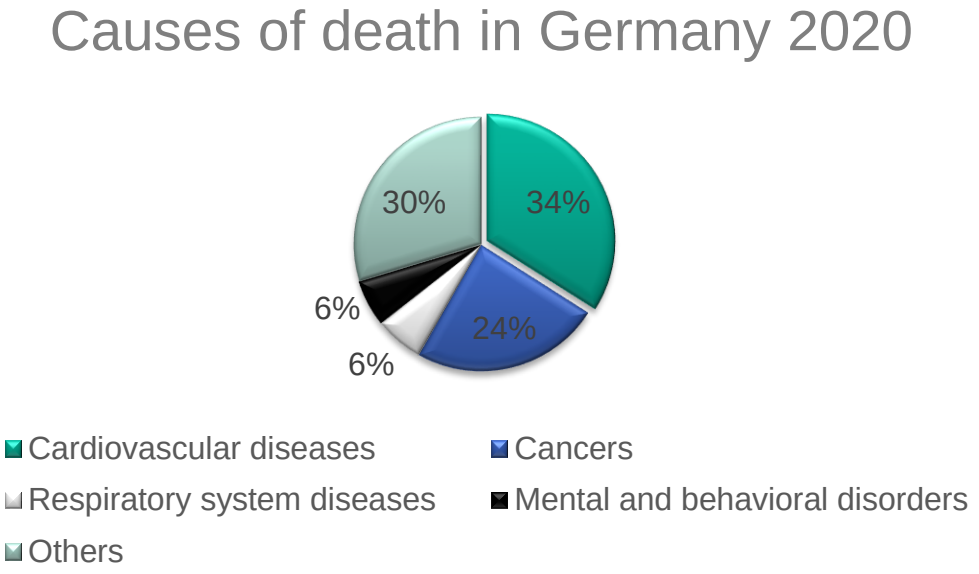
Structure

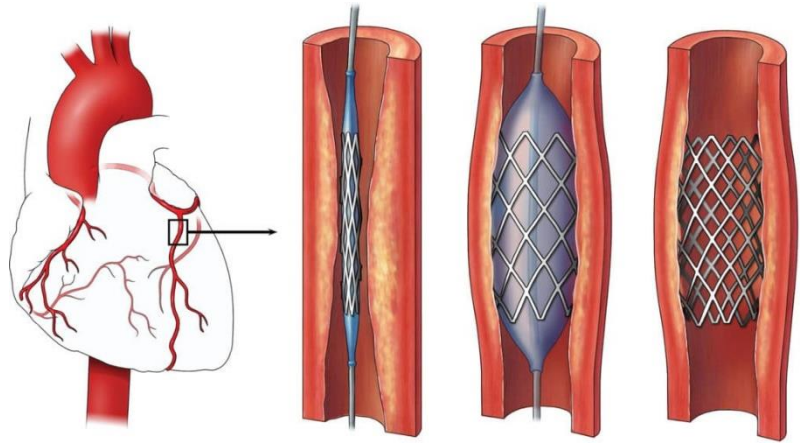
- 1 Motivation and Objective
- 2 Concept
- 3 Methods
- 4 Result and Evaluation
- 5 Conclusion and Outlook

1 Motivation and Objective

- Cardiovascular diseases caused 338,000 deaths [1]
  - 22.3% due to narrowing of heart disease vessels
- Treatable by stent implementation [2]

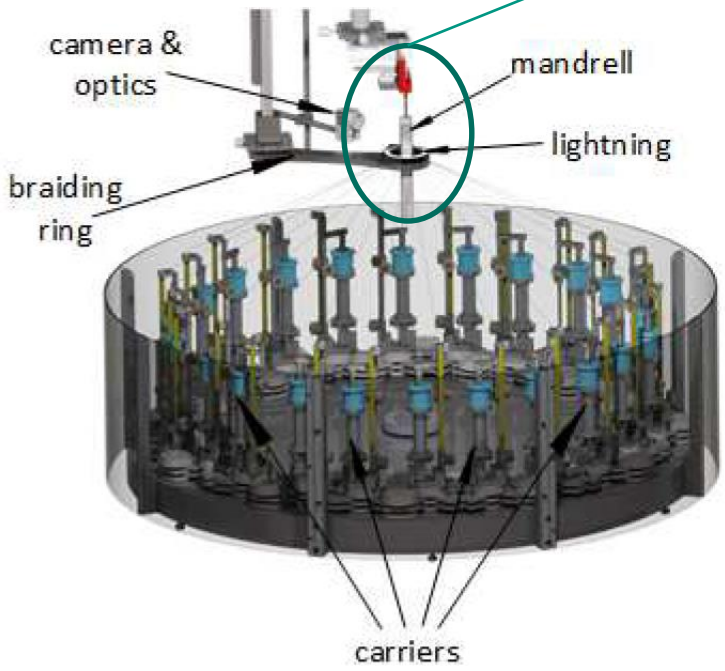
- Stent quality control in manufacturing is essential
  - manual inspection VS. **automatic inspection**





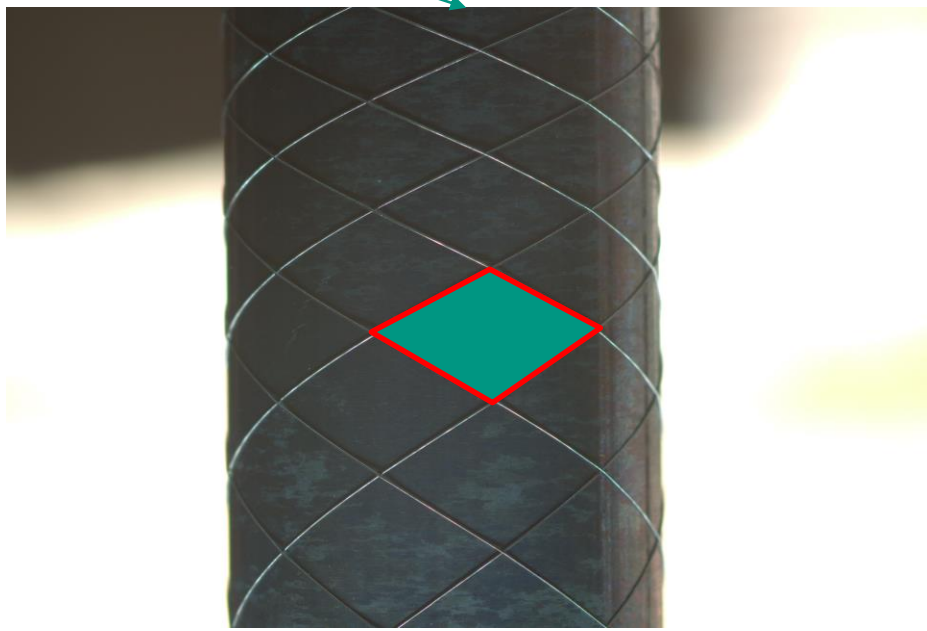
Stent implementation process [2]

Motivation: Stent4Tomorrow



manufacturing system [3]

visual inspection related parts of the system [3]

