GRADIENT AMPLIFICATION AND GRADIENT ORIENTATION IMPROVEMENTS OF CRATER DETECTION ALGORITHMS BASED ON EDGE DETECTORS AND RADON/HOUGH TRANSFORM.

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Summary: Six previously implemented Crater Detection Algorithms (CDAs) were improved using better edge detection, gradient amplification and gradient orientation. The results were analyzed using the Framework for Evaluation of CDAs (FECDA).

Introduction: CDAs' applications range from dating planetary surfaces [1] to advanced statistical analysis [2]. Overview of a large body of CDA-related literature is given in [3]. As noted [3], problems arise when evaluation results of some new CDA have to be compared with already published evaluation results. As a solution to this problem, the FECDA with the first test-field subsystem based on MOLA data has been proposed [3]. It includes: (1) 1/64° and 1/128° MOLA data; (2) the Ground-Truth (GT) catalogues with 17582 [3] and 18711 [4] craters wherein each was confirmed by N. G. Barlow et al. and J. F. Rodionova et al. catalogues; and (3) Topolyzer application for F-ROC evaluation. In the previous work [5, 6], in order to compare overall performance, six CDAs were implemented based on Radon/Hough transform (RH) and gradient edge detectors shown in Table 1. These six CDAs were already improved [7] using standard (non maximum suppression, hysteresis-based thresholding, different implementation of RH) and CDAs' specific (circular-consistency, slip-tuning) techniques. In this work, these six CDAs were additionally improved using better implementation of edge detection, as well as the gradient amplification and the gradient orientation based techniques.

Methods: The implementation of CDAs we are using is described in details in [7]. Here will be presented some additional improvements.

Edge detection improvement. Non-maximum suppression and hysteresis-based thresholding techniques introduced by Canny [8] were turned on for all CDAs, so that influence of newly added improvements can be properly tested in regime where CDAs provides maximal performance. During code review, the algorithm for selection of points for non-maximum suppression was improved. This resulted in better edge detection.

Gradient amplification based improvement. In classical RH implementation, during summation, each pixel from the edge is taken with weight factor 1. Instead, we are using actual value of the gradient, limited on a value that is for 1% larger then the optimal gradient which was used as a threshold.

Gradient orientation based improvement. Similarly with previous technique, gradient orientation was taken into account. For each pixel on the edge, the difference between the orientation of the gradient and the direction of the crater center was computed. Best results were obtained for weight factors 3, 2 and 1, when this difference, rounded to 16 discrete values, is 0, 1 and 2.

Results: The obtained results are shown in Table 1 (the optimal gradient is the same as in the previous work [7]). The analysis using F-ROC and detected edges are shown in Fig. 1. For evaluation of the results, from FECDA [3] the following were used: (1) 1/64° MOLA data; (2) the GT catalogue with 17582 craters as the last official version; and (3) Topolyzer app.

Conclusion: Six CDAs were improved using: (1) better edge detection; (2) gradient amplification; and (3) gradient orientation. Additional technique usually referenced as semblance [9, 10] was tested as well. However, this only insignificantly improved results and

Table 1: Used gradient edge detectors and obtained results before and after modifications described in this paper.

operator	1. Pixel-Difference	2. Separated-Pixel-Difference	3. Roberts	4. Prewitt	5. Sobel	6. Frei-Chen
before:						
TPs	16495	16487	16425	16437	16436	16450
$AUROC_{1\tau}$	73.915%	75.609%	71.913%	75.856%	75.907%	75.891%
$AUROC_{2\tau}$	80.304%	81.365%	78.639%	81.486%	81.508%	81.534%
$AUROC_{5\tau}$	86.390%	86.867%	85.240%	86.832%	86.884%	86.864%
after:						
TPs	16447	16489	16434	16451	16471	16463
$AUROC_{1\tau}$	78.774%	79.993%	78.225%	79.648%	79.784%	79.693%
$AUROC_{2\tau}$	83.652%	84.644%	83.298%	84.162%	84.332%	84.216%
$AUROC_{5\tau}$	88.111%	88.765%	87.866%	88.377%	88.529%	88.444%

only in certain cases. Accordingly, it was not included in the presented results. On the other hand, better edge detection and the gradient amplification slightly improved, while the gradient orientation significantly improved the overall results for all used operators.

