**Activity\_3**

1. First Transformation - SIFT

In this activity, first, the previous codes from Activity 2 are implemented again to detect and extract the features (SIFT method) from the original and transformed image.

Then, the matchFeatures function is used to match the two sets of control points. This function takes the feature descriptors from the two sets, and calculates the similarity between each pair of features based on a distance metric; meaning it measures how close two feature descriptors are in their multi-dimensional space. With the 'Unique' set to true, the function makes sure that each feature in the first set is matched with at most one feature in the second set and vice versa.

The 'MaxRatio' parameter which will be used later to fine-tune the parameter, is used to accept a match only if the ratio of “the distance of the nearest neighbor” to “the distance of the second-nearest neighbor” is below a certain threshold. This helps to take out weak matches. A lower ratio means stricter matching. We will use this parameter in the following sections to reject ambiguous matches. The default value of this parameter is 0.6; by increasing this value the function returns more matches, and vice verca.

Next, the showMatchedFeatures function is used. This function displays lines connecting matching pairs of features between two images, which makes it easier to assess the quality of the matches. The 'montage' option places the images side by side with matching features connected by lines.

Figure 1, shows the initial matched features.

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Figure 1 – Original and the first transformed images, with all of their matched features - SIFT.

As can be seen in the image, we have two or three pairs of features that seem to be incorrect matches as the lines cross each other. For instance, it can be seen that a keypoint in the upper part of the coint in the original image is matched to a keypoint in the down right side of the transformed image. Therefore, further tuning was needed to delete these features.

The MaxRatio parameter was set to multiple numbers to take out incorrect matches. As it was mentioned before, with a higher number for this parameter, the number of features will be higher. We experimented with different numbers (0.9, 0.7, 0.5, 0.4) and finally set this number to 0.4 as with this number, it was evident in the matching figure that we got rid of the incorrect matches. Again, as it was said the default value for this parameter is 0.6, so by using values more than this we are expecting to have more matches compared to Figure 1 which is evident in Figure2. Figure 2 shows the final matched features and their corresponding MaxRatio parameter.

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| MaxRatio = 0.9 | MaxRatio = 0.7 |
| MaxRatio = 0.5 | MaxRatio = 0.4 |

Figure 2 – Original and the first transformed images, with refined parameters.

The table shows the statistical analysis of using different MaxRatio for the first transformation using the SIFT method. Mean Score is the average Euclidean distance between matched feature vectors. Lower values suggest closer and potentially more accurate matches. The Standard Deviation of Scores measures the spread or variability of the match scores around the mean. Lower values indicate more consistency in match quality.

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| --- | --- | --- | --- | --- |
| MaxRatio | Number of Matches | Mean Score | Median Score | Standard Deviation |
| 0.9 | 71 | 0.0212 | 0.0194 | 0.0106 |
| 0.7 | 64 | 0.0211 | 0.0196 | 0.0106 |
| 0.5 | 55 | 0.0213 | 0.0197 | 0.0104 |
| 0.4 | 44 | 0.0231 | 0.0236 | 0.0105 |

1. First Transformation – BRISK

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Figure 3 – Original and the first transformed images, with all of their matched features - BRISK.

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| MaxRatio = 0.9 | MaxRatio = 0.7 |
| MaxRatio = 0.5 | MaxRatio = 0.4 |

Figure 4 – Original and transformed images, with refined parameters - BRISK.

The table shows the statistical analysis of using different MaxRatio for the first transformation using the BRISK method.

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| --- | --- | --- | --- | --- |
| MaxRatio | Number of Matches | Mean Score | Median Score | Standard Deviation |
| 0.9 | 25 | 42 | 45 | 8.63 |
| 0.7 | 18 | 41.5 | 45 | 9.65 |
| 0.5 | 14 | 42.07 | 45.5 | 10.34 |
| 0.4 | 6 | 36 | 39 | 13.62 |

1. Second Transformation – BRISK

Regarding the second transformation, the same method was implemented. Figure 3 shows the initial matched features.

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Figure 5 – Original and the second transformed images, with all of their matched features - BRISK.

Again, the MaxRatio was used to see the influence of a threshold on the matched features. As was said before, the default value is 6, therefore using higher values will result in higher number of matches.

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| MaxRatio = 0.9 | MaxRatio = 0.7 |
| MaxRatio = 0.5 | MaxRatio = 0.4 |

Figure 6 – Original and transformed images, with refined parameters - BRISK.

The table shows the statistical analysis of using different MaxRatio for the second transformation using BRISK method.

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| MaxRatio | Number of Matches | Mean Score | Median Score | Standard Deviation |
| 0.9 | 54 | 43.74 | 44..5 | 6.45 |
| 0.7 | 51 | 43.43 | 44 | 6.48 |
| 0.5 | 31 | 42.06 | 44 | 6.99 |
| 0.4 | 19 | 39.89 | 41 | 7.68 |

1. Second Transformation – SIFT

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Figure 7 – Original and the second transformed images, with all of their matched features - SIFT.

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| MaxRatio = 0.9 | MaxRatio = 0.7 |
| MaxRatio = 0.5 | MaxRatio = 0.4 |

Figure 8 – Original and the second transformed images, with refined parameters - SIFT.

The table shows the statistical analysis of using different MaxRatio for the first transformation using the SIFT method.

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| MaxRatio | Number of Matches | Mean Score | Median Score | Standard Deviation |
| 0.9 | 556 | 0.011 | 0.008 | 0.008 |
| 0.7 | 553 | 0.0109 | 0.008 | 0.009 |
| 0.5 | 550 | 0.0108 | 0.008 | 0.009 |
| 0.4 | 547 | 0.0108 | 0.008 | 0.009 |