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Analysis and Implementation of Fast Corner Detector in Image Stitching for Making Aerial Photogrammetry Images

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Abstract

Aerial photogrammetry is a branch of geography that focuses on capturing objects, areas, or phenomena on the Earth's surface. This process involves using a camera with photographic recording capabilities, supported by a film-based detector. In practice, precise techniques are needed to merge aerial photographs to achieve a wider perspective. This research utilizes the image stitching method to combine images. Image stitching, also known as panoramic imaging, is a technique for merging multiple overlapping images to create a panoramic view or a larger image with an extended field of view. The process relies on identifying key features in overlapping areas, using the FAST corner detector as a reference for alignment. The results of the study indicate that the FAST Corner Detector for threshold 9 is sufficient for use in detecting corners because it produces the largest number of corners with the largest angle formed. Then in scenario two, it shows the accuracy of FAST Corner Detector reaches 100% precision in detecting shape images. Furthermore, in testing several image conditions in the real world, FAST Corner Detector can still detect the corners that exist from engineering images. In scenario 4, the FAST Corner Detector can also perform stitching with various positions, both diagonal and horizontally aligned; there is rotation and implementation of scale with a positive CC value, which means that the image has similarities. and finally based on the test results with MOS, all values show good results. Images with a scale have a similarity level of 75%, so they look not perfectly stitched.

Keywords: Image Stitching, FAST Corner Detector, SURF, Image Registration

I. Introduction

The advancement of digital camera technology in recent years has encouraged all humans to create innovations that can make it easier for humans to use them. Currently, cameras are no longer only used to take photos of nature or humans. Digital cameras can be used to take pictures of the entire earth. One of the functions of digital cameras that is currently needed in technology is to create Aerial Photogrammetry. Aerial Photogrammetry is one of the products of the field of geography in capturing objects, areas, or phenomena on the earth's surface using a tool in the form of a camera with a photographic recording process with the help of a detector in the form of film [1]. The results of this Aerial Photogrammetry Imagery are obtained by taking pictures using vehicles in the form of hot air balloons, airplanes, hang gliders, ultra-light aircraft, and drones [2]. This shooting is done by determining the purpose of the shooting, determining the flight path, and

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determining the direction of flight. With the help of this aerial camera and airplane, aerial photography can be done.

Although digital cameras have many advantages, it turns out that there are still various limitations. One of them is that it is not yet able to capture images with a wide viewing angle, namely panoramic images. To complement this, an image processing technique known as image stitching or panoramic mosaicing emerged, which is a method of combining several images or pictures that have overlapping fields of view to produce a panoramic image or picture that has a larger size so that the image has a wider viewing angle [3].

In general, image stitching has two main components, namely, image registration and image merging. Image registration talks about finding similarities between 2 images through features, and merging talks about the process of combining images. In the image stitching process, there are many methods that can be used, including the FAST Corner Detector, Harris Corner Detector, Hessian Feature Detector, SIFT, SURF, and many more methods that are being developed. In this study, the FAST Corner Detector method was used because it has good capabilities in detecting corners. In the process, it is necessary to know how many pixels are used as a threshold or corner detector. This method can combine several images, where the detected corners are used as a reference for merging so that it can be more efficient in selecting the overlapping that occurs. In addition, there are several other obstacles, namely the ability to detect simple images (shapes), images with clarity constraints, scaled images, rotated images, and different image positions.

So that in this study the FAST Corner Detector method will be implemented in determining the Correspondence Point in the image stitching process and analyzing the results of image stitching using the FAST corner detector between the stitched image and the original image. To evaluate the results, a comparison method is used with a human vision for simple images, followed by image similarity with cross-correlation and stitching success with Mean Opinion Score.

