Automated crack advancement detection for small scale fracture experiments

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Introduction

Evaluation of in-situ fracture mechanical experiments require accurate and reliable knowledge about crack growth. At the micron to sub-micron scale crack extension is accessible via continuous stiffness measurements[1] (CSM) and/or image based observations. To capture crack growth on images, a high image acquisition rates are required. The standard method for image based evaluation (IB) is digital image correlation, which is hardly applicable and requires a distinct patterned surface. Hence, images are evaluated manually, which is a tedious and user-dependent task. In order to overcome this task, a novel algorithm is proposed which utilizes computer vision techniques.

Crack characteristics

Crack characteristics in fracture:

- crack length (CL)
- crack opening angle (COA)
- crack opening displacement (COD)

} depending on crack tip and crack flank

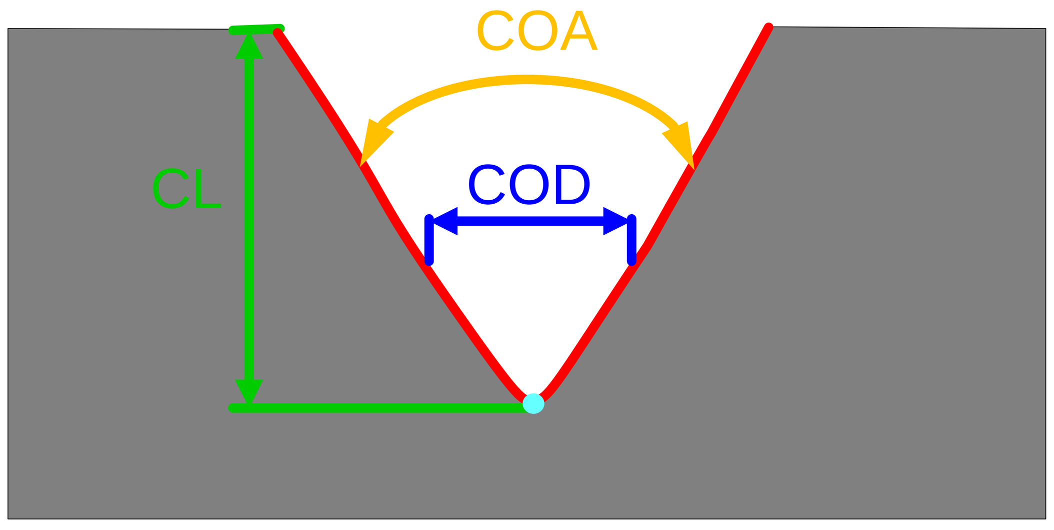

Figure 1: Crack characteristics in fracture mechanics.

