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AN EXPERIMENTAL EVALUATION OF ALGORITHMS IN PROCESSING UNMANNED AERIAL VEHICLE (UAV) IMAGES.

Amoo, Nureni Babatunde[1*], Odeyemi, Felix Gbenga.[1], Suru, Whenayo Peter[1], Abdurraheem, Sharafuddeen.[2], and Elufisan, Paul Tomilola[3]

[1]Department of Surveying and Geo-informatics, The Federal Polytechnic , Ede, Osun State, Nigeria.
[2]Kaduna Polyechnic, Kaduna State.
[3]Department of Surveying and Geo-informatics, Federal University of Technology, Akure, Ondo State, Nigeria.

[*]Corresponding author: olojaone78@yahoo.com; Tel: +2348069155169

Abstract: Image matching is a crux of computer vision and has a major part to play in everyday lives. As an alternative to traditional image acquisition methods, UAVs bridge the gap between terrestrial and airborne photogrammetry and enable flexible acquisition of high-resolution images. This paper describes the experimental evaluation of algorithms for processing unmanned aerial vehicle (UAV) images. So in this case the aim of this paper is to evaluate and compare effectiveness of the image matching algorithms, Speed Up Robust Features (SURF) and Binary Robust Invariant Scalable Keypoints (BRISK) over a pair of aerial images acquired from an Unmanned Aerial Vehicle (UAV) and these images were used to verify the effectiveness of the image matching algorithms and coordinates were also measured and extracted from the images. The data used was acquired from a secondary source. The evaluation and comparison of the algorithms were based on the number of points or features detected, number of features matched, total image matching time and efficiency. It was shown that SURF is the most efficient algorithm with 76% efficiency in terms of correctness and speed of execution. From the statistical analysis carried out, the standard deviation of pixel coordinate extracted from images based on SURF algorithm with value of X= 0.1017 and Y= 0.1110 was the least.

Keywords: **brisk, evaluation, image matching, unmanned aerial vehicle images, surf.**

1.0 INTRODUCTION

Recent years have witnessed the fast developments of unmanned aerial vehicles (UAVs). As an alternative to traditional image acquisition methods, UAVs bridge the gap between terrestrial and airborne photogrammetry and enable flexible acquisition of high resolution images. Image matching can be seen as the process of finding conjugate points in two or more overlapping images automatically and this process serve as one of the fundamental tasks in digital photogrammetry (Calonder et al., 2010).

The key issue connected with image matching is a choice of a matching entity (a primitive that is compared with a primitive in other images) and a similarity measure a quantitative measure evaluating the match of entities (Ackermann, 2009).

Image matching is an important issue in the photogrammetry field and an academic hotspot for research. It is one of the key technologies in target recognition, three-dimensional reconstruction, image retrieval (Gruen and Zhang, 2002; Richard et al., 2010).

So in this sense the aim of this paper is to evaluate and compare effectiveness of the image matching algorithms. The two competing methods for scale invariant image descriptors, SURF and BRISK were chosen, adjusted and evaluated for the purpose of this paper. The programming and image processing aspect of this work was achieved with the aid of MATLAB.

2.0 STUDY AREA

The study area covers a part of the Federal University of Technology Akure, Ondo State. FUTA is located in sub-locality, Akure locality. Akure is a city in South-western Nigeria and is the largest city and capital of Ondo State. The latitude and longitude of the area lie between 07^0 15' 2.78''N and 05^0 12' 36.96'' E and 07^0 35' 02'' and 06^0 20' 14'' respectively. The map description of the study area is shown in Figure 1.1.