II. LITERATURE REVIEW

A. Image Stitching

Image Stitching is the process of combining several overlapping photos or images with a field of view to produce a panoramic image that has a wider size. Image stitching technology can be used to produce wide panoramic images that show long roads [4]. Generally done through the use of computer software, to perform stitching requires the same overlap between the main image and the sliced image. Currently, some digital cameras can already stitch their photos internally. The process of image stitching according to [9] is first feature matching, image registration and seam removal. In general, the Image Stitching Process can be divided into two main components, namely:

1) Image Registration: In this stage, the process of aligning two images into a coordinate system occurs so that it produces an overlapping image by setting the correspondence between the two images as the basis for aligning the areas that will overlap.

2) Image Merging: The process of combining images that have been matched so that they become one complete image with a larger size. This is done based on the correspondence point found in the registration process.

B. Image Registration

According to Wang, Z., & Yang, Z in [9], image registration is a process of combining several different images in the same area with different viewing angles. Image Registration basically consists of the following steps:

1) Feature Detection: Feature detection is the process of bringing out features from an object, whether boundaries, edges, contours, line intersections, or corners, which can be done manually and automatically. Furthermore, this feature will be represented by each point, which is called Control Point (CPs).

2) Feature Matching: Feature Matching is the correspondence between features that have been detected in the image with those detected in the reference image to be formed. Many descriptor features and similarity measurements with spatial relationships between features are used to form the image.

3) Transform model estimation: The types and parameters in the transform model are called mapping functions, which function to align the input image with the reference image by estimating the area to be overlapped. The parameters of the mapping function are calculated based on the average of the predetermined correspondence features.

4) Image Resampling and Transformation: The image used is transformed based on the mapping function. The value of the image in the form of non-integer (coordinates) is calculated using the appropriate interpolation technique.

C. FAST Corner Detector

One method in feature detection, especially in the Feature-based Method, is the FAST corner detector. Fast stands for Features from Accelerated Segment Test. FAST Corner detector evaluates the difference in pixel intensity of 16 different pixels around a circular area, identifying corners based on pixel intensity significantly higher or lower than its neighbors [10]. The segment testing criteria in the FAST corner detector are calculated by considering sixteen pixels from the image that are around the candidate corner (P). The detector classifies P as a corner if there is a set of n adjacent pixels in a circle, all of which are brighter than the pixel intensity Ip (candidate) + threshold (t) or all darker than Ip- threshold. FAST Cornet detector illustration can be seen in Fig 1.

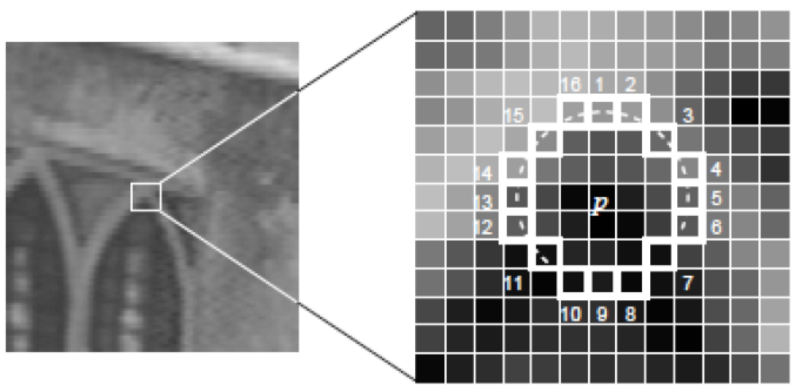


Fig. 1. Illustration of FAST Corner Detector [11]

How it works:

1. Pixels 1 and 9 are checked. If both are at threshold (t) with Ip, then P cannot be a corner because P will be a corner if the surrounding pixels are brighter than the pixel intensity Ip (candidate) + threshold (t) or all darker than Ip (candidate) - threshold (t).
2. If P is still possible to be a corner, then pixels 5 and 13 are checked.
3. If P is a corner, then in the test circle, at least three of the tests must be brighter than Ip+t or darker than Ip-t.
4. If all of them do not happen, then P is not a corner.
5. The test criteria can be applied to the remaining pixels by checking all pixels in the circle.

