**Normalization results for pairs 1\_0.ppm\_1\_4.ppm from subset HPatches\_mikolajczyk\_set10\_Pairs50\v\_graffiti**

**1\_0.ppm: 1\_4.ppm: **

**Table 1 - Found homography parameters and normalization accuracy assessment**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Original:  img1: 92,129 img2: 33,936 | h11 | h12 | h13 | h21 | h22 | h23 | h31 | h32 | h33 | avg ErrPar (param) | avg ErrIM (pixel) | max ErrIM | avg ErrCPM (corner) | max ErrCPM | Expert rate |
| SIFT | -1,004 | 0,206 | 60,542 | -9,286 | 1,926 | 567,6 | -0,016 | 0,003 | 1 | 0,523 | 0,665 | 1,588 | 464,668 | 742,562 |  |
| SURF128 | -0,439 | -0,442 | 292,934 | -0,066 | -0,066 | 43,667 | -0,001 | -0,002 | 1 | 0,244 | 0,415 | 1,004 | 593,121 | 906,673 |  |
| SURF64 | 2,23 | -1,093 | 683,935 | 3,643 | 0,088 | 408,674 | 0,006 | 0 | 1 | 0,44 | 1,187 | 2,413 | 3189,807 | 10650,574 |  |
| ORB | 0,16 | 0,546 | 208,584 | -0,22 | 1,61 | -36,522 | -0,001 | 0,002 | 1 | 0,192 | 0,638 | 1,643 | 807,29 | 2479,437 |  |
| ORB1000 | 0,01 | -1,756 | 532,871 | 0,248 | -2,091 | 524,618 | 0 | -0,004 | 1 | 0,462 | 0,183 | 0,447 | 504,823 | 546,686 |  |
| BRISK | 0,356 | 0,063 | 233,533 | 0,021 | 1,12 | -7,379 | -0 | -0 | 1 | 0,131 | 0,305 | 0,825 | 69,425 | 105,17 |  |
| KAZE | -0,671 | -0,694 | 347,769 | -1,15 | -1,01 | 533,419 | -0,002 | -0,002 | 1 | 0,398 | 0 | 0 | 542,329 | 805,535 |  |
| AKAZE | 0,383 | -2,151 | -108,688 | -0,264 | -3,191 | 379,817 | -0,002 | -0,007 | 1 | 0,517 | 0 | 0 | 759,321 | 1282,112 |  |
| Original matrix | 0,621 | 0,056 | 221,79 | 0,22 | 1,156 | -23,942 | 0 | -0 | 0,999 |  |  |  |  |  |  |

where h11, h12, h13, h21, h22, h23, h31, h32, h33 - parameters of found homography matrix H\* or of original one H;   
avgErrPar - average error of found parameters, the accuracy of found homography matrix parameters with a preliminary minimax normalization of found and original matrices;  
avgErrIM - average error of inlier coordinate matching;  
inliers - correct matches; outliers - false matches;  
maxErrIM – maximum error of inlier coordinate matching;  
avgErrCPM - average error of corner point matching;  
maxErrCPM - maximum error of corner point matching;  
expert rate - experts assessment of normalization accuracy with a 5-point scale: 0 - normalization failed, 1 - insufficient, 2 - satisfactory, 3 - good, 4 – excellent.

**Table 2 - Quantitative evaluation of descriptors, precision and recall estimation (with found overlap)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | NP1 | NP2 | NM | NI | DP1 | DP2 | OP1 | OP2 | NPO1 | NPO2 | NMO | DPO1 | DPO2 | Precision | RecallO1 | Comments |
| SIFT | 2674 | 3923 | 81 | 8 | 0,0052 | 0,0077 | 99,6307 | 90,2084 | 2673 | 3699 | 81 | 0,0052 | 0,008 | 0,0988 | 0,003 |  |
| SURF128 | 4796 | 5953 | 77 | 12 | 0,0094 | 0,0116 | 99,8262 | 88,9727 | 4784 | 5296 | 76 | 0,0094 | 0,0116 | 0,1558 | 0,0025 |  |
| SURF64 | 4796 | 5953 | 96 | 9 | 0,0094 | 0,0116 | 99,9912 | 15,6258 | 4796 | 1189 | 96 | 0,0094 | 0,0149 | 0,0938 | 0,0019 |  |
| ORB | 9147 | 13269 | 79 | 6 | 0,0179 | 0,0259 | 62,7385 | 66,1047 | 7460 | 9834 | 62 | 0,0232 | 0,0291 | 0,0759 | 0,0008 |  |
| ORB1000 | 1000 | 1000 | 11 | 5 | 0,002 | 0,002 | 91,5125 | 96,0637 | 924 | 870 | 11 | 0,002 | 0,0018 | 0,4545 | 0,0054 |  |
| BRISK | 3523 | 5203 | 25 | 6 | 0,0069 | 0,0102 | 86,7842 | 37,5395 | 3142 | 1989 | 24 | 0,0071 | 0,0103 | 0,24 | 0,0019 |  |
| KAZE | 2045 | 2163 | 9 | 4 | 0,004 | 0,0042 | 95,9404 | 87,1098 | 1967 | 1885 | 9 | 0,004 | 0,0042 | 0,4444 | 0,002 |  |
| AKAZE | 1755 | 1982 | 14 | 4 | 0,0034 | 0,0039 | 82,7799 | 59,7559 | 1677 | 1121 | 12 | 0,004 | 0,0037 | 0,2857 | 0,0024 |  |