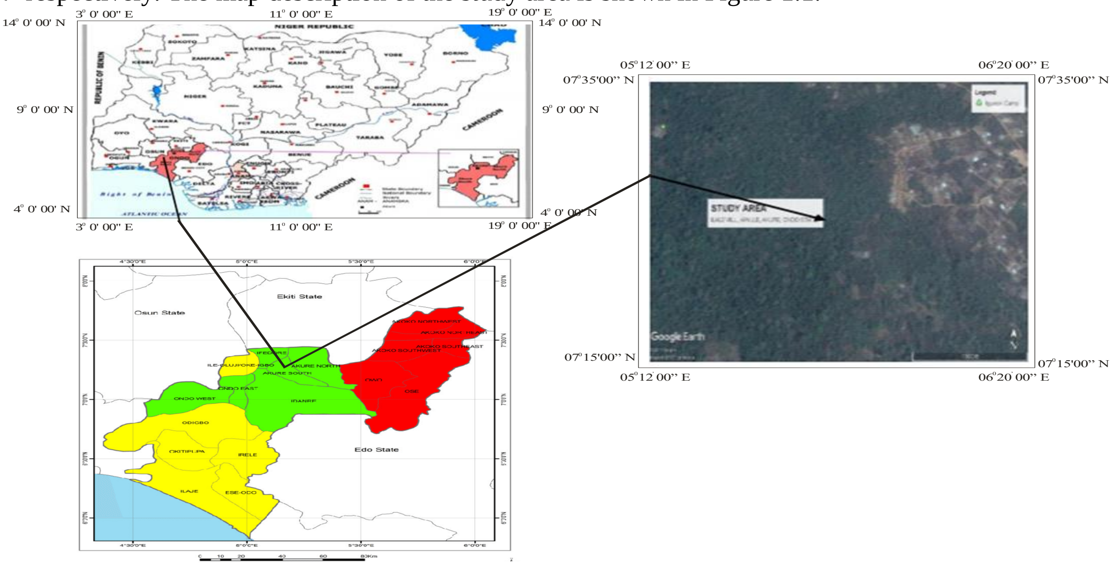

Figure 1.1: Showing the Map of Nigeria, Ondo State and the image of the project area (Source: www.google.com/Nigeria)

3.0 RESEARCH METHODOLOGY

(a) This work is based on an experimental evaluation of Algorithms in processing Unmanned Aerial Vehicle (UAV) images. In achieving this, two image matching algorithms were adopted for the matching of Unmanned Aerial Vehicle (UAV) images and each of these algorithms was evaluated based on their results. These Algorithms are:
   i. Speed Up Robust Features (SURF)Algorithm and
   ii. Binary Robust Invariant Scalable Keypoints (BRISK) Algorithm

(b) Each of these image matching algorithms adopted for this work has different methods, procedures and stages by which they were used in image matching and these different methods used by these were adopted for this work. Therefore, the presentation of evaluation of these algorithms with respect to each other which are widely accepted as a standard of comparison under common image transformations and this is done to see the algorithm that is the best.

(c) Also in addition to the research work, a program was written to measure and extract coordinates from the aerial images.