D. SURF Descriptor

According to [7], SURF is a popular method for detecting and describing key points in an image. A descriptor is a pixel area around the generated keypoint (corner). The descriptor describes the distribution of neighboring pixel intensities around the key point. Each descriptor has a value:

1. Position of the x-axis & y-axis
2. Scale (Scale at which the corner feature is detected)
3. Metric (Value describing the strength of the detected feature)
4. Sign Of Laplacian (Sign Of Laplacian is determined during the detection process)
5. Orientation (Angle between the x-axis and the origin)

The first process is to match the resulting orientation based on information from the circular area around the pixel that is the keypoint. Then the next process creates a box-shaped area at the selected orientation and extracts the SURF descriptor from that area. Then, the feature-matching process between the two images is carried out. Feature matching is done by comparing the intensity and existing descriptors.

E. RANdom SAmple Consensus (RANSAC)

The RANSAC (Random Sample and Consensus) algorithm was first introduced by Fischler and Bolles as a method for estimating certain parameters contaminated by outliers (mean deviation points) in large numbers. RANSAC, with its robustness, is widely used in various fields, including signal estimation, image stitching, and pattern detection in image processing [12]. Ransac is an estimation procedure that uses a minimal sample data set to estimate parameters from observed data containing outliers. Ransac is a non-deterministic algorithm that produces results with a certain probability, with the possibility of increasing this probability and then having many iterations.

A basic assumption is that the data consists of inliers, namely the data distribution that can be explained by some series of model parameters, and outliers, which are data that do not fit the model. RANSAC is used to select a set of inliers that match the homography with the image. In RANSAC, the best results are achieved by determining how many iterations are performed and selecting a random subset of the original data. These data are hypothetical inliers, and the hypothesis is then tested as follows:

- A model is constructed based on the initial set of hypothetical inliers, with all its free parameters derived from the dataset.
- The remaining data points are then tested against this fitted model, and any point that aligns with the model is also treated as a hypothetical inlier.
- The model is considered satisfactory if a sufficient number of points are classified as hypothetical inliers.
- The model is then refined using the complete set of hypothetical inliers, as the initial estimation was based on only a subset of them.
- Finally, the model is assessed by calculating the error of the inliers relative to the model.

III. RESEARCH METHOD

In this study, a system was built that implements the image stitching process in the formation of panoramic images. In general, its formation is divided into several stages, namely Image Registration and image merging. Each method has a continuous process, so each output produced by a process affects the input of the next process, as seen in Fig 2.

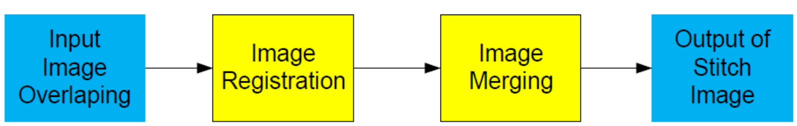


Fig. 2. Illustration of FAST Corner Detector

The initial stage is the image registration process. At this stage, the process of aligning two images occurs, which overlap each other by setting the correspondence between the two reference images and the sensed image. In general, the registration process is divided into several stages, namely, feature detection, feature matching, transform model estimation, and image resampling and transformation.

Before merging, first matching is done at each detected point using the FAST Corner detector, which will be used as a reference for merging. Each corner of the reference image will be compared with all corners of the detected image. In this study, the SURF descriptor is used because, based on research [5][6], SURF has a higher quality than several other methods in producing descriptors. To get the right angle, a separation between inliers and outliers is carried out using RANSAC. So, by using the right angle, these images can be combined into a larger image. This process can be seen in Fig. 3.