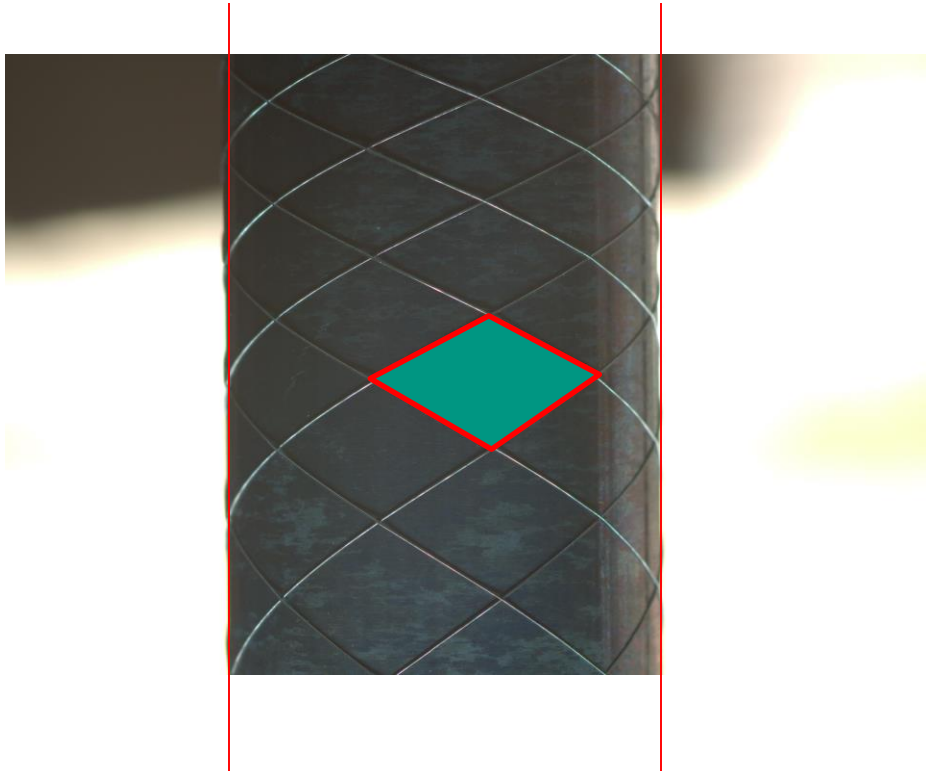


focus on the stent

Objective: Borders extraction

- Issue 1: the pitch size
  - how to “enlarge”?
- Issue 2: the background useless
  - how to remove?
- **Solution**: borders extraction!

- **Extra**: the diameter of the mandrel already known (in **mm**)
  - calculate the distance of the borders
  - build mapping relations between image (in **pixel**) and human perception (in **mm**)

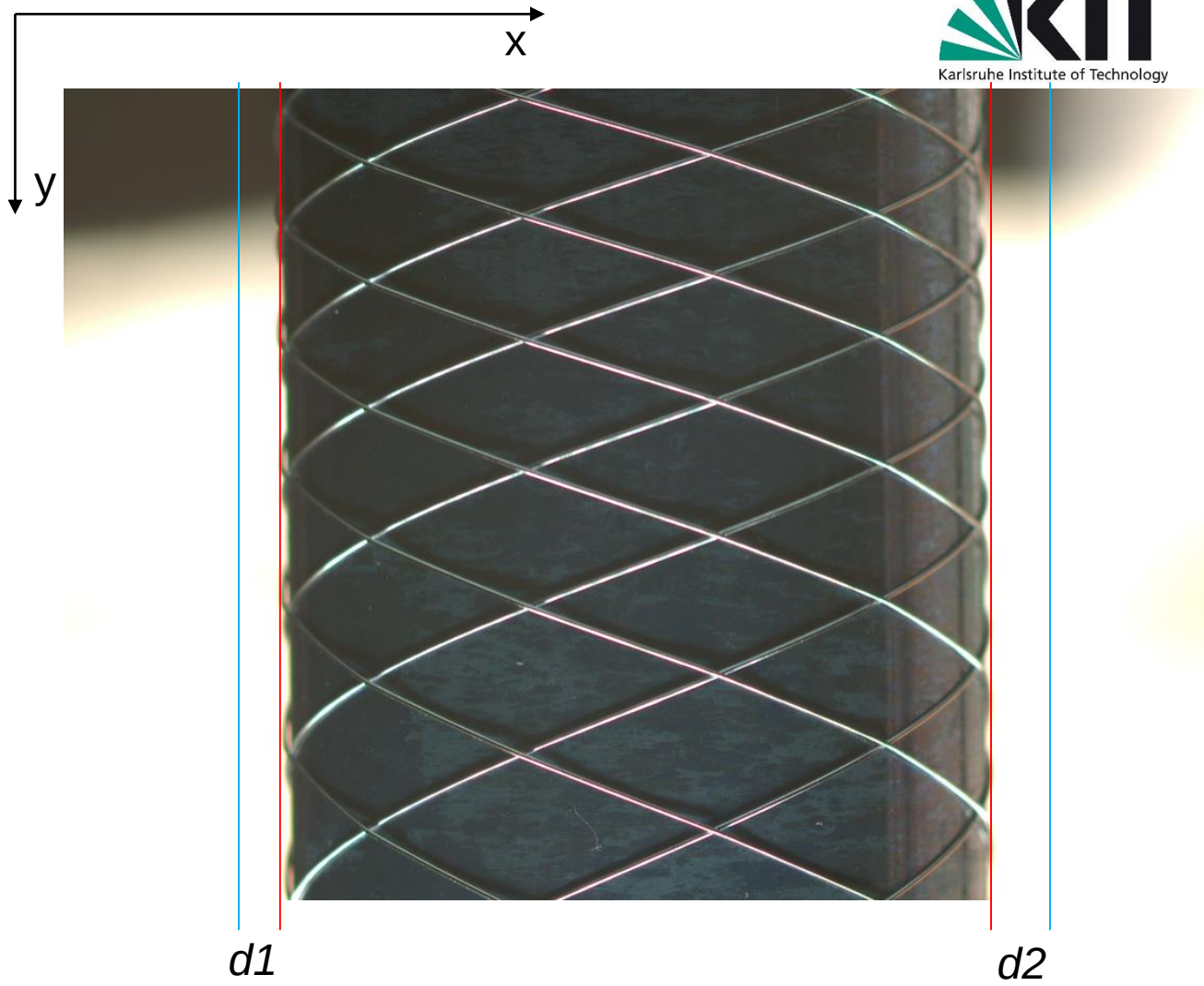


2 Concept

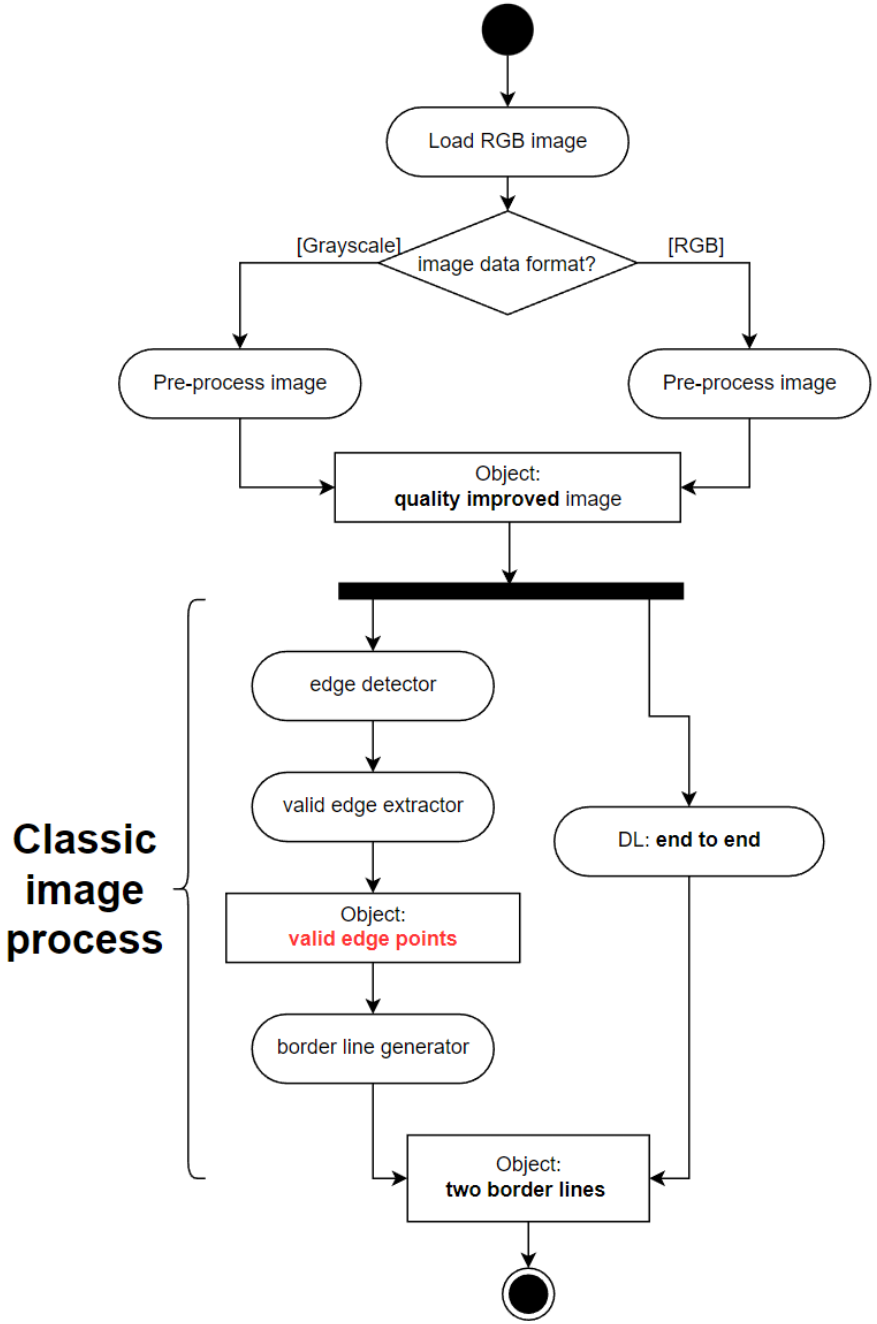
- **Assumption**:
  - the border lines are vertical to the x-axis of image