Conceptual Framework

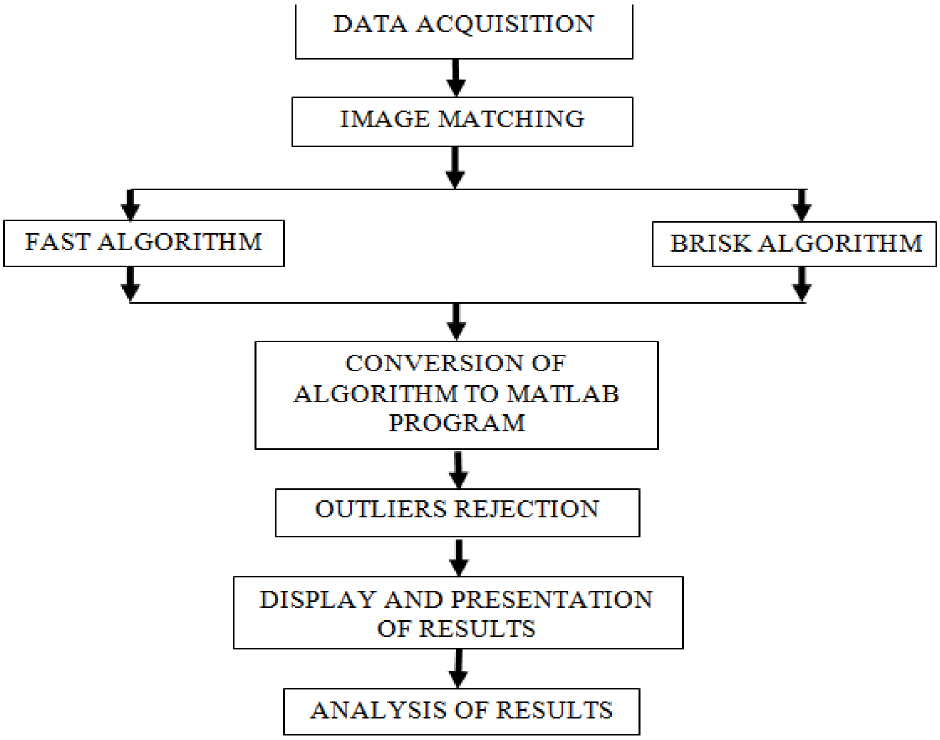

Figure 2.1: Conceptual framework diagram

(d) The figure 2.1 shows the step by step procedures involved in the execution of this project. The dataset which consists of pair of overlapping aerial photographs of part of Federal University of Technology, Akure (FUTA) taken with an Unmanned Aerial Vehicle (UAV) was acquired from a secondary source. The quality of the data was tested in terms of the drone type used to collect the data, specification of the data, resolution of the aerial photographs and the percentage of overlap to check whether it is suitable for use for this work.

(e) As earlier said that the Unmanned Aerial Vehicles (UAV) images were matched using two different image matching algorithms and the methods used by these algorithms in image matching are discussed below:

3.1 SPEED UP ROBUST FEATURES (SURF) ALGORITHM

SURF approximates the DoG with box filters. Instead of Gaussian averaging the image, squares are used for approximation since the convolution with square is much faster if the integral image is used. Also this can be done in parallel for different scales. The SURF uses a BLOB detector which is based on the Hessian matrix to find the points of interest. For orientation assignment, it uses wavelet responses in both horizontal and vertical directions by applying adequate Gaussian weights.

3.2 BINARY ROBUST INVARIANT SCALABLE KEYPOINTS (BRISK) ALGORITHM

BRISK is an image matching algorithm for high quality, fast keypoint detection, description and matching. The method is rotation as well as scale invariant to a significant extent, achieving performance comparable to the state-of-the-art while dramatically reducing computational cost. It achieves comparable quality of matching at much less computation time. The goal at this step is to identify salient points in the image that, ideally, could be uniquely differentiated from any other point. To do so, these points must be searched across the image and scale dimensions using a saliency criterion (Leuteneggeretal, 2011). This idea has been demonstrated by (Calonder et al., 2010) to be very efficient, however here we employ it in a far more qualitative manner. In BRISK, we identify the characteristic direction of each keypoint to allow for orientation-normalized descriptors and hence achieve rotation invariance which is key to general robustness. The key stages in BRISK are namely feature detection, descriptor composition and keypoint matching. They are described as follows:

Sample pair of overlapping images is shown in figure 3.1 (a) and (b). The images are RGB images shown below.

Image 1: 1080×108, 101 KB. (b) Image 2: 1080×717, 121 KB.

Figure 3.1 (a) and (b): Image datasets used for the experiment

4.0 EXPERIMENTAL RESULTS

The method for the two image matching algorithms has been extensively tested and the results displayed and gotten from MATLAB are shown below.

4.1 Features Detected in Images

Features are detected in both images using SURF and BRISK algorithms and the number of features detected by each image matching algorithm is stated.

(a) Image 1

(b) Image 2

Figure 4.1 (a) and (b): Detected Features using SURF on image1 and Image 2

The figure 4.1 (a) and (b) show the detected features using SURF on image 1 and image 2. The green plus (+) sign on the image indicate the interest point locations where SURF algorithm detects features. It was observed that **474** features were detected in image 1 and **643** features was detected in image 2.

(a) Image 1 *(b) Image 2*

Figure 5.1 (a) and (b): Detected Features using BRISK on image1 and Image 2

The figure 5.1 (a) and (b) show the detected features using BRISK on image 1 and image 2. The green plus (+) sign on the image indicate the interest point locations where BRISK algorithm detects features. It was observed that **797** features were detected in image 1 and **1129** features was detected in image 2.