Preprocessing steps for edge extraction

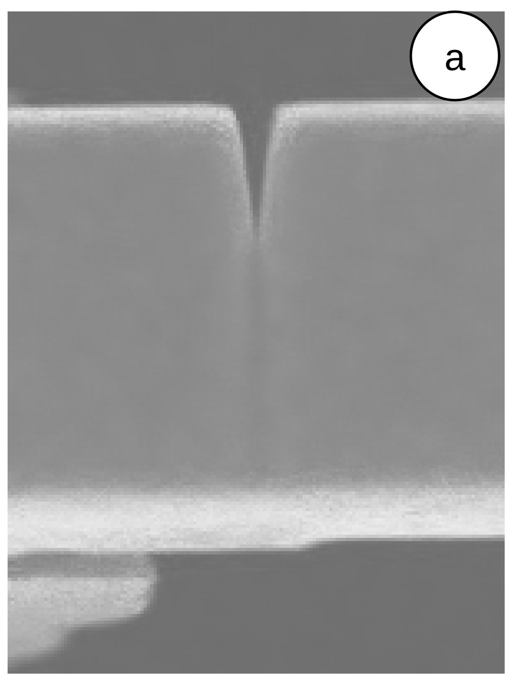

Figure 2a: Region selection

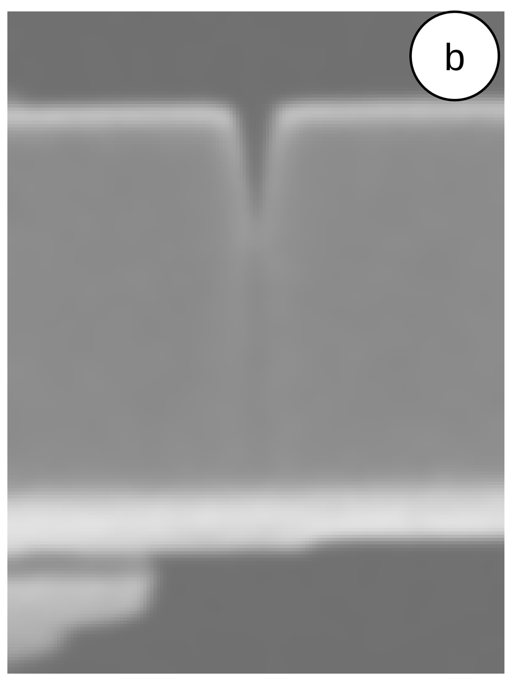

Figure 2b: Blur to reduce noise

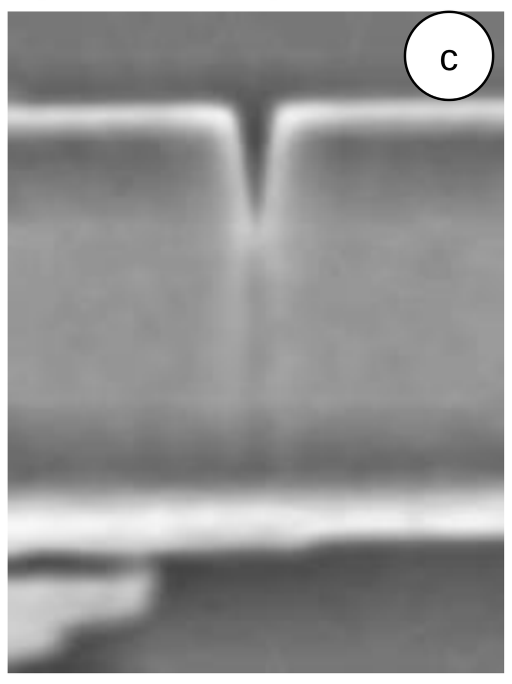

Figure 2c: Contrast enhancement[2]

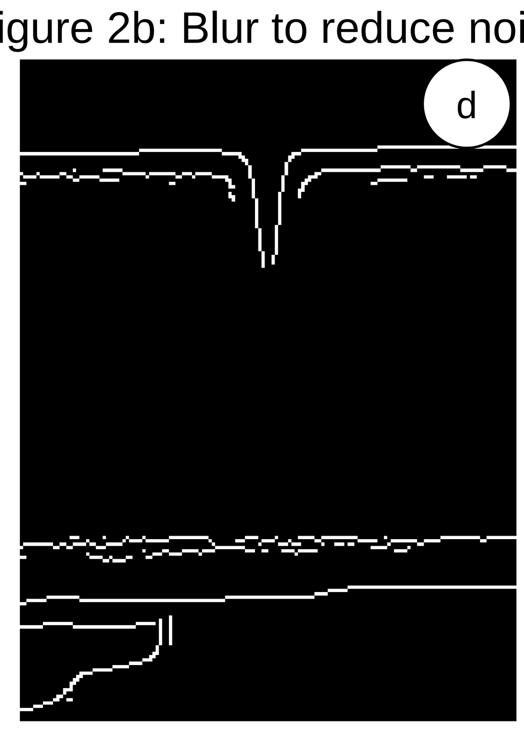

Figure 2d: Extract edges[3]

Crack length tracking

Crack length: distance between crack tip and sample surface
Initialization: Define point close to crack tip → used to determine crack flank by searching for closest edge line on first image.
Following images: Edge line which has lowest mean distance to previous crack flank = crack flank & lowest point = crack tip.