- Input: RGB image
- Output: two border lines

- Metrics:
  - 1. RSE (root square error): $\sqrt{d1^2 + d2^2}$
  - 2. Execution time

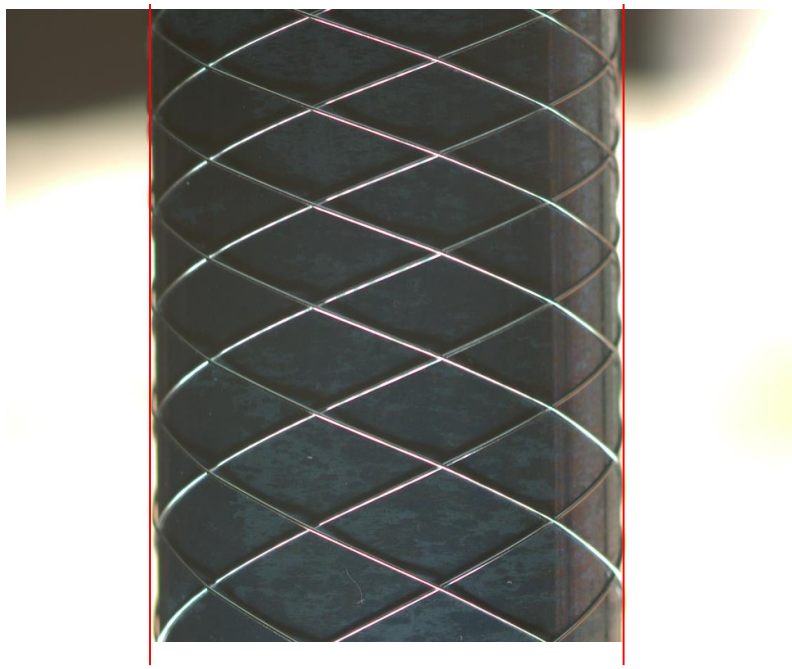


Concept: diagram

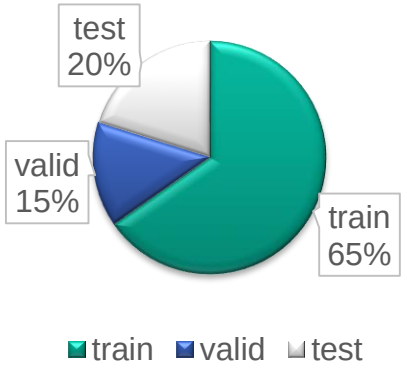


3 Methods: Dataset

- Original Image (RGB):
  - size: 2064*3088*3 (> 5 MB)
- The labels:
  - **two border lines** vertical to the x-axis
  - format: [x_left_border, x_right_border]
- Dataset splitting:



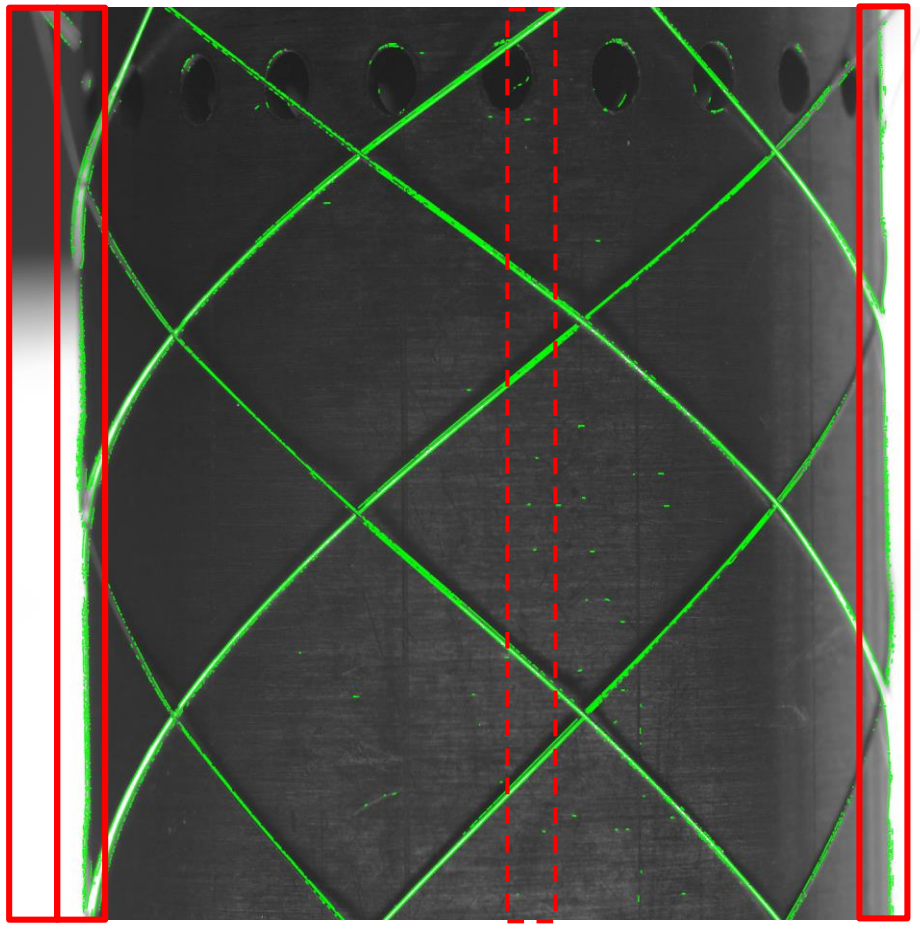
	Training	Validation	Test
Total	5529	1224	1694
Usable[1]	4881	1085	1508



