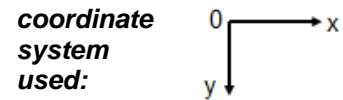


Results for the Indentation Image Group “SteelPolished”
including error analysis with respect to dates manually determined by Expert A
 (Indentation vertices manually obtained by Expert A: see file “SteelPolished_ExpertA_Table.pdf”)

40 indentation images obtained from Steel-316 samples, 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.



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 = (325,79) E = (485,205) S = (336,334) W = (184,219)	6.4031 4.2426 1.4142 8.6023 average: 5.1656	N-S: 255.2371 W-E: 301.3254 mean: 278.2813 true mean: 270.0671	absolute error: 8.2142 relative error: 3.0415 %
2	N = (378,83) E = (526,210) S = (384,337) W = (242,213)	2.2361 2.8284 2.8284 1.0000 average: 2.2232	N-S: 254.0709 W-E: 284.0158 mean: 269.0434 true mean: 268.5498	absolute error: 0.4935 relative error: 0.1838 %
3	N = (378,83) E = (526,210) S = (384,337) W = (242,213)	2.2361 2.8284 2.8284 1.0000 average: 2.2232	N-S: 254.0709 W-E: 284.0158 mean: 269.0434 true mean: 268.5498	absolute error: 0.4935 relative error: 0.1838 %

4	N = (363,40) E = (535,184) S = (367,338) W = (202,191)	4.0000 1.0000 1.0000 4.1231 average: 2.5308	N-S: 298.0268 W-E: 333.0736 mean: 315.5502 true mean: 315.5262	absolute error: 0.0240 relative error: 0.0076 %
5	N = (363,40) E = (535,184) S = (367,338) W = (202,191)	4.0000 1.0000 1.0000 4.1231 average: 2.5308	N-S: 298.0268 W-E: 333.0736 mean: 315.5502 true mean: 315.5262	absolute error: 0.0240 relative error: 0.0076 %
6	N = (370,61) E = (515,187) S = (373,318) W = (232,190)	1.4142 3.1623 1.0000 1.4142 average: 1.7477	N-S: 257.0175 W-E: 283.0159 mean: 270.0167 true mean: 272.0117	absolute error: 1.9950 relative error: 0.7334 %
7	N = (380,85) E = (532,221) S = (384,354) W = (228,223)	2.0000 2.2361 1.0000 1.0000 average: 1.5590	N-S: 269.0297 W-E: 304.0066 mean: 286.5182 true mean: 286.0281	absolute error: 0.4900 relative error: 0.1713 %
8	N = (380,85) E = (532,221) S = (384,354) W = (228,223)	2.0000 2.2361 1.0000 1.0000 average: 1.5590	N-S: 269.0297 W-E: 304.0066 mean: 286.5182 true mean: 286.0281	absolute error: 0.4900 relative error: 0.1713 %
9	N = (345,78) E = (502,213) S = (348,353) W = (196,217)	1.0000 1.0000 3.0000 2.0000 average: 1.7500	N-S: 275.0164 W-E: 306.0261 mean: 290.5212 true mean: 292.5455	absolute error: 2.0243 relative error: 0.6920 %
10	N = (398,53) E = (552,183) S = (402,321) W = (258,185)	1.4142 2.2361 2.2361 3.1623 average: 2.2622	N-S: 268.0299 W-E: 294.0068 mean: 281.0183 true mean: 284.5408	absolute error: 3.5224 relative error: 1.2379 %
11	N = (356,69) E = (500,193) S = (359,320) W = (214,197)	2.2361 2.2361 1.4142 1.4142 average: 1.8251	N-S: 251.0179 W-E: 286.0280 mean: 268.5230 true mean: 270.0393	absolute error: 1.5164 relative error: 0.5615 %
12	N = (357,26) E = (538,182) S = (360,343) W = (179,183)	0.0000 2.2361 1.0000 2.8284 average: 1.5161	N-S: 317.0142 W-E: 359.0014 mean: 338.0078 true mean: 340.0154	absolute error: 2.0076 relative error: 0.5904 %