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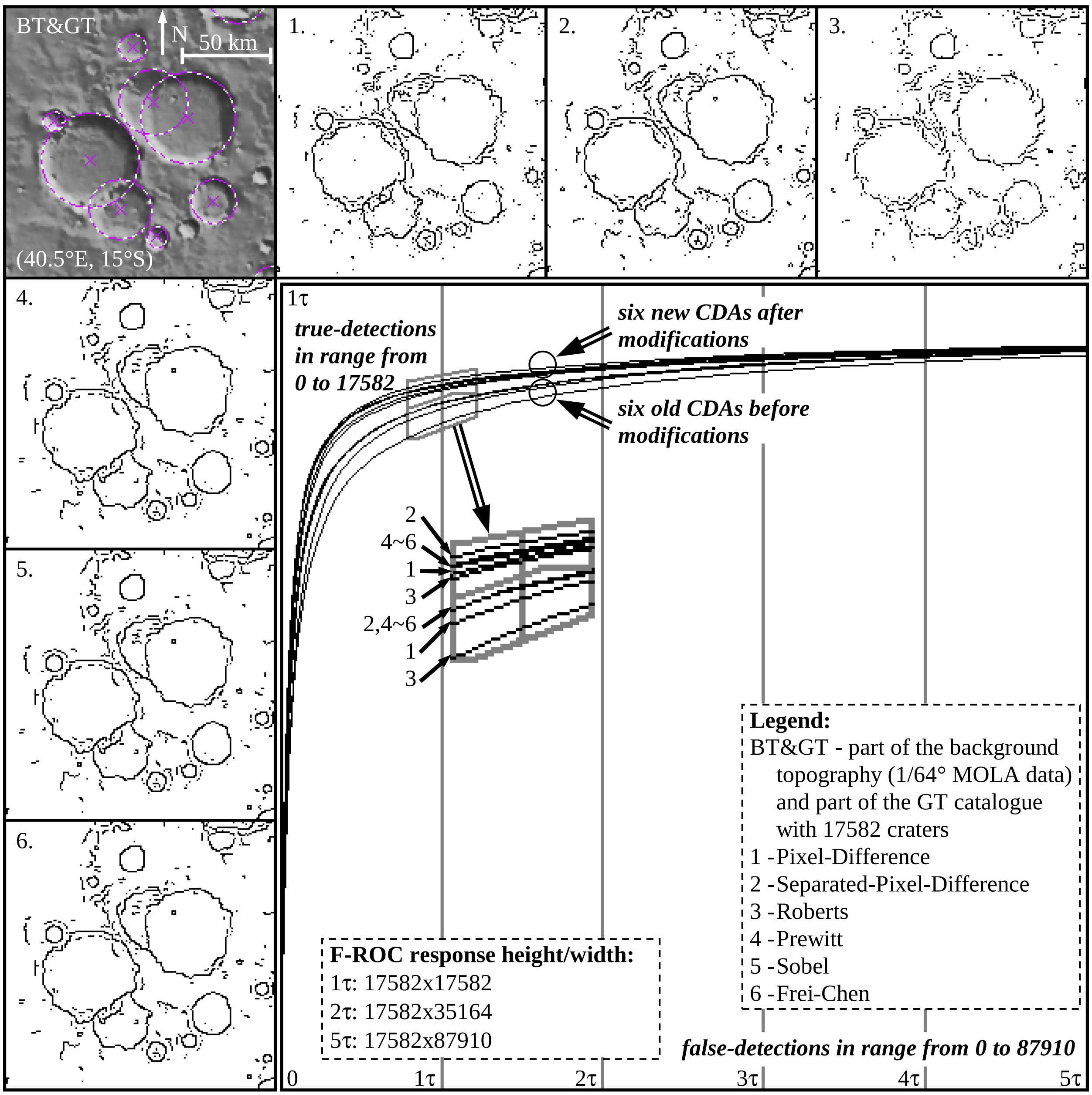

Figure 1: Detected edges (left and top) and F-ROC evaluations (right-bottom) for operators from Table 1.