1 Some images are truncated when being read

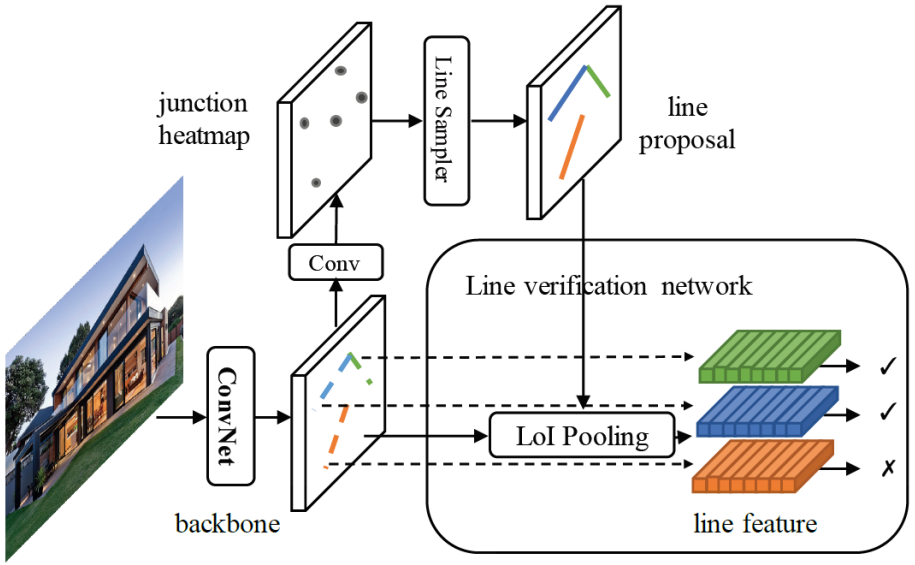
Method: classic image process

- **Step 1**. edge detector
  - Bottom-up approachs:
    - LSD (2010): still typical today [4]
    - EDLines (2011): 10 times faster than LSD [5]
    - Canny**PF** (2015): parameter free [6]
  - Top-down approachs: based on hough transformation
    - MCMLSD (CVPR 2017) [7]
- **Step 2**. valid edge extractor
  - filter: moving window
- **Step 3**. border line generator
  - least square method



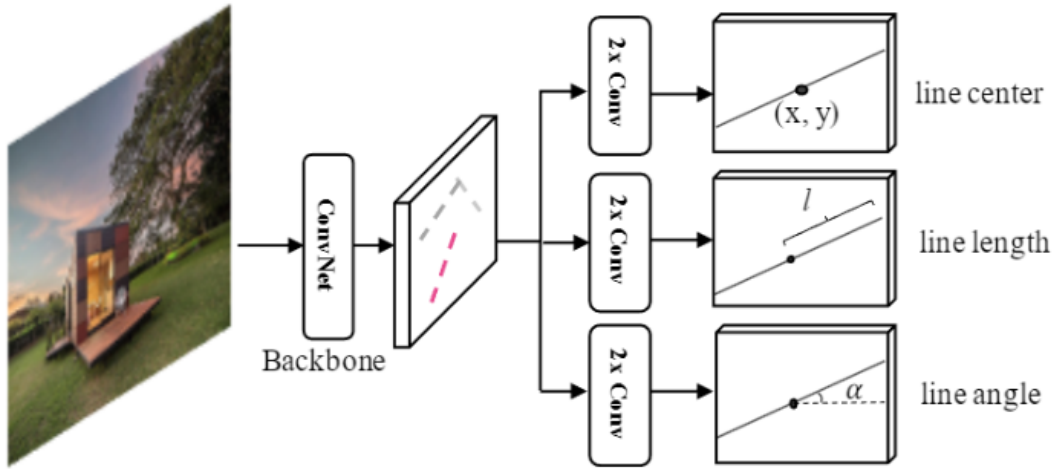
Method: deep learning

- HT-LCNN (ECCV 2020) [8]
  - based on LCNN (ICCV 2019)
  - add a trainable Hough transfrom block into a deep network



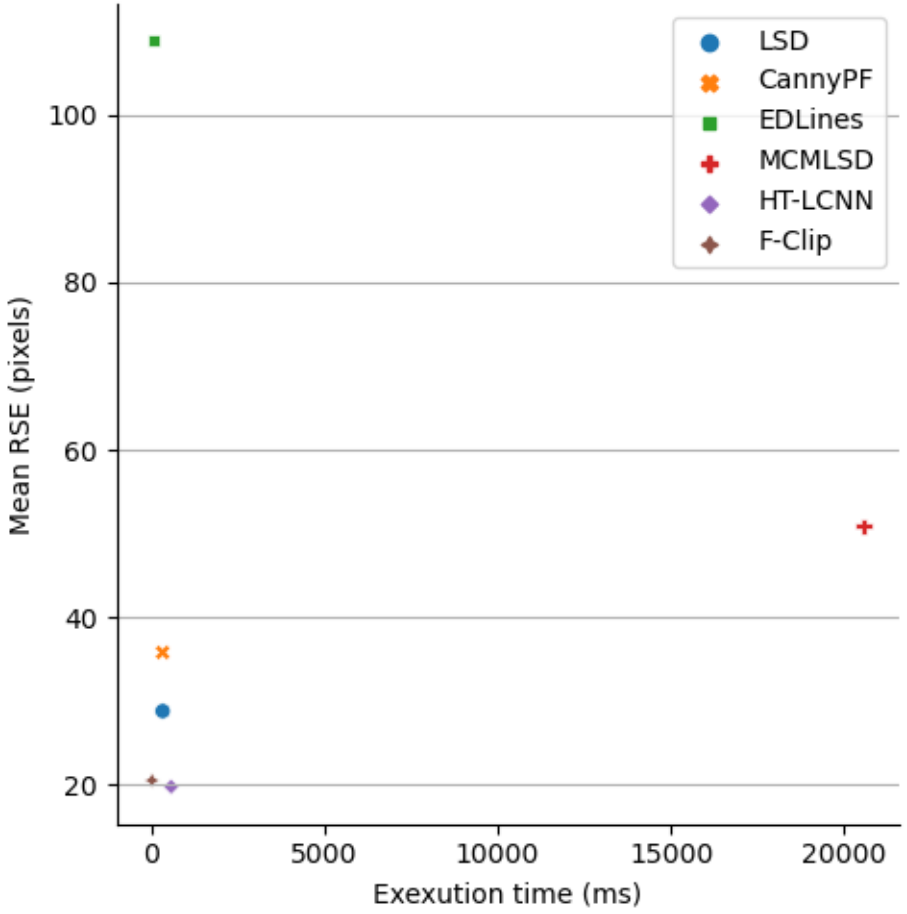
An overview of LCNN architecture

- F-Clip [9]
  - SOTA of line detectors (2021)
  - one stage: much more faster
  - the representation of a line