13	N = (349,67) E = (479,202) S = (335,338) W = (189,210)	18.3848 1.0000 6.4031 6.4031 average: 8.0478	N-S: 271.3614 W-E: 290.1103 mean: 280.7358 true mean: 269.5236	absolute error: 11.2122 relative error: 4.1600 %
14	N = (346,54) E = (492,194) S = (345,334) W = (200,195)	5.3862 1.4142 2.8284 1.0000 average: 2.6570	N-S: 280.0018 W-E: 292.0017 mean: 286.0018 true mean: 283.5116	absolute error: 2.4901 relative error: 0.8783 %
15	N = (357,53) E = (505,193) S = (361,325) W = (215,196)	1.0000 2.2361 1.4142 2.8284 average: 1.8697	N-S: 272.0294 W-E: 290.0155 mean: 281.0225 true mean: 283.0264	absolute error: 2.0039 relative error: 0.7080 %
16	N = (311,97) E = (456,230) S = (315,369) W = (167,231)	2.2361 3.0000 3.1623 4.1231 average: 3.1304	N-S: 272.0294 W-E: 289.0017 mean: 280.5156 true mean: 286.5156	absolute error: 5.4960 relative error: 1.9216 %
17	N = (330,69) E = (479,209) S = (335,352) W = (179,213)	1.0000 1.4142 1.0000 2.0000 average: 1.3536	N-S: 283.0442 W-E: 300.0267 mean: 291.5354 true mean: 293.5216	absolute error: 1.9861 relative error: 0.6766 %
18	N = (333,60) E = (492,206) S = (334,353) W = (176,210)	2.0000 1.0000 0.0000 1.4142 average: 1.1036	N-S: 293.0017 W-E: 316.0253 mean: 304.5135 true mean: 303.5060	absolute error: 1.0055 relative error: 0.3313 %
19	N = (320,66) E = (481,209) S = (326,352) W = (168,212)	2.2361 1.0000 1.0000 1.0000 average: 1.3090	N-S: 286.0629 W-E: 313.0144 mean: 299.5387 true mean: 297.5387	absolute error: 2.0134 relative error: 0.6767 %
20	N = (326,63) E = (482,206) S = (329,352) W = (176,207)	1.0000 0.0000 2.0000 1.4142 average: 1.1036	N-S: 289.0156 W-E: 306.0016 mean: 297.5086 true mean: 298.5086	absolute error: 0.5085 relative error: 0.1706 %
21	N = (316,73) E = (465,214) S = (318,352) W = (167,216)	1.4142 2.2361 3.1623 4.0000 average: 2.7031	N-S: 279.0072 W-E: 298.0067 mean: 288.5069 true mean: 292.5394	absolute error: 4.0325 relative error: 1.3784 %

22	N = (353,57) E = (495,190) S = (355,327) W = (220,191)	2.0000 6.0828 1.4142 6.0828 average: 3.8949	N-S: 270.0074 W-E: 275.0018 mean: 272.5046 true mean: 280.0161	absolute error: 7.5115 relative error: 2.6825 %
23	N = (391,55) E = (539,183) S = (394,324) W = (251,185)	1.4142 4.1231 1.4142 8.0623 average: 3.7534	N-S: 269.0167 W-E: 288.0069 mean: 278.5118 true mean: 285.5264	absolute error: 7.0146 relative error: 2.45671 %
24	N = (388,58) E = (538,194) S = (392,325) W = (250,199)	1.0000 5.0000 2.0000 5.8310 average: 3.4577	N-S: 267.0210 W-E: 288.0434 mean: 277.5367 true mean: 283.0294	absolute error: 5.4927 relative error: 1.9407 %
25	N = (393,52) E = (551,192) S = (396,330) W = (262,205) Segmentation cuts W-vertex by light spot in center.	2.0000 4.1231 3.0000 21.9545 average: 7.7694	N-S: 278.0162 W-E: 289.2922 mean: 283.6542 true mean: 296.5294 diff NS-WE:	absolute error: 12.8752 relative error: 4.3420 %
26	N = (388,53) E = (535,182) S = (392,314) W = (249,184)	1.0000 5.0000 3.0000 4.1231 average: 3.2808	N-S: 261.0306 W-E: 286.0070 mean: 273.5188 true mean: 280.0227	absolute error: 6.5039 relative error: 2.3226 %
27	N = (386,95) E = (542,222) S = (389,359) W = (251,229)	1.4142 3.6056 2.8284 7.0711 average: 3.7298	N-S: 264.0170 W-E: 291.0842 mean: 277.5506 true mean: 284.0470	absolute error: 6.4964 relative error: 2.2871 %
28	N = (391,81) E = (539,210) S = (392,340) W = (274,223) Segmentation cuts W-vertex by light spot in center.	2.2361 2.2361 3.1623 24.1661 average: 7.9501	N-S: 259.0019 W-E: 265.3187 mean: 262.1603 true mean: 275.0483 diff NS-WE:	absolute error: 12.8880 relative error: 4.6857 %
29	N = (335,57) E = (480,186) S = (335,316) W = (199,188)	3.6056 3.1223 3.6056 9.0554 average: 4.8572	N-S: 259.0000 W-E: 281.0071 mean: 270.0036 true mean: 278.5373	absolute error: 8.5338 relative error: 3.0638 %
30	N = (390,57) E = (539,191) S = (394,323) W = (250,190)	1.4142 4.4721 1.4142 4.1231 average: 2.8559	N-S: 266.0301 W-E: 289.0017 mean: 277.5159 true mean: 282.5183	absolute error: 5.0024 relative error: 1.7706 %