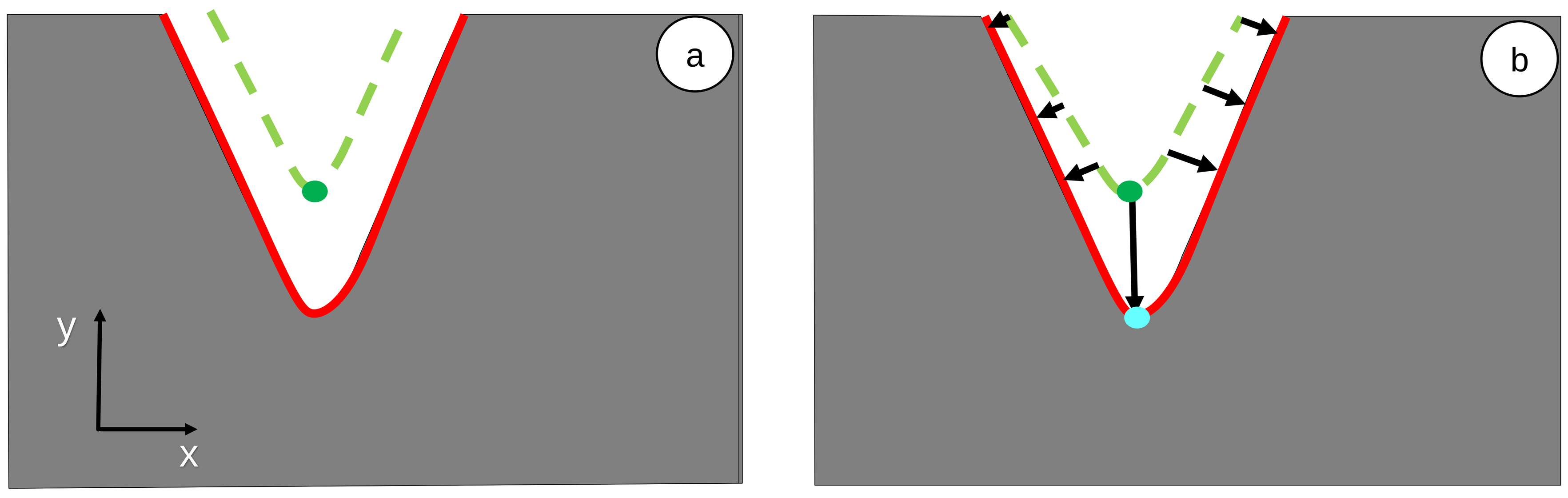

Figure 3: Schematic drawing of finding crack flank and crack tip on following frames.

Crack length comparison

a to b: CSM and IB give same crack length.
b to c: Burst is captured by both techniques.
c to d: IB estimates larger crack length compared to CSM.
Explanation: non-straight crack front & IB sees only crack cross section.

