Imperfection_ResultsA

Results for the Indentation Image Group "Imperfection"

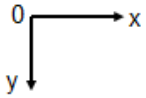
including error analysis with respect to dates manually determined by Expert A

(Indentation vertices manually obtained by Expert A: see file "Imperfection_ExpertA_Table.pdf")

35 indentation images obtained from Steel-316 samples, images with special presence of imperfections, 640x480 pixels, acquired by a CCD camera implemented in the microdurometer Mitutoyo model HM-124, 50-fold magnification, indenter load 500 gf.
University of Veracruz at Boca del Rio / CINVESTAV-IPN at Mexico City, Mexico, 2018.

Each image presents exactly one indentation footprint of rhombic form. The table contains the x,y-coordinates of its four vertices determined by the method reported in the article "Indentation image analysis for Vickers hardness testing" (Domínguez-Nicolás and Wiederhold), submitted to IEEE-CEE Conference 2018, June 2018.

coordinate system used:



This report only contains the results of the standard option of the method as described in the article mentioned above, where no special pre-processing is performed before binarization, morphological filtering, region growing and identification of the largest area 8-connected component as region of interest (ROI) which pretends to coincide with the indentation footprint.

The implementation was made within the software environment DIAS (shareware, University Jena, Germany), where gray images are integer valued between 0 and 255, most image processing operations are performed within integer arithmetic, and where the Harris-Stephen corner detector was applied to the binary segmented image, without previous Gaussian filter, using parameter k=0.04 and threshold 100 for the corner response function. An equivalent implementation is being developed in MATLAB.

Image number	coordinates (x,y) of vertices North(N), East(E), South(S), West(W) obtained by the automatic method	error (Euclidean distance in pixels) with respect to the true vertex manually determined by Expert A	rhombus diagonal lengths in pixels calculated automatically and from Expert A true dates	absolute error (in pixels) and relative error of mean diagonal length versus true dates due to Expert A
1	N = (285,87) E = (420,210) S = (298,334) W = (158,209)	8.6023 3.1623 7.6158 1.0000 average: 5.0951	N-S: 247.3419 W-E: 262.0019 mean: 254.6719 true mean: 246.5307 diff NS-WE: 14.6600	absolute error: 8.1412 relative error: **3.3023 %**
2	N = (287,70) E = (424,189) S = (294,298) W = (163,182)	8.4853 7.0711 2.0000 7.2111 average: 6.1919	N-S: 228.1074 W-E: 261.0938 mean: 244.6006 true mean: 235.0051 diff NS-WE: 32.9864	absolute error: 9.5955 relative error: **4.0831 %**
3	N = (289,138) E = (434,243) S = (305,364) W = (162,243)	12.0000 1.4142 5.0990 7.6156 average: 6.5322	N-S: 226.5657 W-E: 272.0000 mean: 249.2828 true mean: 242.5321 diff NS-WE: 45.4343	absolute error: 6.7508 relative error: **2.7834 %**

4	N = (323,72) E = (478,209) S = (327,353) W = (178,211)	1.4142 2.2361 6.0828 1.4142 average: 2.7868	N-S: 281.0285 W-E: 300.0067 mean: 290.5176 true mean: 288.5179 diff NS-WE: 18.9782	absolute error: 1.9997 relative error: **0.6931 %**
5	N = (256,58) E = (412,198) S = (261,345) W = (107,202)	1.0000 2.0000 1.0000 1.0000 average: 1.2500	N-S: 287.0436 W-E: 305.0262 mean: 296.0349 true mean: 297.5347 diff NS-WE: 17.9827	absolute error: 1.4998 relative error: **0.5041 %**
6	N = (288,83) E = (424,203) S = (294,328) W = (156,209)	1.0000 6.0828 2.2361 4.0000 average: 3.3297	N-S: 245.0735 W-E: 268.0672 mean: 256.5703 true mean: 260.5244 diff NS-WE: 2.9937	absolute error: 3.9541 relative error: **1.5178 %**
7	N = (356,107) E = (467,203) S = (356,306) W = (251,210)	2.0000 3.6056 1.0000 3.6056 average: 2.5528	N-S: 199.0000 W-E: 216.1134 mean: 207.5567 true mean: 211.5114 diff NS-WE: 17.1134	absolute error: 3.9547 relative error: **1.8697 %**
8	N = (268,122) E = (396,236) S = (274,345) W = (143,238)	2.2361 6.4031 1.4142 10.8166 average: 5.2175	N-S: 223.0807 W-E: 253.0079 mean: 238.0443 true mean: 230.5112 diff NS-WE: 29.9272	absolute error: 7.5331 relative error: **3.2680 %**
9	N = (367,119) E = (503,248) S = (368,370) W = (240,253) artefact near N	10.0500 2.2361 2.0000 4.0000 average: 4.5715	N-S: 251.0020 W-E: 263.0475 mean: 257.0248 true mean: 250.0038 diff NS-WE: 12.0455	absolute error: 7.0209 relative error: **2.8083 %**
10	N = (328,82) E = (485,217) S = (328,359) W = (177,221)	2.8284 3.1623 5.3852 2.2361 average: 3.4030	N-S: 277.0000 W-E: 308.0260 mean: 292.5130 true mean: 297.0112 diff NS-WE: 31.0260	absolute error: 4.4982 relative error: **1.5145 %**
11	N = (405,76) E = (515,180) S = (407,284) W = (305,186)	1.4142 1.0000 3.0000 8.0623 average: 3.3691	N-S: 208.0096 W-E: 210.0857 mean: 209.0477 true mean: 215.0152 diff NS-WE: 2.0761	absolute error: 5.9675 relative error: **2.7754 %**
12	N = (401,139) E = (513,242) S = (405,346) W = (300,245)	1.0000 2.8284 1.0000 8.2462 average: 3.2687	N-S: 207.0386 W-E: 213.0211 mean: 210.0299 true mean: 216.0292 diff NS-WE: 5.9825	absolute error: 5.9993 relative error: **2.7771 %**