31	N = (364,71) E = (517,201) S = (368,332) W = (225,202)	1.0000 4.1231 2.0000 4.1231 average: 2.8116	N-S: 261.0306 W-E: 292.0017 mean: 276.5162 true mean: 282.0226	absolute error: 5.5065 relative error: 1.9525 %
32	N = (373,66) E = (521,194) S = (378,320) W = (235,196)	2.2361 4.0000 5.0990 7.0000 average: 4.5838	N-S: 254.0492 W-E: 286.0070 mean: 270.0281 true mean: 279.0273	absolute error: 8.9992 relative error: 3.2252 %
33	N = (366,74) E = (510,206) S = (365,329) W = (244,217) Segmentation cuts W-vertex by light spot in center.	1.0000 3.1623 3.1623 18.8680 average: 6.5481	N-S: 255.0020 W-E: 266.2274 mean: 260.6146 true mean: 271.5045	absolute error: 10.8898 relative error: 4.0109 %
34	N = (352,69) E = (495,198) S = (353,324) W = (231,189) Segmentation cuts W-vertex by light spot in center.	1.4142 3.6056 1.0000 20.5913 average: 6.6528	N-S: 255.0020 W-E: 264.1534 mean: 259.5777 true mean: 270.5180	absolute error: 10.9403 relative error: 4.0442 %
35	N = (326,96) E = (471,225) S = (330,353) W = (198,227) Segmentation cuts W-vertex by light spot in center.	2.0000 5.0990 4.0000 10.0410 average: 5.2872	N-S: 257.0311 W-E: 273.0073 mean: 265.0192 true mean: 275.5187	absolute error: 10.4994 relative error: 3.8108 %
36	N = (351,101) E = (497,232) S = (352,360) W = (209,234)	2.2361 5.3852 2.0000 5.0000 average: 3.6553	N-S: 259.0019 W-E: 288.0069 mean: 273.5044 true mean: 280.0220	absolute error: 6.5176 relative error: 2.3275 %
37	N = (388,56) E = (538,195) S = (389,323) W = (275,210) Segmentation cuts W-vertex by light spot in center.	14.0000 2.2361 3.6056 28.7924 average: 12.1585 Error in N due to artefact adhered.	N-S: 267.0018 W-E: 263.4274 mean: 265.2146 true mean: 273.2146	absolute error: 8.3147 relative error: 3.0398 %
38	N = (389,63) E = (533,193) S = (389,324) W = (255,195)	0.0000 4.1231 3.6056 5.0000 average: 3.1822	N-S: 261.0000 W-E: 278.0072 mean: 269.5036 true mean: 275.5116	absolute error: 6.0080 relative error: 2.1807 %

39	N = (387,72) E = (535,204) S = (393,332) W = (267,217) Segmentation cuts W-vertex by light spot in center.	1.0000 5.0000 3.0000 25.0799 average: 8.5199	N-S: 260.0692 W-E: 268.3151 mean: 264.1922 true mean: 279.0420	absolute error: 14.8498 relative error: 5.3217 %
40	N = (356,79) E = (505,204) S = (358,332) W = (223,205)	1.0000 1.4142 1.0000 2.0000 average: 1.3536	N-S: 253.0079 W-E: 282.0018 mean: 267.5048 true mean: 269.5124	absolute error: 2.0075 relative error: 0.7449 %

Relative Error Histogram of these 40 images:

relative error between 4 and 6 %: 6 images (13, 25, 28, 33, 34, 39)
relative error between 2 and 4 %: 11 images (1, 22, 23, 26, 27, 29, 32, 35, 36, 37, 38)
relative error between 1 and 2 %: 6 images (10, 16, 21, 24, 30, 31)
relative error less than 1 %: 17 images (2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 17, 18, 19, 20, 40)

relative error less than or equal 2 %: 23 images = 57.5 % of 40
relative error less than or equal 4 %: 34 images = 85 % of 40
relative error more than 4 %: 6 images = 15 % of 40 (this is still too bad ...)