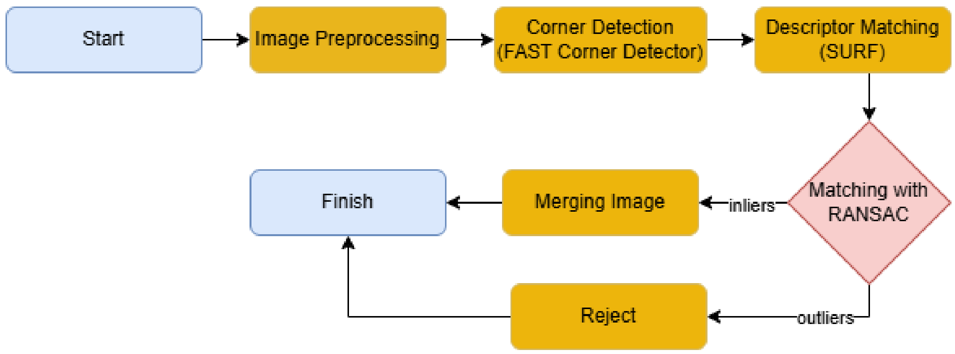


Fig. 3. Image Merging Flowchart

To test the feasibility, it can be tested by experimenting with a group of images with large lighting, moving images, and stitching analysis [14]. So, in this study, 5 test scenarios were carried out, namely threshold, simple object detection ability, testing with image interference, testing with different shooting conditions, and testing with human vision comparison.

IV. RESULTS AND DISCUSSION

A. Scenario 1

In this scenario, the method for selecting the threshold value used by the FAST Corner Detector is to calculate the number of points generated at all possible thresholds (the number of pixels as a corner requirement) that exist n= (9,10,11,12,13) along with the threshold intensity corner that will be used. The results of the calculation of testing scenario 1 can be seen in Table I.

TABLE I
RESULT TESTING SCENARIO 1

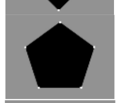
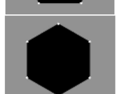
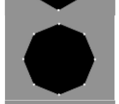
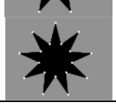
Threshold (n)	Angle (degree)	Intensity Treshold	Number of Corner
9	157.5	0.1	3368
		0.3	868
		0.5	262
10	135.0	0.1	2983
		0.3	753
		0.5	202
11	112.5	0.1	2623
		0.3	675
		0.5	164
12	90.0	0.1	2309
		0.3	587
		0.5	144
13	67.5	0.1	2105
		0.3	520
		0.5	110

The selection of the threshold value N (the number of pixels checked as a requirement for a corner) in the FAST Corner Detector method is carried out according to the needs of using this method. In image stitching, many detection points are needed whose uniformity will be sought so that it can produce better and more corresponding points. This will make it easier for the system to carry out the stitching process. According to the test results, the threshold n in FAST that is suitable for use is n = 9. Because at this threshold, more points are produced, and this threshold produces the largest angle to form a corner. In addition, n = 9 is the middle threshold that can handle points that are considered corners that produce points that are not too many and not too few. N < 8 is not counted because it produces an angle smaller than n=9. N =8 does not produce an angle because it is a straight line. Then, the threshold N=9 is the threshold value that produces the largest angle with the largest number of points.

B. Scenario 2

The second scenario tests the accuracy of point detection produced by the FAST Corner Detector method. In this scenario, testing is carried out on several types of images whose angles can be calculated by the eye so that the resulting angle precision value can be calculated. The calculation results can be seen in Table 2.

TABLE 2
RESULT TESTING SCENARIO 2

No	Image	Angle (degree)		Number of Corner		Precision
		In	Out	Manual	System	
1		120	240	3	3	100%
2		90	270	4	4	100%
3		72	288	5	5	100%
4		60	300	6	6	100%
5		45	315	8	8	100%
6		72	288	10	10	100%
7		120	240	6	6	100%
8		51.4	308.6	14	14	100%
9		40	320	18	18	100%

Based on the test results on the FAST corner detector, the precision value of each test image is obtained which has the same value, namely = 100%. The images tested have different angle sizes from each other. This value illustrates the accuracy of corner determination carried out by the FAST corner detector based on human corner perception. This precision value is obtained from a comparison between the number of corners from human vision and the corners from the system's detection results. The resulting value is classified as very good because there are no corners that are not detected.