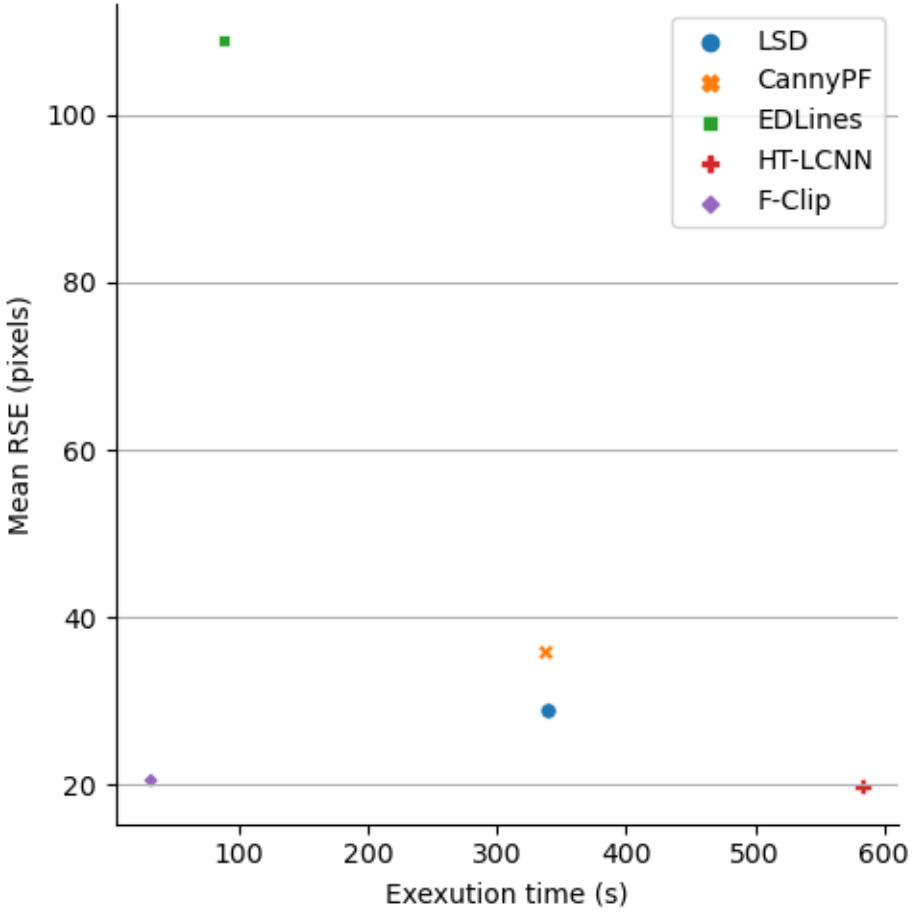


An overview of F-Clip architecture

4 Result & Evaluation

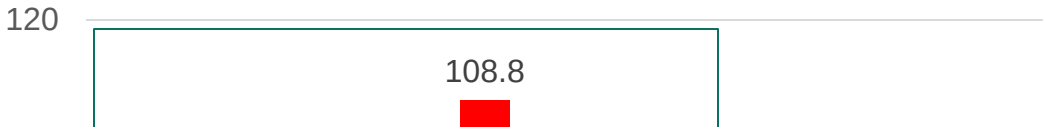


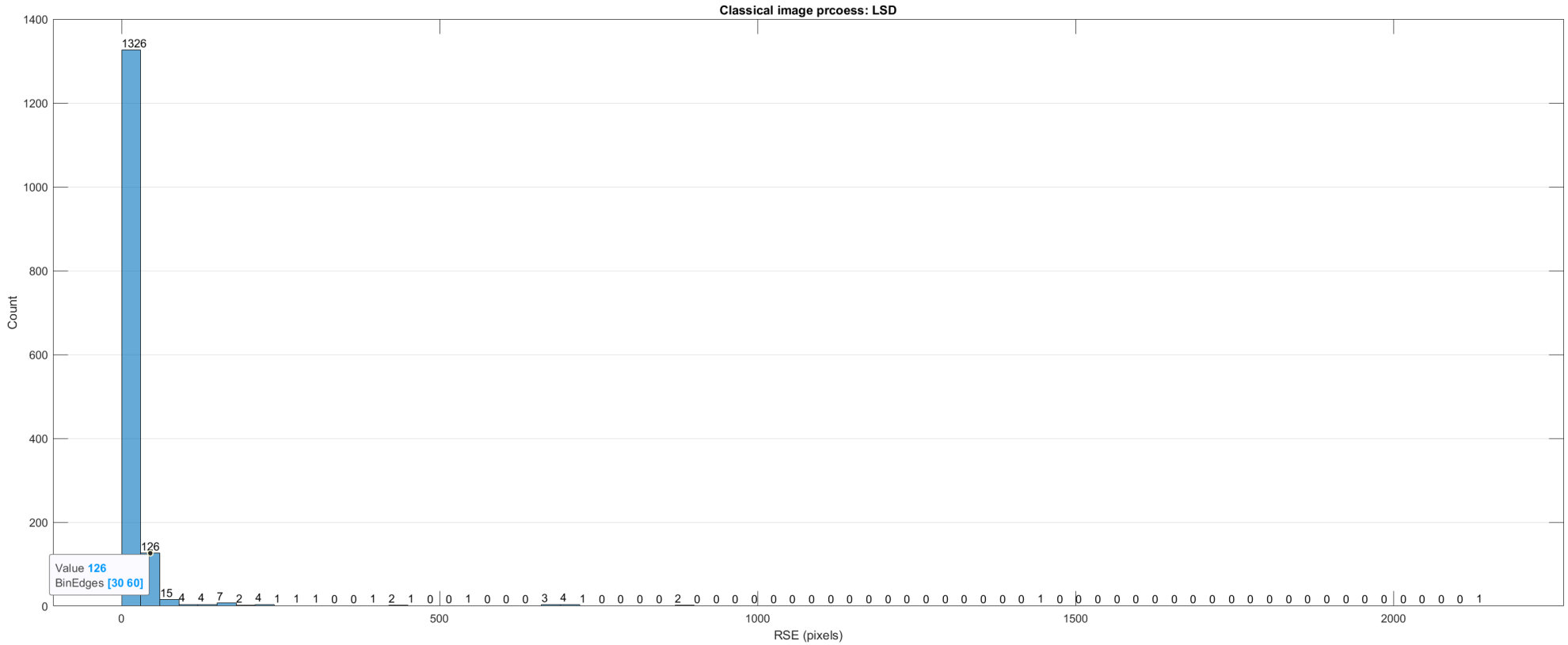
Without MCMLSD



Evaluation: RSE