4.2 Feature Image Matching

The feature matching technique adopted here is Normalized Cross Correlation technique which was used in matching SURF and BRISK features.

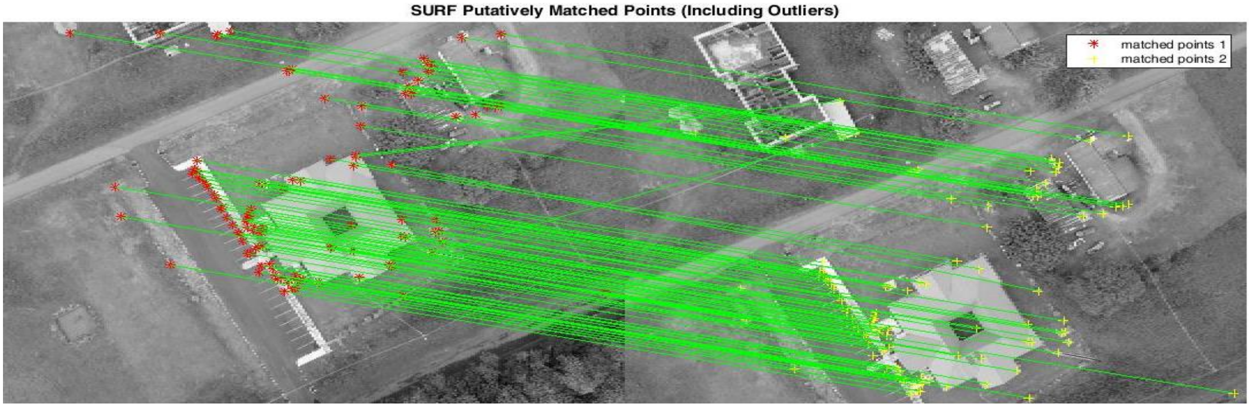

Figure 6.1(a): Image matching with SURF Algorithm including outliers

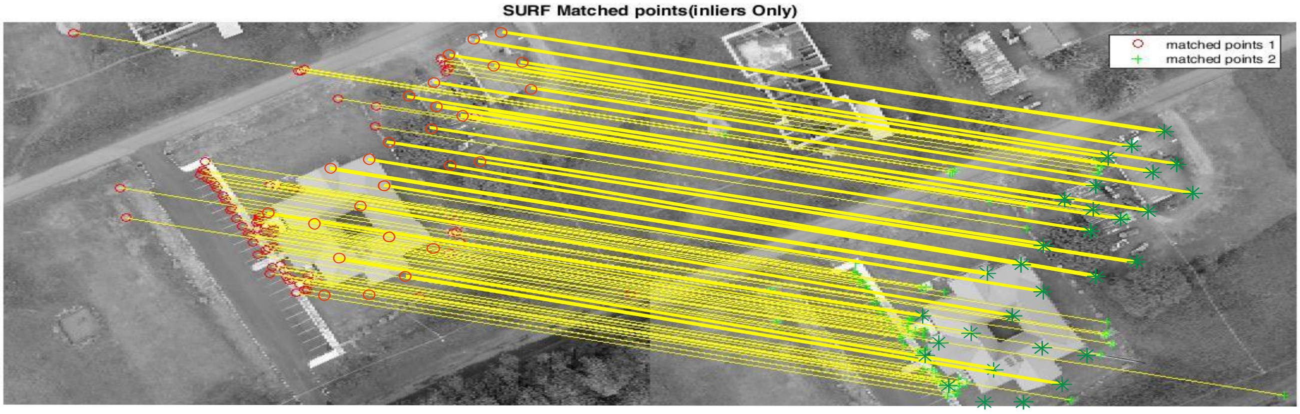

Figure 6.1(b): Image matching with SURF Algorithm including inliers only

In figure 6.1 (a), the green lines connect same features or points in the two overlapping photographs that are matched together. Also the small red asterisks sign indicates the matched points or features on image1 while the small yellow plus sign indicates the matched points or features on image2. So, the features matching which was done in the figure above shows **230** matched points including outliers for SURF algorithm. The number of outliers is **90** features while in Figure 6.1 (b) the yellow lines connect the same features or points in the two overlapping photographs that are matched together. The small red asterisks sign indicates the matched points on image 1 while the green small sign indicates the matched point or features on image 2.So, the feature matching which was done in the figure above shows matched points including inliers only for SURF algorithm. The number of inliers is **140** features.