C. *Scenario 3*

The third scenario is carried out to determine the results of the Fast corner detector on various types of images (G) that have been engineered. This test is conducted to demonstrate real-world conditions in taking photos that are not ideal, for example, the presence of fog, smoke, or other obstructions, high and low shooting conditions, and various lighting conditions.

The engineered images used are processed using Photoshop with various types, namely normal images (N), blur / BL (Gaussian blur), Noise / NS (Uniform distribution), Scale0.5 / SC5 (reduce 0.5 times), Scale2 / SC (Enlarge 2 times), Bright / BR1 (25), and bright / BR2 (50). In this test, the number of detected points will be calculated with the conditions of each image as attached in Fig. 4.

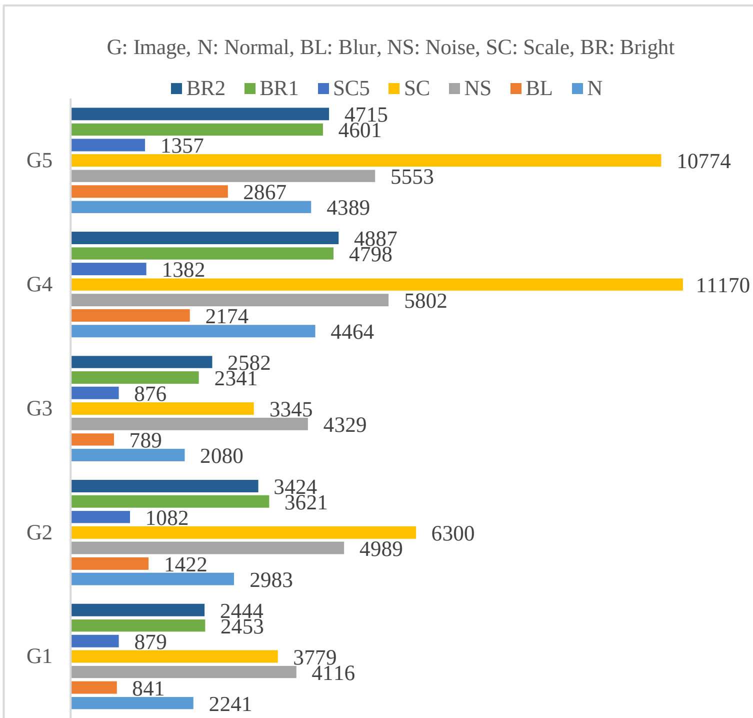


Fig. 4. Result Testing Scenario 3

Based on the test results above, it can be seen that corner detection in the FAST corner detector method is greatly influenced by the condition of the image. Images that are given a blur effect will experience a reduction in the number of detected points. This is because the detected features are disguised in the blur effect so that the prominent features are not detected by the detector. The addition of noise increases the number of corners because the noise also becomes a corner in the image. For images that are enlarged with a scale = 2, there is a significant increase in corners up to twice the number of normal images. This is because the image size is enlarged twice so that the pixels detected as corners will be more.

While in the image whose brightness is increased by 50%, there is an increase in the number of corners that is not too significant. This happens because, in the process of adding brightness, the previously detected bright features are no longer detected due to their increased intensity. The greater the brightness value, the number of corners will increase, but this addition is followed by a reduction in the number of points that initially had bright intensity so that when it reaches the threshold, the corners will disappear because the image will become uniformly white.

D. Scenario 4

The fourth scenario calculates the correlation value using cross correlation between the output image generated by the system, with the original image that has been provided previously. [13] The Cross-Correlation value is increasingly positive, approaching 1, meaning that there is increasing similarity between the compared images. So that from the measurement results, all Cross-Correlation values get positive values, which can be seen in the following Table 3.

TABLE 3
RESULT TESTING SCENARIO 4

No	Image	Cross-Correlation
1		0.9705
2		0.9706
3		0.8848
4		0.7542
5		0.9338

The test results are grouped into three classes, as follow.