where NP - number of found key points; NP1, NP2 - number of found key points for image1 and image2 respectively;  
NM - number of matches found with NNDR method, NM=NI+NO;  
NI - number of inliers found with RANSAC method;  
NO - number of outliers discarded with RANSAC method;   
DP - density of key points (per cent), DP= NP/(height x width) , height, width - vertical and horizontal image sizes respectively (pixels)  
DP1, DP2 - density of key points points for image1 and image2 respectively;  
OP1, OP2 - overlap percentage for image1 and image2 respectively;  
NPO1, NPO2 - number of found key points on overlap for image1 and image2 respectivelyy;  
NMO - number of matches on overlap found with NNDR method;  
DPO1, DPO2 - density of key points points on overlap for image1 and image2 respectively;   
OA - overlap area (pixels), OA1, OA2 - overlap area for image1 and image2 respectively;  
DPO1= NPO1/OA1; DPO2= NPO2/OA2;  
Precision = NI/ NM - the rate to evaluate the part of inliers to all found matches with NNDR method;  
RecallO1 = NI/ NPO1 - completeness of inlier retrieval relative to the number of all key points on overlap for image1. The rate illustrates usefulness of the found key points for normalization.

**Table 3 - Estimation of time costs**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Name | NP1 | NP2 | DesT1, sec | DesT2, sec | MatchT, sec | InlierT, sec | AvgDesT, ms | AvgMatchT, ms | AvgInlierT, ms | TotalNormT, sec |
| SIFT | 2674 | 3923 | 0,349293 | 0,429951 | 0,322443 | 0,065927 | 0,120111 | 3,980773 | 8,240897 | 1,167614 |
| SURF128 | 4796 | 5953 | 0,843273 | 0,580079 | 0,723644 | 0,075712 | 0,136635 | 9,397972 | 6,309291 | 2,222707 |
| SURF64 | 4796 | 5953 | 0,497805 | 0,589626 | 0,388473 | 0,072311 | 0,10142 | 4,046589 | 8,034608 | 1,548215 |
| ORB | 9147 | 13269 | 0,043378 | 0,058246 | 0,658385 | 0,077025 | 0,004565 | 8,333991 | 12,837435 | 0,837034 |
| ORB1000 | 1000 | 1000 | 0,021693 | 0,046626 | 0,039487 | 0,003508 | 0,034159 | 3,589741 | 0,701508 | 0,111314 |
| BRISK | 3523 | 5203 | 0,10098 | 0,138355 | 0,153158 | 0,081299 | 0,027627 | 6,12632 | 13,549911 | 0,473793 |
| KAZE | 2045 | 2163 | 0,857242 | 0,818884 | 0,110829 | 0,003761 | 0,398888 | 12,314322 | 0,940373 | 1,790716 |
| AKAZE | 1755 | 1982 | 0,142347 | 0,17382 | 0,064411 | 0,022971 | 0,084404 | 4,600784 | 5,742678 | 0,403549 |

where DesT – descriptor creation time (time for key point detection and descriptor computation), DesT1, DesT2 – creation time of descriptors for image1 and image2 respectively;  
MatchT - retrieval time of matching found with NNDR method for the pair;  
InlierT – inlier retrieval time found with RANSAC method for the pair;  
AvgDesT – average time for one descriptor creation;  
AvgMatchT - average time for one match retrieval with NNDR method;  
AvgInlierT – average time for one inlier retrieval with RANSAC method;  
TotalNormT – total normalization time for the pair.