**Normalization results for pairs 1\_0.ppm\_1\_2.ppm from subset HPatches\_mikolajczyk\_set10\_Pairs50\v\_graffiti**

**1\_0.ppm: 1\_2.ppm: **

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

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Original:  img1: 97,601 img2: 54,976 | 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 | 0,751 | -0,286 | 225,95 | 0,327 | 1,022 | -76,882 | 0 | -0 | 1 | 0,612 | 1,164 | 3,323 | 4,14 | 5,81 |  |
| SURF128 | 0,755 | -0,298 | 225,197 | 0,33 | 1,007 | -75,27 | 0 | -0 | 1 | 0,749 | 1,366 | 3,76 | 6,269 | 7,237 |  |
| SURF64 | 0,759 | -0,294 | 223,499 | 0,333 | 1,002 | -74,888 | 0 | -0 | 1 | 0,623 | 1,628 | 3,88 | 6,352 | 9,947 |  |
| ORB | 0,764 | -0,297 | 225,527 | 0,332 | 1,026 | -77,618 | 0 | 0 | 1 | 0,505 | 1,112 | 4,854 | 5,428 | 6,409 |  |
| ORB1000 | 0,75 | -0,3 | 225,471 | 0,323 | 1 | -72,399 | 0 | -0 | 1 | 0,954 | 1,102 | 3,218 | 9,015 | 9,783 |  |
| BRISK | 0,759 | -0,297 | 225,109 | 0,329 | 1,014 | -75,934 | 0 | -0 | 1 | 0,661 | 1,058 | 4,055 | 5,984 | 7,132 |  |
| KAZE | 0,759 | -0,296 | 223,487 | 0,329 | 0,999 | -73,778 | 0 | -0 | 1 | 0,718 | 1,331 | 3,765 | 6,954 | 13,046 |  |
| AKAZE | 0,758 | -0,297 | 225,147 | 0,332 | 1,009 | -75,507 | 0 | -0 | 1 | 0,665 | 1,144 | 3,752 | 4,528 | 6,192 |  |
| Original matrix | 0,769 | -0,285 | 222,68 | 0,339 | 1,034 | -81,069 | 0 | 0 | 0,998 |  |  |  |  |  |  |

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 | 3506 | 593 | 391 | 0,0052 | 0,0068 | 97,5689 | 54,6783 | 2655 | 2014 | 592 | 0,0053 | 0,0072 | 0,6594 | 0,1473 |  |
| SURF128 | 4796 | 5583 | 369 | 200 | 0,0094 | 0,0109 | 97,5641 | 55,3785 | 4776 | 3560 | 369 | 0,0096 | 0,0126 | 0,542 | 0,0419 |  |
| SURF64 | 4796 | 5583 | 432 | 229 | 0,0094 | 0,0109 | 97,6299 | 55,1436 | 4777 | 3551 | 432 | 0,0096 | 0,0126 | 0,5301 | 0,0479 |  |
| ORB | 9147 | 12592 | 558 | 334 | 0,0179 | 0,0246 | 97,6799 | 55,2521 | 9147 | 9083 | 558 | 0,0183 | 0,0321 | 0,5986 | 0,0365 |  |
| ORB1000 | 1000 | 1000 | 102 | 74 | 0,002 | 0,002 | 97,6289 | 55,5605 | 1000 | 824 | 102 | 0,002 | 0,0029 | 0,7255 | 0,074 |  |
| BRISK | 3523 | 5038 | 384 | 277 | 0,0069 | 0,0098 | 97,6303 | 55,4018 | 3523 | 3514 | 384 | 0,007 | 0,0124 | 0,7214 | 0,0786 |  |
| KAZE | 2045 | 2372 | 345 | 221 | 0,004 | 0,0046 | 97,651 | 55,4393 | 2042 | 1526 | 345 | 0,0041 | 0,0054 | 0,6406 | 0,1082 |  |
| AKAZE | 1755 | 2154 | 162 | 116 | 0,0034 | 0,0042 | 97,6482 | 55,1375 | 1755 | 1555 | 162 | 0,0035 | 0,0055 | 0,716 | 0,0661 |  |

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 | 3506 | 0,270691 | 0,306045 | 0,234445 | 0,001384 | 0,09426 | 0,395353 | 0,003539 | 0,812564 |
| SURF128 | 4796 | 5583 | 0,384731 | 0,411228 | 0,534589 | 0,001936 | 0,076938 | 1,448749 | 0,009681 | 1,332484 |
| SURF64 | 4796 | 5583 | 0,363559 | 0,391214 | 0,281464 | 0,004986 | 0,072938 | 0,651537 | 0,021773 | 1,041224 |
| ORB | 9147 | 12592 | 0,033243 | 0,068566 | 0,631442 | 0,001476 | 0,004539 | 1,131616 | 0,004418 | 0,734728 |
| ORB1000 | 1000 | 1000 | 0,021596 | 0,022108 | 0,027249 | 0,001025 | 0,021852 | 0,267146 | 0,013851 | 0,071978 |
| BRISK | 3523 | 5038 | 0,10964 | 0,128421 | 0,16565 | 0,00078 | 0,028305 | 0,43138 | 0,002815 | 0,40449 |
| KAZE | 2045 | 2372 | 0,717154 | 0,853049 | 0,120685 | 0,001212 | 0,355159 | 0,349812 | 0,005484 | 1,692101 |
| AKAZE | 1755 | 2154 | 0,154329 | 0,155676 | 0,066514 | 0,000791 | 0,080105 | 0,410579 | 0,006817 | 0,377311 |

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.