1) Upper class: It is a classification of stitching results whose cross-correlation has a value greater than 0.9 (x > 0.9). This class is an image that is stitched only by shifting the position of the image, without changing the shape of the image itself. In the test, the types included in this class are diagonal, horizontal to the right, and horizontal to the front.

2) Middle class: It is a classification of stitching results whose cross-correlation has a value between 0.8 and 0.9 (0.8 <x <0.9). In this class, there is a decrease in the correlation value due to the rotation variable that affects the shape of the image so that the position of the pixels in the image changes and affects the correlation results (cross-correlation), which in the test is worth 0.8848.

3) Lower class: It is a classification of stitching results whose cross-correlation has a value smaller than 0.8 (x < 0.8). In this class, the type of image that is included is an image that has a scale. This happens because there is a variable of magnification or reduction of pixels from the image that affects the process of matching corners and stitching.

E. Scenario 5

In this test, the calculation of opinion results (questionnaires) was carried out on 20 respondents using the Mean Opinion Score (1-4). Each respondent will assess five stitched images, with different ways of combining them. Subjective quality evaluation is the most accurate method to measure quality based on perception, which is represented by the MOS score of subjective assessments collected from a number of users [15].

Based on the results of the Mean Opinion Square (MOS) calculation in Fig. 5, it can be seen that based on the human eye, the errors that occur in the stitching results are not very visible, especially for images 1, 2, 3 and 5. Meanwhile, for image 4, there were 3 respondents who managed to see the inaccuracy in the stitching. The test using MOS is in accordance with the results of the fourth test, which produced a cross-correlation value for image 4 in the lower class. This occurs because the inaccuracy of the stitching in the 4th image is only a few pixels, so it cannot be fully examined by the human eye. Also, with the many color variations in aerial photogrammetry, the displacement and inaccuracy of several pixels are disguised.

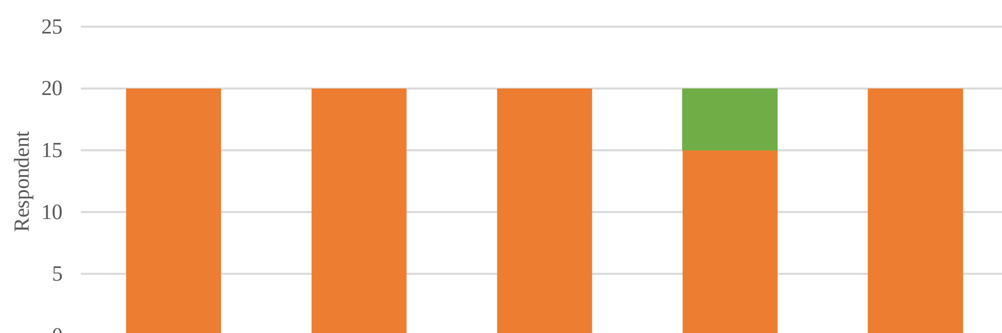


	Image 1	Image 2	Image 3	Image 4	Image 5
Bad	0	0	0	0	0
Fair	0	0	0	5	0
Good	0	0	0	0	0
Excellent	20	20	20	15	20

Fig. 5. Mean Opinion Square Testing

V. CONCLUSION

From this study, several things can be concluded. The FAST corner detector method can be applied in the image stitching process to form a complete aerial photogrammetry image with a larger size, with various image shapes and directions of merging. This process produces images grouped into three classes based on their Cross-correlation, namely: the upper class with a large cross-correlation value of 0.9 for diagonal stitching images, horizontal to the right, and horizontal to the front. Then, the lower class has a cross-correlation value between 0.8 and 0.9 for images that have rotation, and the lower class has a small cross-correlation value of 0.8 for images that have a scale factor. The FAST corner detector method is suitable for use in detecting features of an image, especially for aerial photogrammetry images that have a lot of color diversity. The accuracy of corner detection produced by FAST corner is very high, so that the FAST corner detector can also be used on images other than aerial photogrammetry.