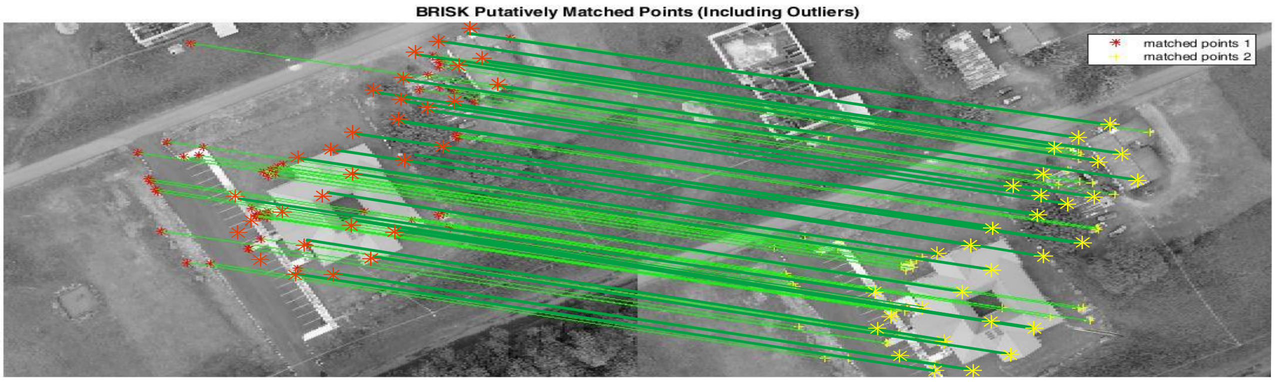

Figure 7.1(a): Image matching with BRISK Algorithm including outliers

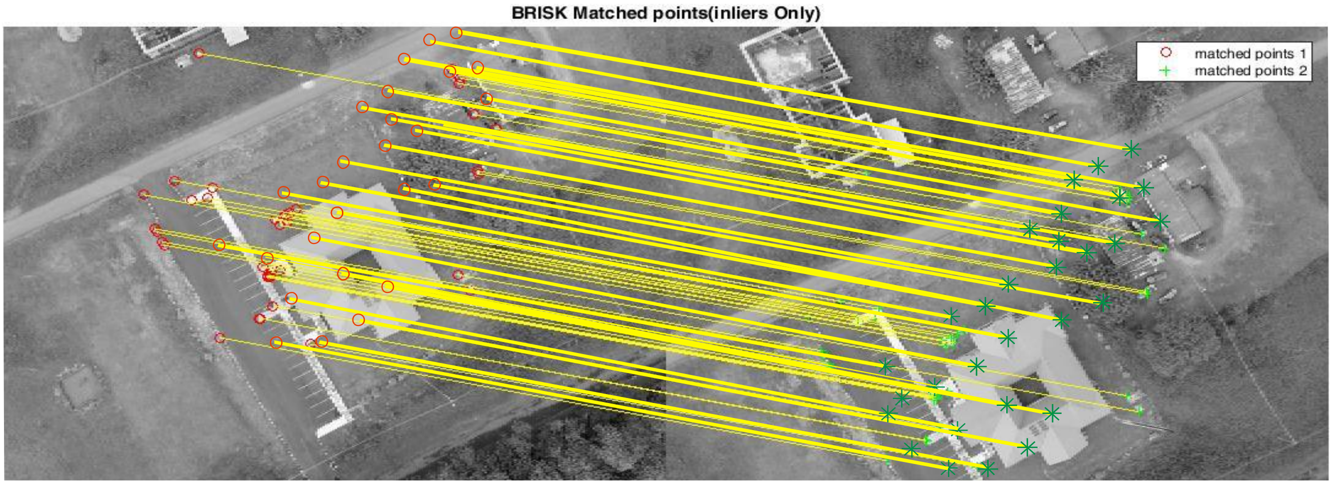

Figure 7.1(b): Image matching with BRISK Algorithm including inliers only

In figure 7.1 (a), the green lines connect same features or points in the two overlapping photographs that are matched together. Also the small red asterisks sign indicates the matched points or features on image1 while the small yellow asterisks sign indicates the matched points or features on image2. So, the features matching which was done in the figure above shows **190** matched points including outliers for BRISK algorithm. The number of outliers is **70** features while in Figure 7.1 (b) the yellow lines connect the same features or points in the two overlapping photographs. The small red asterisks sign indicates the matched points on image 1 while the green small sign indicates the matched point or features on image 2.So, the above shows matched points including inliers only. The number of inliers is **120** features.

5.0 ANALYSIS OF RESULTS

This paper aims at providing an overall fast as well as robust detection, description and matching. The performance of all these stages in SURF and BRISK were evaluated. Based on the experimental results shown above, quantitative comparison of each algorithm was done based on the number of points or features detected, number of features matched, total image matching time and efficiency

