**Normalization results for pairs 1\_0.ppm\_1\_5.ppm from subset HPatches\_mikolajczyk\_set10\_Pairs50\v\_graffiti**

**1\_0.ppm: 1\_5.ppm: **

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Original:  img1: 94,192 img2: 29,913 | 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 | -0,031 | -0,124 | 64,208 | -0,098 | -0,415 | 215,085 | -0 | -0,002 | 1 | 0,34 | 9,341 | 27,652 | 529,514 | 780,969 |  |
| SURF128 | -0,012 | -0,014 | 13,797 | -0,187 | -0,217 | 198,364 | -0,001 | -0,001 | 1 | 0,353 | 0,806 | 1,664 | 2258,166 | 6949,666 |  |
| SURF64 | -1,203 | 0,372 | -74,975 | -54,867 | 12,983 | 606,168 | -0,102 | 0,024 | 1 | 0,96 | 0,453 | 1,074 | 817,392 | 1234,789 |  |
| ORB | 0,319 | 0,363 | -146,206 | -0,143 | -0,014 | 122,138 | 0,001 | -0,002 | 1 | 0,387 | 0,523 | 0,908 | 731,691 | 1253,592 |  |
| ORB1000 | 0,087 | -0,167 | 77,629 | -0,008 | -0,883 | 499,549 | 0 | -0,002 | 1 | 0,375 | 0,744 | 1,319 | 1997,006 | 4056,64 |  |
| BRISK | -0,034 | -0,077 | 87,138 | 0,331 | -1,182 | 403,708 | 0 | -0,002 | 1 | 0,379 | 0,194 | 0,341 | 782,132 | 1817,317 |  |
| KAZE | -0,198 | 0,053 | 142,011 | -0,042 | -0,011 | 39,42 | -0,001 | 0 | 1 | 0,318 | 0,115 | 0,287 | 5622,522 | 19976,238 |  |
| AKAZE | -0,295 | -0,044 | 202,506 | -0,352 | 0,127 | 191,578 | -0,002 | 0 | 1 | 0,328 | 0 | 0 | 1170,161 | 3473,324 |  |
| Original matrix | 0,438 | -0,677 | 457,54 | 0,454 | 1,035 | -50,458 | 0,001 | -0 | 1,006 |  |  |  |  |  |  |

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 | 4792 | 49 | 7 | 0,0052 | 0,0094 | 99,5441 | 98,6393 | 2666 | 4743 | 49 | 0,0052 | 0,0094 | 0,1429 | 0,0026 |  |
| SURF128 | 4796 | 5953 | 54 | 6 | 0,0094 | 0,0116 | 91,8863 | 18,96 | 4308 | 1288 | 48 | 0,0092 | 0,0133 | 0,1111 | 0,0014 |  |
| SURF64 | 4796 | 5953 | 47 | 11 | 0,0094 | 0,0116 | 95,2367 | 18,8379 | 4555 | 1205 | 41 | 0,0093 | 0,0125 | 0,234 | 0,0024 |  |
| ORB | 9147 | 17242 | 56 | 7 | 0,0179 | 0,0337 | 70,6594 | 98,9551 | 7959 | 17242 | 51 | 0,022 | 0,034 | 0,125 | 0,0009 |  |
| ORB1000 | 1000 | 1000 | 12 | 5 | 0,002 | 0,002 | 86,1918 | 20,667 | 942 | 283 | 12 | 0,0021 | 0,0027 | 0,4167 | 0,0053 |  |
| BRISK | 3523 | 6697 | 23 | 6 | 0,0069 | 0,0131 | 67,4811 | 82,9828 | 2238 | 6181 | 14 | 0,0065 | 0,0145 | 0,2609 | 0,0027 |  |
| KAZE | 2045 | 1875 | 8 | 5 | 0,004 | 0,0037 | 0 | 59,4398 | 1977 | 912 | 7 | ∞ | 0,003 | 0,625 | 0,0025 |  |
| AKAZE | 1755 | 1749 | 19 | 4 | 0,0034 | 0,0034 | 3,5271 | 74,7271 | 1544 | 1483 | 17 | 0,0855 | 0,0039 | 0,2105 | 0,0026 |  |

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 | 4792 | 0,306163 | 0,45696 | 0,304 | 0,089779 | 0,104927 | 6,204075 | 12,825504 | 1,156902 |
| SURF128 | 4796 | 5953 | 0,467292 | 0,489775 | 0,690666 | 0,086583 | 0,089853 | 12,790109 | 14,430494 | 1,734316 |
| SURF64 | 4796 | 5953 | 0,259113 | 0,342324 | 0,246545 | 0,054337 | 0,055765 | 5,24564 | 4,939714 | 0,902319 |
| ORB | 9147 | 17242 | 0,033205 | 0,051665 | 0,682275 | 0,057258 | 0,003313 | 12,183487 | 8,179664 | 0,824403 |
| ORB1000 | 1000 | 1000 | 0,020896 | 0,023398 | 0,017008 | 0,005507 | 0,022146 | 1,41733 | 1,101482 | 0,066809 |
| BRISK | 3523 | 6697 | 0,077725 | 0,137711 | 0,140408 | 0,033479 | 0,021312 | 6,104688 | 5,579777 | 0,389323 |
| KAZE | 2045 | 1875 | 0,555114 | 0,560882 | 0,076897 | 0,00202 | 0,285293 | 9,612118 | 0,404002 | 1,194913 |
| AKAZE | 1755 | 1749 | 0,109152 | 0,165001 | 0,040126 | 0,059554 | 0,078267 | 2,111919 | 14,888621 | 0,373833 |

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.