The variables of scale, rotation, noise and brightness affect the results of image detection as indicated by the number of points that change and the stitching results for scale and rotation images are included in the middle and lower classes. Based on the results of subjective assessments, in general the resulting images are excellent (valued 4), and only scaled images have respondents who give a good value (3) because there is a slight shift. The threshold value N (number of points as a corner requirement) suitable for use in this study is N = 9. For further research, researchers recommend choosing a reliable image-matching method. Then, calibration is needed to get good results. The FAST corner detector method is applied to Video because of its speed advantage.

REFERENCES

[1] K. Dimitrov, I. Damyanov, D. Saliev and T. Valkovski, "Pasture Research Using Aerial Photography and Photogrammetry," 2021 29th National Conference with International Participation (TELECOM), Sofia, Bulgaria, 2021, pp. 121-124, doi: 10.1109/TELECOM53156.2021.9659796.

[2] Arcgis. 2024. "What is photogrammetry?". Photohttps://pro.arcgis.com/en/pro-app/latest/help/data/imagery/introduction-to-ortho-mapping.htm

[3] Bruno, Nazarena & Perfetti, Luca & Fassi, Francesco & Roncella, Riccardo. (2024). Photogrammetric Survey of Narrow Spaces in Cultural Heritage: Comparison of Two Multi-Camera Approaches. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XLVIII-2/W4-2024. 87-94. 10.5194/isprs-archives-XLVIII-2-W4-2024-87-2024.

[4] J. Shan, W. Jiang, Y. Huang, D. Yuan and Y. Liu, "Unmanned Aerial Vehicle (UAV)-Based Pavement Image Stitching Without Occlusion, Crack Semantic Segmentation, and Quantification," in IEEE Transactions on Intelligent Transportation Systems, vol. 25, no. 11, pp. 17038-17053, Nov. 2024, doi: 10.1109/TITS.2024.3424525.

[5] R Lionnie, TM Kadarina,Alaydrus M. 2018. Analisis Metode SIFT dan SURF untuk Sistem Pendeteksi Gambar Termanipulasi Penyerangan Copy-Move Forgery. InComTech Universitas Mercubuana.

[6] S. A. K. Tareen and Z. Saleem, "A comparative analysis of SIFT, SURF, KAZE, AKAZE, ORB, and BRISK," 2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), Sukkur, Pakistan, 2018, pp. 1-10, doi: 10.1109/ICOMET.2018.8346440.

[7] Riabko, A., & Averyanova, Y. (2024). Comparative analysis of SIFT and SURF methods for local feature detection in satellite imagery.

[8] Kaur, H., Koundal, D., & Kadyan, V. 2021. Image fusion techniques: a survey. Archives of computational methods in Engineering, 28(7), 4425-4447.

[9] Wang, Z., & Yang, Z. 2020. Review on image-stitching techniques. Multimedia Systems, 26(4), 413-430.

[10] Yazdi, Reza, and Hassan Khotanlou. "Robust Corner Detector Based on Local Maximum and Minimum Differences." 2024 10th International Conference on Web Research (ICWR). IEEE, 2024.

[11] Edward Rosten and Tom Drummond, “Machine learning for high-speed corner detection” in 9th European Conference on Computer Vision, vol. 1, 2006, pp. 430–443

[12] Zhang, G., & Chen, Y. 2020. More informed random sample consensus. In 2020 8th International Conference on Control, Mechatronics and Automation (ICCMA) (pp. 197-201). IEEE.

[13] Szeliski, Richard. 2006. Image Alignment and Stitching:A Tutorial. Microsoft Research Microsoft Corporation: Redmond

[14] Ai, Yunting, and Jiangming Kan. "Image mosaicing based on improved optimal seam-cutting." *IEEE Access* 8 (2020): 181526-181533.

[15] Cheon, M., Yoon, S. J., Kang, B., & Lee, J. 2021. Perceptual image quality assessment with transformers. In *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition* (pp. 433-442).