5.1 Number of Points or Features Detected and Matched

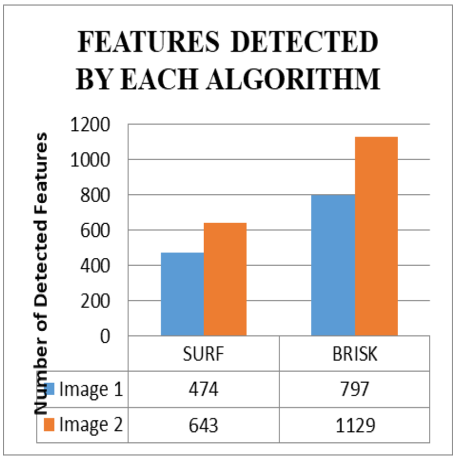

Figure 8.1: Features detected by SURF and BRISK

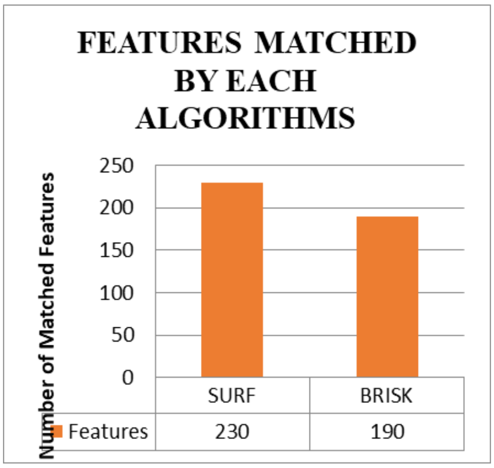

Figure 9.1: Features matched by SURF and BRISK

The figure 8.1 shows in graphical form the number of features detected in each image by each of the image matching algorithm. It shows that BRISK algorithm detected the highest number of features in both images. The figure 9.1 shows that SURF algorithm has the highest number of matched features from both images. This indicates that SURF algorithm has the ability of matching more corresponding features or points detected in two or more images.

5.2 Timings

Tests were performed to measure the relation between execution time in the steps of detection, description and matching of the algorithms. The time was recorded with the aid of a stopwatch and the result in time is shown in table 1.0 below. Each timing value presented in the table is the average of **10 measurements** (to minimize errors which arise because of processing glitches). Table 1.0 and figure 10.1 show in tabular and graphical form respectively, the Average Image Matching Time by each algorithm.