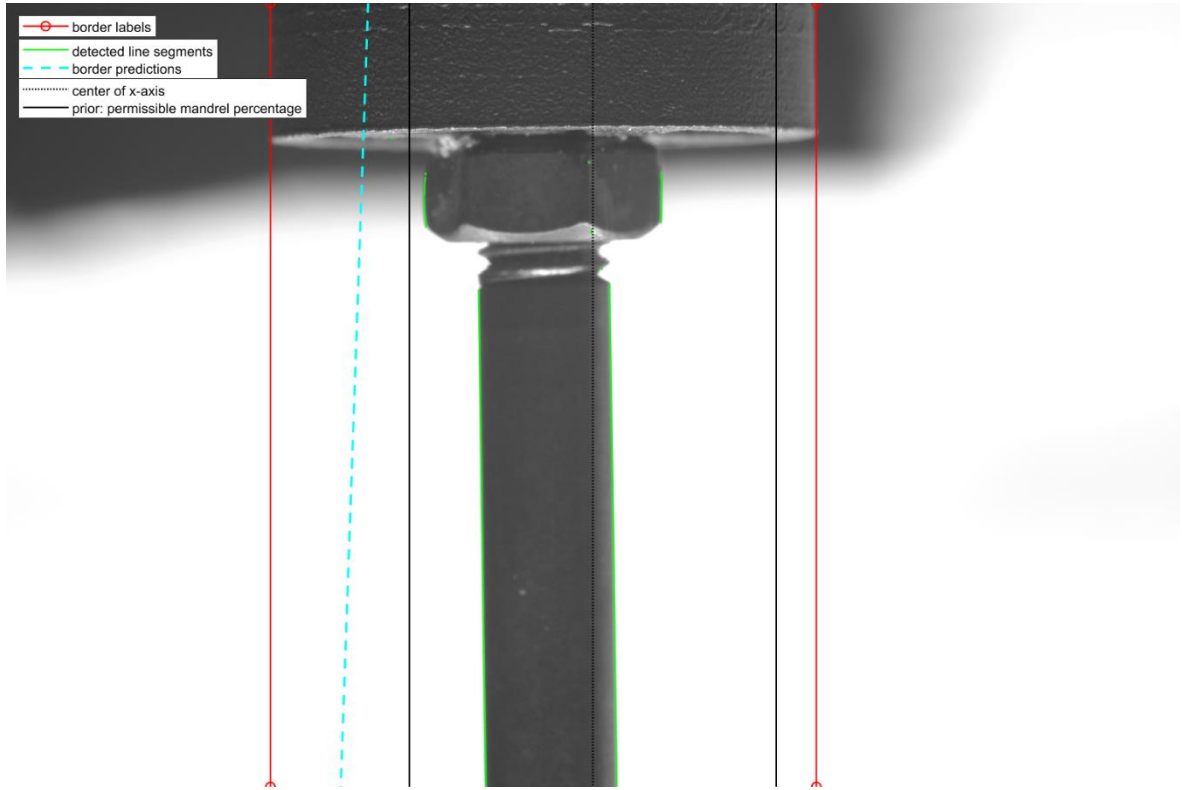
- Classic image process: LSD



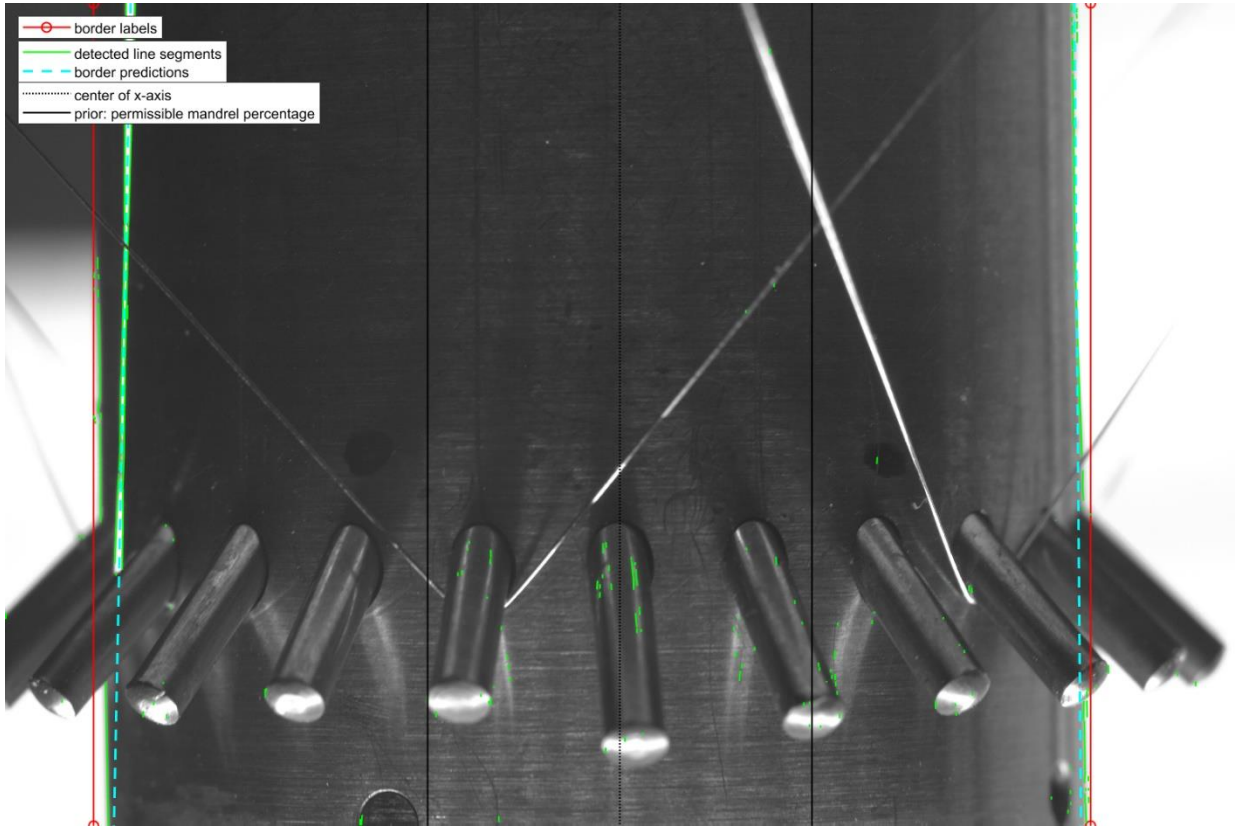


Evaluation: RSE

- LSD: 2 kinds of bad cases



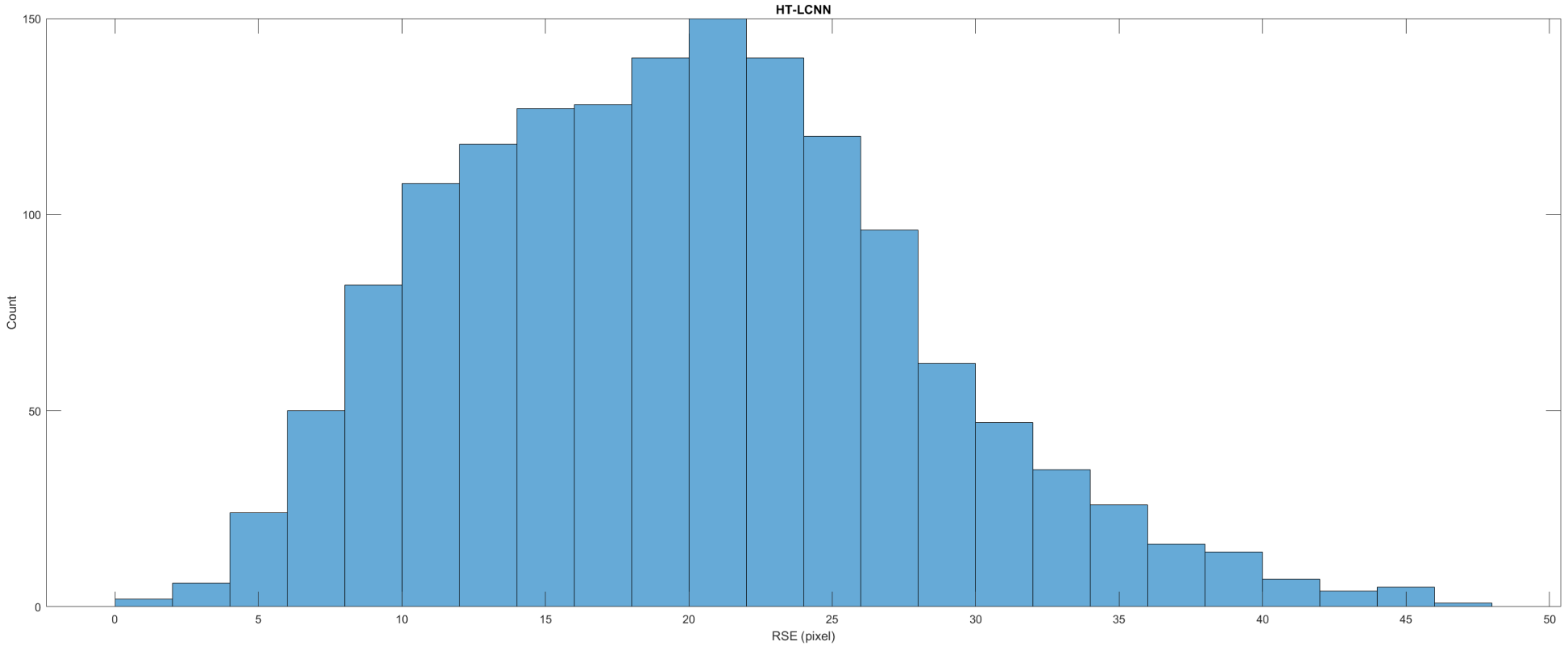
Case 1: no edge detected around the borders