13	N = (309,106) E = (459,242) S = (315,377) W = (169,246)	2.0000 1.0000 2.0000 2.2361 average: 1.8090	N-S: 271.0664 W-E: 290.0276 mean: 280.5470 true mean: 279.5183 diff NS-WE: 18.9612	absolute error: 1.0287 relative error: **0.3680 %**
14	N = (287,97) E = (427,217) S = (293,344) W = (152,221)	1.4142 1.4142 1.4142 1.0000 average: 1.3107	N-S: 247.0729 W-E: 275.0291 mean: 261.0510 true mean: 262.0446 diff NS-WE: 27.9562	absolute error: 0.9936 relative error: **0.3792 %**
15	N = (308,87) E = (426,196) S = (313,300) W = (198,196)	1.0000 2.0000 1.4142 1.0000 average: 1.3536	N-S: 213.0587 W-E: 228.0000 mean: 220.5293 true mean: 220.5336 diff NS-WE: 14.9413	absolute error: 0.0043 relative error: **0.0019 %**
16	N = (291,76) E = (456,213) S = (296,352) W = (141,213)	1.0000 2.2361 1.4142 1.0000 average: 1.4126	N-S: 276.0453 W-E: 315.0000 mean: 295.5226 true mean: 296.0395 diff NS-WE: 38.9547	absolute error: 0.5169 relative error: **0.1746 %**
17	N = (272,93) E = (429,228) S = (275,374) W = (118,234)	1.0000 2.2361 0.0000 0.0000 average: 0.8090	N-S: 281.0160 W-E: 311.0579 mean: 296.0369 true mean: 297.0235 diff NS-WE: 30.0419	absolute error: 0.9866 relative error: **0.3322 %**
18	N = (327,68) E = (476,205) S = (332,344) W = (185,208)	1.0000 5.0000 3.0000 1.0000 average: 2.5000	N-S: 276.0453 W-E: 291.0155 mean: 283.5304 true mean: 287.0220 diff NS-WE: 14.9702	absolute error: 3.4916 relative error: **1.2165 %**
19	N = (328,49) E = (482,187) S = (332,335) W = (176,187)	1.4142 1.4142 1.0000 2.0000 average: 1.4571	N-S: 286.0280 W-E: 306.0000 mean: 296.0140 true mean: 298.9943 diff NS-WE: 19.9720	absolute error: 1.9903 relative error: **0.6679 %**
20	N = (270,103) E = (437,249) S = (278,397) W = (116,251)	3.1623 2.2361 2.2361 0.0000 average: 1.9086	N-S: 294.1088 W-E: 321.0062 mean: 307.5575 true mean: 310.0311 diff NS-WE: 26.8974	absolute error: 2.4736 relative error: **0.7978 %**
21	N = (278,79) E = (435,223) S = (282,368) W = (126,225)	2.2361 4.1231 2.2361 2.0000 average: 2.6488	N-S: 289.0277 W-E: 309.0065 mean: 299.0171 true mean: 303.5286 diff NS-WE: 19.9788	absolute error: 4.5115 relative error: **1.4863 %**