Table 1.0: Average Image Matching Time

Algorithm	Mean Image Matching Time (seconds)
SURF	0.00212
BRISK	0.00271

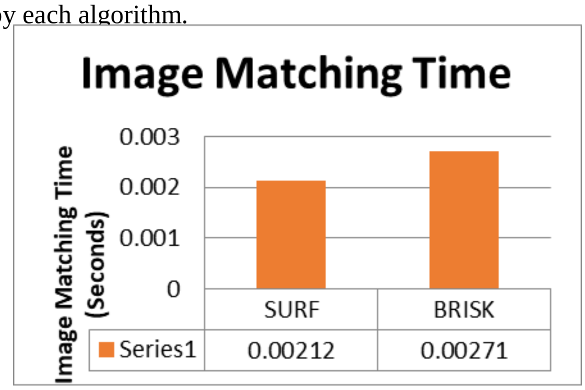

Figure 10.1: The average image matching time by each

The timing shows that SURF algorithm is fastest in detecting and matching of features.

5.3 Efficiency

According to Mair et al., (2010) the efficiency of each algorithm was evaluated and it is calculated based on the experimental result, using a relation given by:

$$\% \, Efficiency = \frac{2 \times NoofMatches}{\text{Total number of features detected}} \qquad (1.0)$$

The efficiency of each algorithm was calculated and the result is shown in table 4.8 below. The results showed that the number of matches is significantly lesser than the number of features detected. Therefore, it established that the number of matches is by themselves not very good. What is needed is to evaluate and compare that how much of features that are detected by the algorithm are actually useful in the process of matching then to their correspondents. So, the most efficient algorithm based on the experimental result is SURF with 76% efficiency.

5.4 Repeatability

The detector repeatability score as defined by (Mikolajczyk et al., 2005) is calculated as the ratio between the corresponding keypoints and the minimum total number of keypoints visible in both images. The correspondences are identified by looking at the overlap area of the keypoint region in one image (i.e. the extracted circle) and the projection of the keypoint region from the other image (i.e. ellipse-like): if the region of intersection is larger than 50% of the union of the two regions, it is considered a correspondence. The result is shown in table 2.0 below.

5.5 Recall and Precision Evaluation

Recall and precision are two relevant metrics used to show the effectiveness of a descriptor method. Recall measures the proportion of correct positives matches, considering all the possible correct positive matches between two images. While precision measures the proportion of false positives matches, considering all the performed matches between those images (Alexander et al., 2013). Mathematically,

$$\textbf{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negative} \qquad (2.0)$$

$$\textbf{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive} \qquad (3.0)$$

These curves in figure 6 represent the algorithm capacity to keep a small number of false positives (precision) while it associates the maximum number of keypoints between two images (recall)

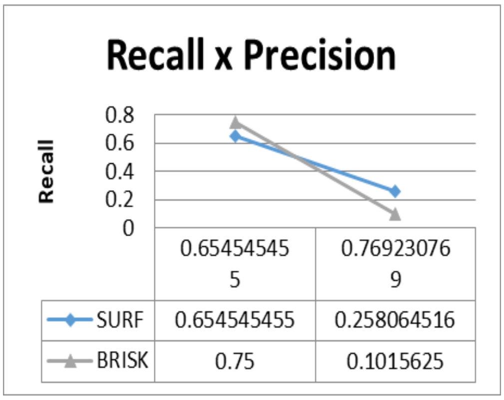

Figure 11.1: Recall and Precision line

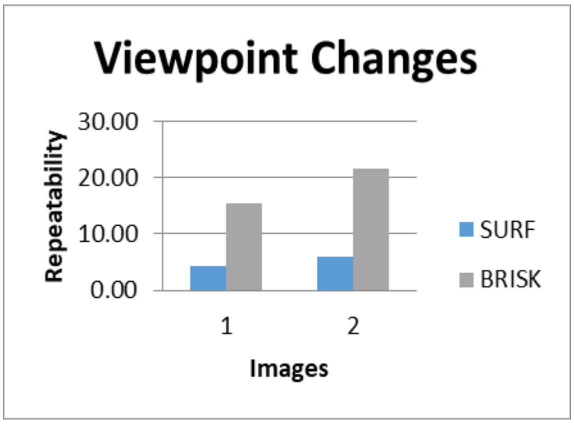

Figure 12.1: Repeatability test for images

5.6 Statistical Analysis

The standard deviation of X, Y, pixel coordinates of image points extracted from the image through SURF and BRISK algorithm was computed as shown in table 3.0 below. From the statistical analysis carried out, the standard deviation of pixel coordinate extracted from images based on SURF algorithm with value of X= 0.1017 and Y= 0.1110 was the least.