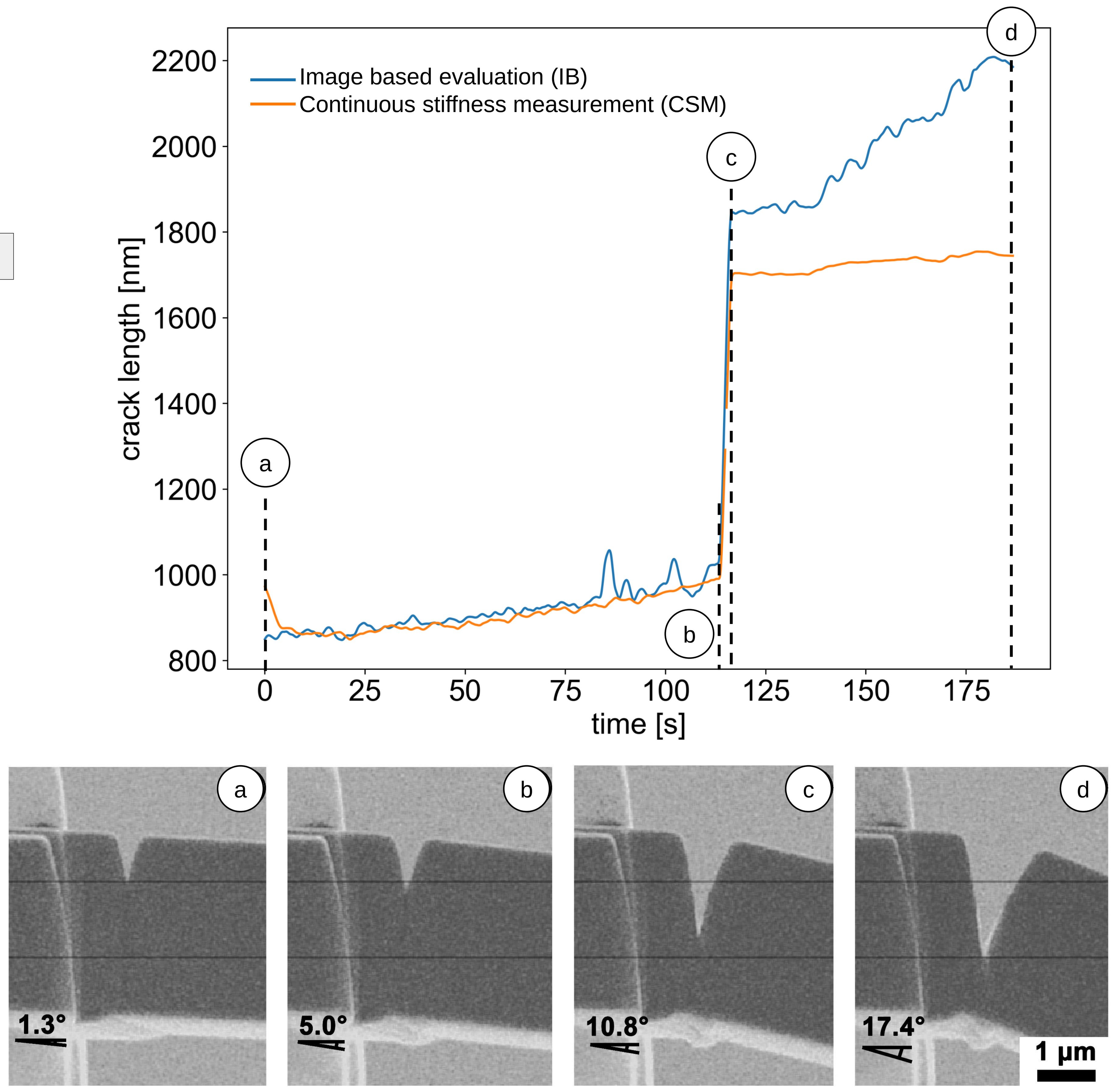

Figure 4: Comparing calculated crack extension from IB and CSM.

Conclusion

The proposed algorithm improves the manual image based crack extension evaluation by its speed, user-independents and reproducibility. Also the obtained crack length by the algorithm agree well with the calculated crack length from CSM signal. Due to its speed it is possible to consider all captured images, which allows for further fracture mechanical investigations. Further, improvements would be possible by additionally estimate COD and COA.

Literature

[1] M. Alfreider, et al.D. Kozic, O. Kolednik, and D. Kiener, "In-situ elastic-plastic fracture mechanics on the microscale by means of continuous dynamical testing," Mater. Des., vol. 148, pp. 177–187, 2018.
[2] S. M. Pizer et al., "Adaptive Histogram Equalization and Its Variations.," Comput. vision, Graph. image Process., vol. 39, no. 3, pp. 355–368, 1987
[3] J. Canny, "A Computational Approach to Edge Detection," IEEE Trans. Pattern Anal. Mach. Intell., vol. PAMI-8, no. 6, pp. 679–698, 1986.

Acknowledgement

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