Case 2: noise (stent wire) around the left border

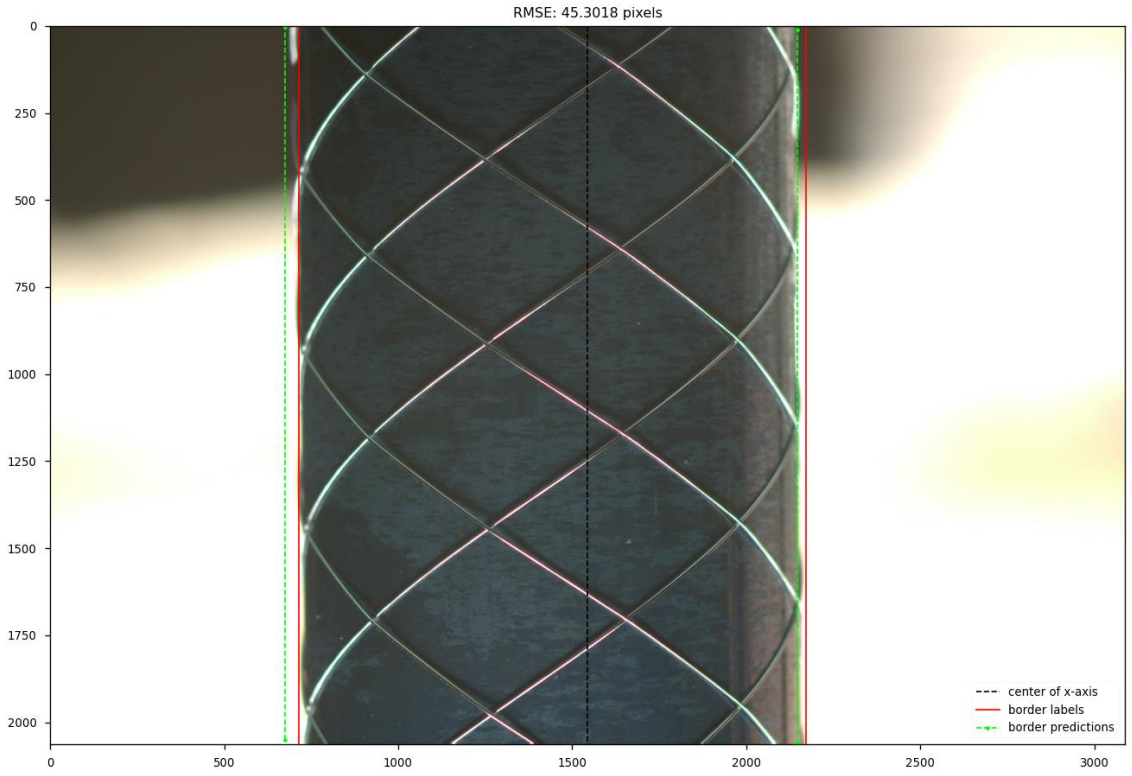
Evaluation: RSE

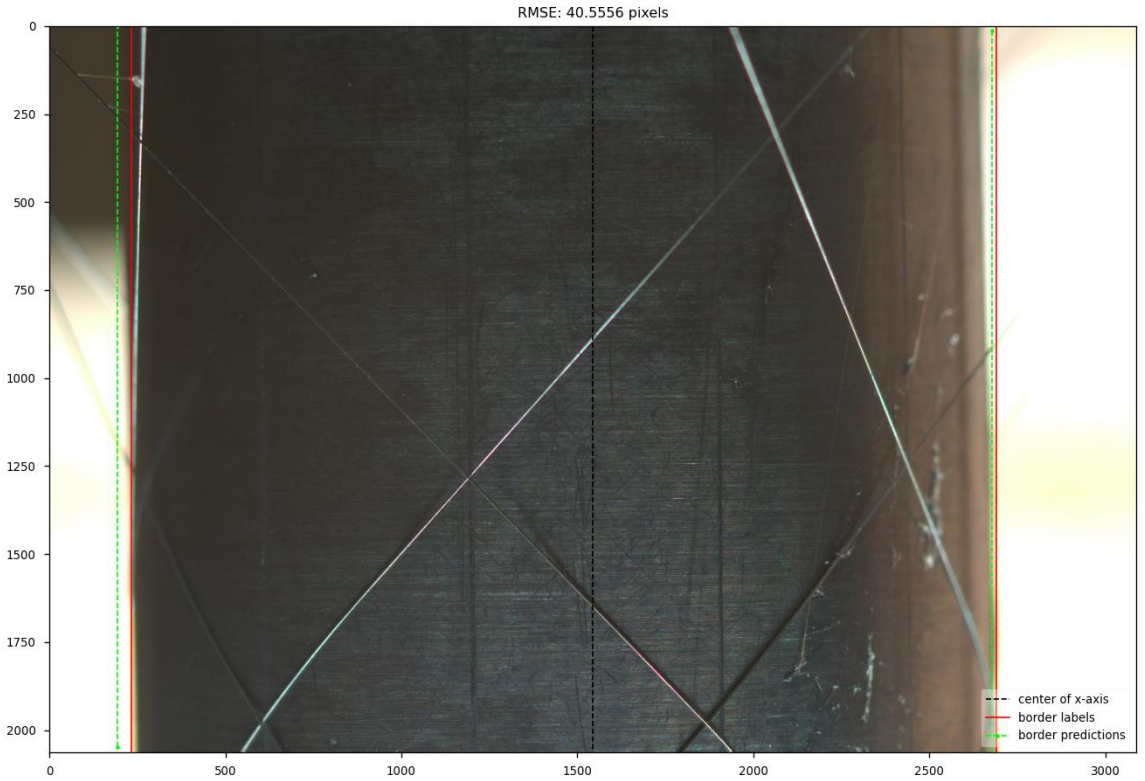
- Deep learning: HT-LCNN



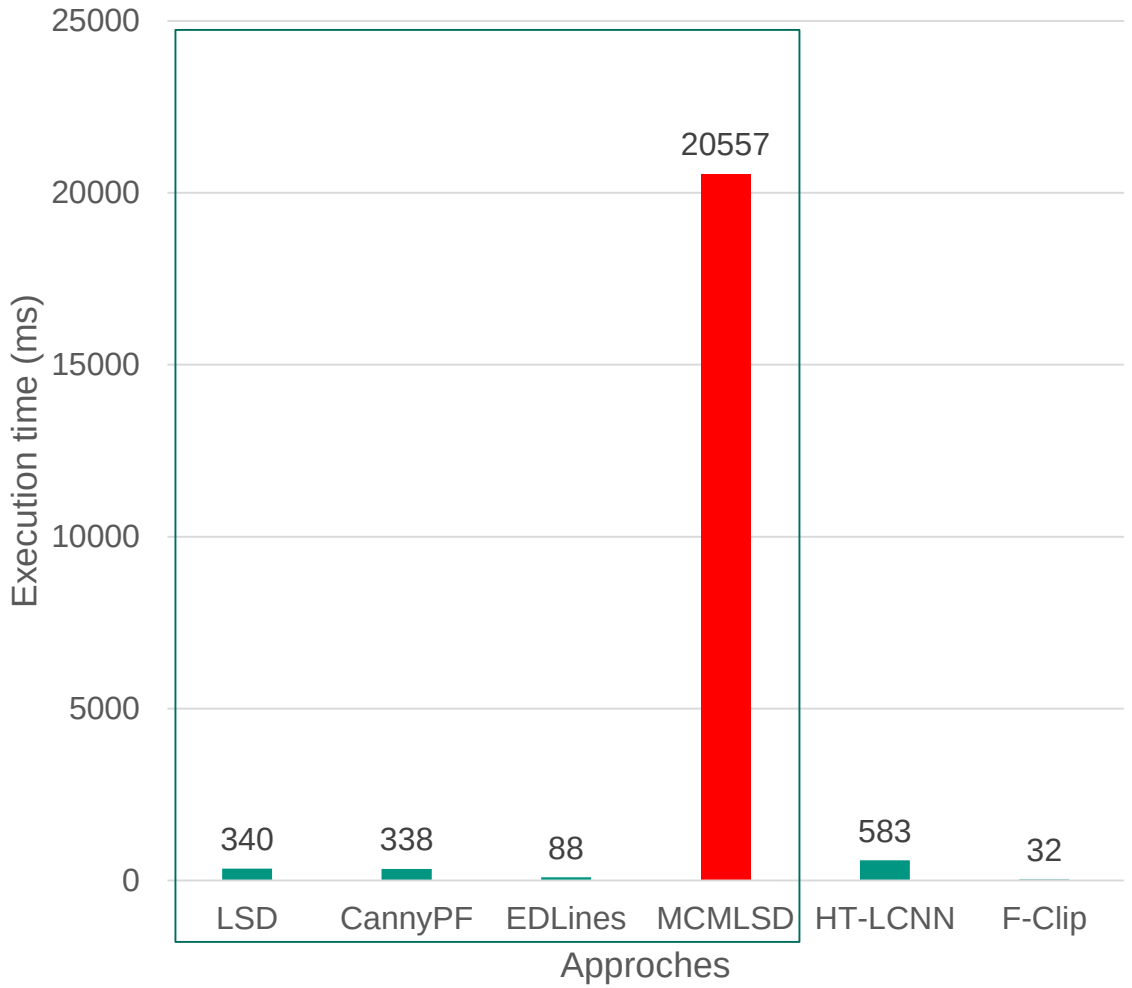
Evaluation: RSE

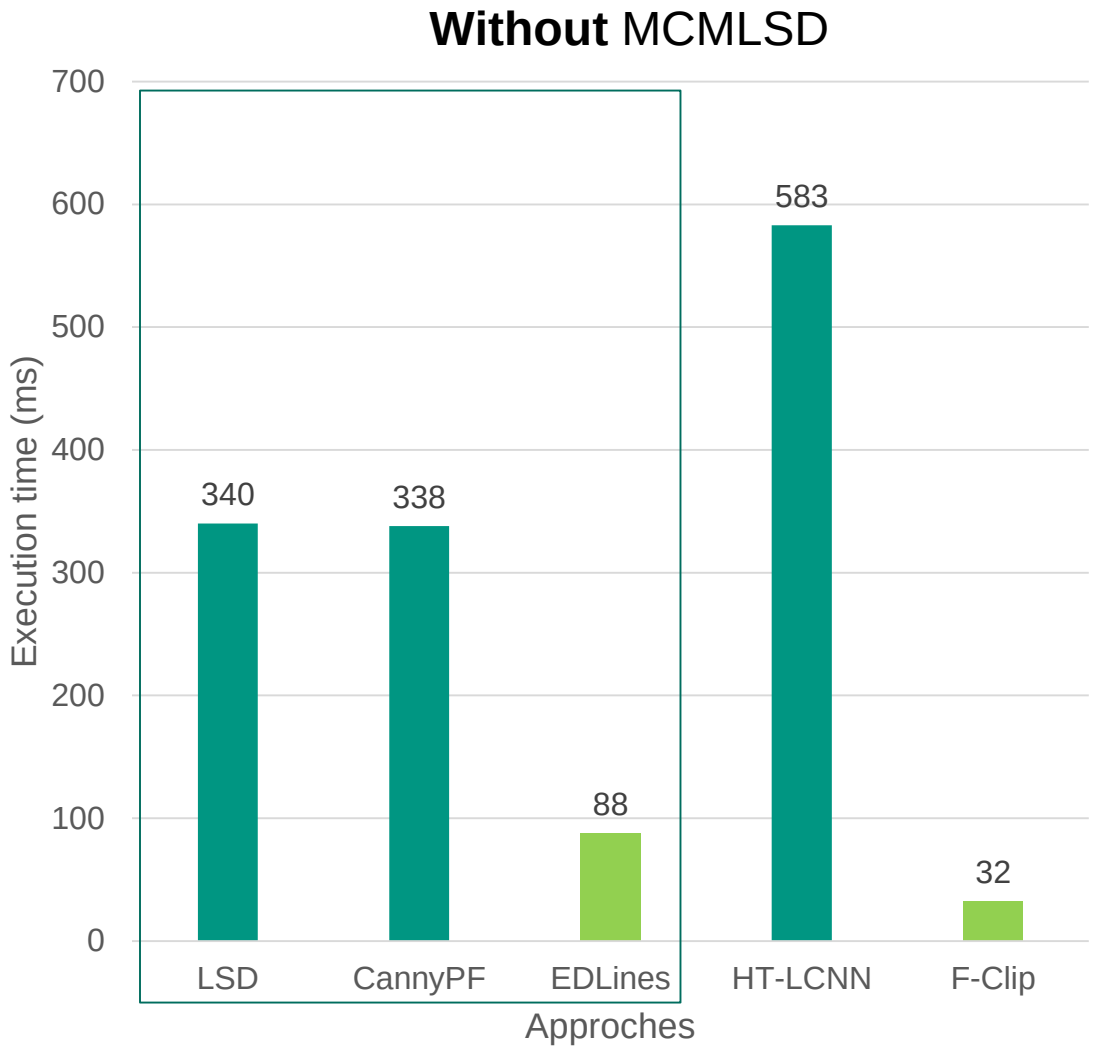
- HT-LCNN: the **predicted** left border line in the left side of the **labeled**





Evaluation: execution time



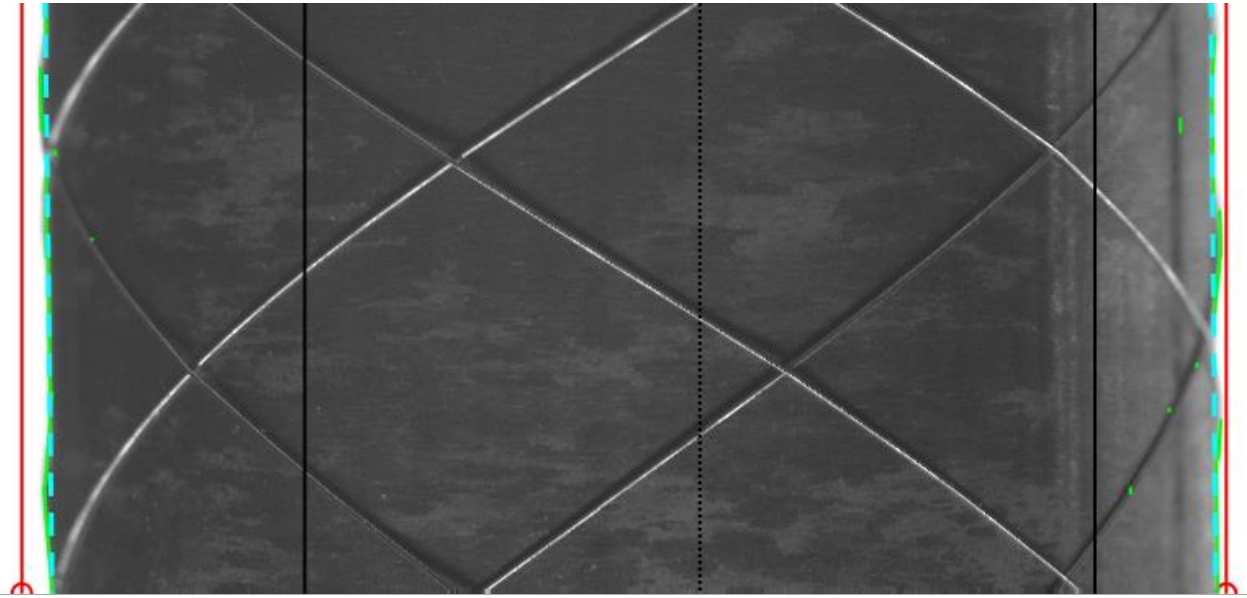


5 Conclusion and outlook

- Conclusion:
  - Implemented / reproduced 6 approches to detect the border lines
    - 4 in classic image process: LSD, EDLines, CannyPF, MCMLSD
    - 2 in deep learning: HT-LCNN, F-Clip
  - Metric RSE:
    - **DL models** show better performance: more **robust** to the noise
    - Lowest of all: **HT-LCNN** 19.77 pixels
    - Lowest of classic methods: **LSD** 28.8 pixels
  - Metric execution time: F-Clip is the fastest with 32 (ms / image)

- Outlook:
  - Classic image process: based on LSD, deal with the two bad cases (robust to noise)
  - Deep learning: try to use two junctions to represent a border line instead of the vertical line
    - compared to the top point of the left border (obstruction from the background), easy to percept for human being

Thank you for your attention!



Appendix - Reference

[1]