5.7 An Assessment on the joint performance

An assessment on the joint performance of all these stages in SURF compared to BRISK. Based on the experimental results shown in the table of results below, quantitative comparison of each algorithm was done base on the number of points or features detected, number of features matched, total image matching time, efficiency and repeatability.

Table 2.0: The Results of Quantitative Comparison for Each Image Matching Algorithm.

Algorithm	**Features Detected in Image Pairs**		**Features Matched**	**Inliers**	**Outliers**	**Mean Image Matching Time(seconds)**	**Repeatability (%)**	**Efficiency (%)**
	Image 1	**Image 2**						
SURF	474	643	230	140	90	0.00212	576.47	76
BRISK	797	1129	190	120	70	0.00271	37.23	34

5.8 Comparison of Image Matching Algorithms based on various Parameters

Comparison of image matching algorithms shown in the table below was done based on various parameters according to the results that were gotten.

Table 3.0: Comparison of each Image Matching Algorithm based on various parameters.

COMPARISON POINTS	SURF	BRISK
RATE OF FEATURE DETECTION	High	Very High
RATE OF MATCHING FEATURES	Very High	High
SPEED	Very Fast	slow
EFFICIENCY	More efficient	Less Efficient
REPEATABILITY	Low	High

6.0 CONCLUSION AND FUTURE WORKS

The main objectives of this paper were to evaluate image matching algorithms in unmanned aerial vehicle (UAV) images with a view to determining the most efficient image matching techniques using SURF and BRISK algorithms. This system was then tested to validate the functionality and efficiency of the algorithms.

Based on the experimental result it can, therefore, be concluded that SURF algorithm is the most efficient algorithm with 76% efficiency based on its correctness and speed of execution with the least standard deviation of pixel coordinate extracted from images with value of X = 0.1017 and Y= 0.1110, result showed that SURF algorithm is faster in detection and matching of features.

As a part of future work, it is recommended to use more image matching algorithms in addition to the ones used in this research using the same dataset. It is expected that these would improve the efficiency.

REFERENCES

Ackermann, F. (2009). Digital Image Correlation: Performance and Potential Application in Photogrammetry. Photogrammetric Record, 11(64): 429-439.

Alexander G., Camila T., Rodrigo de Bem and Diana A. (2013). Performance Evaluation of BRISK Algorithm on Mobile Devices. *In Proceedings of the International Conference on Computer Vision Theory and Applications* (VISAPP-2013), pages 5-11.

Calonder, M., Lepetit, V., Strecha, C., and Fua, P. (2010). Brief: Binary Robust Independent Elementary Features. In Proceedings of the 11th European Conference on Computer Vision (ECCV 2010), pages 778-792.

Gruen, A. and Zhang, L. (2002). Automatic DTM generation from three-line scanner (TLS) images. *International Archives of Photogrammetry Remote Sensing and Spatial Information Sciences,* 34(3/A), pp. 131-137.

Leutenegger, S., Chli, M. and Siegwart, R. (2011). BRISK: Binary Robust Invariant Scalable Keypoints. *In Proceedings of the 13th International Conference on Computer Vision* (ICCV 2011).

Mair, E., Gregory, D.H., Darlus, B., Michael, S., and Gerhard, H., (2010). Adaptive and Generic Corner Detection Based on the Acceretaed Segment Test. European Conference on Computer Vision pp 183-196.

Mikolajczyk, K., Tuytelaars, C., Schmid, A., Zisserman, J., Matas, F., Schaffalitzky, T. K., and Gool, L. (2005). A Comparison of Affine Region Detectors. *International Journal of Computer Vision* (IJCV), 65(1):43–72, 2, 5.

Richard, J.C., Tang, Y., and Sith, J, (2010). A class of Algorithms for Mixed-Integer. *Journal of Global Optimization,* pp 49-57.