22	N = (322,104) E = (478,243) S = (327,383) W = (171,246)	2.0000 1.0000 2.0000 1.4142 average: 1.6036	N-S: 279.0448 W-E: 307.0147 mean: 293.0297 true mean: 292.0257 diff NS-WE: 27.9699	absolute error: 1.0040 relative error: **0.3438 %**
23	N = (288,94) E = (450,231) S = (285,385) W = (140,236)	3.0000 4.1231 32.6497 2.2361 average: 10.5022	N-S: 291.0155 W-E: 310.0403 mean: 300.5279 true mean: 283.1176 diff NS-WE: 19.0249	absolute error: 17.4103 relative error: **6.1495 %**
24	N = (319,74) E = (481,214) S = (325,360) W = (169,215)	6.3246 1.4142 2.8284 6.0828 average: 4.1625	N-S: 286.0629 W-E: 312.0016 mean: 299.0323 true mean: 294.5894 diff NS-WE: 25.9387	absolute error: 4.4428 relative error: **1.5081 %**
25	N = (254,82) E = (395,207) S = (261,332) W = (131,207)	7.8102 2.0000 5.8310 1.0000 average: 4.1603	N-S: 250.0980 W-E: 264.0000 mean: 257.0490 true mean: 250.5271 diff NS-WE: 13.9020	absolute error: 6.5219 relative error: **2.6033 %**
26	N = (402,83) E = (551,216) S = (400,359) W = (305,261) Segmentation dis-connects part of W	2.8284 6.0000 11.7047 68.6003 average: 22.2834	N-S: 276.0072 W-E: 250.0820 mean: 263.0446 true mean: 279.0288 diff NS-WE: 25.9263	absolute error: 15.9842 relative error: **5.7285 %**
27	N = (286,56) E = (436,192) S = (291,334) W = (138,194)	1.4142 1.4142 4.0000 0.0000 average: 1.7071	N-S: 278.0450 W-E: 298.0067 mean: 288.0258 true mean: 286.0222 diff NS-WE: 19.9618	absolute error: 2.0037 relative error: **0.7005 %**
28	N = (318,106) E = (458,227) S = (321,356) W = (188,231)	1.0000 1.0000 1.0000 0.0000 average: 0.7500	N-S: 250.0180 W-E: 270.0296 mean: 260.0238 true mean: 260.0321 diff NS-WE: 20.0116	absolute error: 0.0083 relative error: **0.0032 %**
29	N = (353,48) E = (504,189) S = (352,327) W = (213,195) Difficult image – material broken !	12.7279 2.2361 1.0000 2.2361 average: 4.5500	N-S: 279.0018 W-E: 291.0618 mean: 285.0318 true mean: 280.6288 diff NS-WE: 12.0601	absolute error: 4.4030 relative error: **1.5690 %**
30	N = (334,40) E = (481,180) S = (334,318) W = (183,185)	1.0000 1.4142 5.3852 3.1623 average: 2.7404	N-S: 278.0000 W-E: 298.0419 mean: 288.0210 true mean: 291.0528 diff NS-WE: 20.0419	absolute error: 3.0319 relative error: **1.0417 %**

31	N = (335,51) E = (489,189) S = (340,323) W = (190,190)	1.0000 2.0000 1.0000 5.0990 average: 2.2748	N-S: 272.0460 W-E: 299.0017 mean: 285.5238 true mean: 287.0220 diff NS-WE: 26.9557	absolute error: 1.9942 relative error: **0.6936 %**
32	N = (331,91) E = (488,247) S = (338,389) W = (163,237) Difficult image !	8.0623 10.6302 6.3246 24.2074 average: 12.3061	N-S: 298.0822 W-E: 325.1538 mean: 311.6180 true mean: 291.1771 diff NS-WE: 27.0716	absolute error: 20.4409 relative error: **7.0201 %**
33	N = (328,64) E = (480,202) S = (332,334) W = (177,199)	3.6056 3.6056 1.4142 3.6056 average: 3.0577	N-S: 270.0296 W-E: 303.0148 mean: 286.5222 true mean: 291.0115 diff NS-WE: 32.9852	absolute error: 4.4892 relative error: **1.5426 %**
34	N = (323,56) E = (480,206) S = (327,346) W = (170,212) Difficult image !	3.0000 2.0000 8.0000 4.1231 average: 4.2808	N-S: 290.0276 W-E: 310.0581 mean: 300.0581 true mean: 299.0632 diff NS-WE: 20.0305	absolute error: 0.9796 relative error: **0.3276 %**
35	N = (349,75) E = (533,219) S = (366,346) W = (214,207) Difficult image, E-vertex error cannot be avoided.	0.0000 37.0135 3.1623 3.1623 average: 10.8345	N-S: 271.5327 W-E: 319.2256 mean: 295.3792 true mean: 279.9216 diff NS-WE: 47.6929	absolute error: 15.4576 relative error: **5.5221 %**

Summary on relative errors of the mean diagonal length:

image	relative error for standard option of the method
1	3.3023
2	4.0831
3	2.7834
4	0.6931
5	0.5041
6	1.5178
7	1.8697
8	3.2680
9	2.8083
10	1.5145
11	2.7754
12	2.7771
13	0.3680
14	0.3792
15	0.0019
16	0.1746
17	0.3322
18	1.2165

19	0.6679
20	0.7978
21	1.4863
22	0.3438
23	6.1495
24	1.5081
25	2.6033
26	5.7285
27	0.7005
28	0.0032
29	1.5690
30	1.0417
31	0.6936
32	7.0201
33	1.5426
34	0.3276
35	5.5221

Error occurrences for standard option:

Error less than 0.5%:	13, 14, 15, 16, 17, 22, 28, 34 ---	8 images
Error between 0.5 and 1%:	4, 5, 19, 20, 31 ---	5 images
Error between 1 and 2%:	6, 7, 10, 18, 21, 24, 27, 29, 30, 33 ---	10 images
Error between 2 and 3%:	1, 3, 9, 11, 12, 25 ---	6 images
Error between 3 and 4%:	8 ---	1 image
Error larger than 4%:	2, 23, 26, 32, 35 ---	5 images
Error larger than 6%:	32 ---	1 image

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