

A Comparative Study: Evaluating Mosaic Generation and Utilization

Nyamkhagva Sengee¹, Tserennadmid Tumurbaatar^{1*}

Abstract

This study investigates the creation of large-scale images through mosaic construction and evaluates the outcomes thereof. The initial phase of the study involves a comprehensive comparison of algorithms commonly employed in mosaic creation, focusing on their respective strengths and weaknesses in terms of precision and computational efficiency. The experimentation is conducted on a dataset comprising 150 images obtained from SenseFly's aerial surveys. Results reveal that the utilization of the SURF algorithm for mosaic creation yields the highest precision, with a matching value of 30.6381 and a processing time of 605.5 seconds, surpassing other algorithms. However, employing the SURF algorithm for processing entire images poses challenges in terms of computational complexity, processing time, and memory usage. To address this, a methodology is proposed to selectively apply algorithms based on segment characteristics, enhancing precision and reducing processing time. Experimental results demonstrate that employing this approach reduces processing time to 120.2 seconds and minimizes error, resulting in superior outcomes when utilizing the SURF algorithm for the entire dataset.

Key Words: Image Mosaic, SURF, MSER, FREAK.

I. INTRODUCTION

Computer science, especially image processing algorithms, are currently being utilized extensively across various fields, yielding fruitful results. Generating large-scale images, particularly creating mosaic images, involves aggregating multiple smaller images to form a single large image, a process that is applicable in many contexts. In our research project, we have explored different approaches to evaluating the effectiveness of mosaic creation with the aim of mitigating environmental degradation through increased surveillance.

The first phase of this work is to compare different methods of creating large-scale mosaics using many small images. The main goal of the mosaic method is to combine many small items to create one large picture or mosaic. Additionally, given the complexity of mosaic creation methods, the selection of appropriate algorithms for mosaic creation is critical. Moreover, as mosaic creation often involves a significant number of images, extensive computational resources and time are required. Therefore, selecting suitable algorithms capable of producing accurate results within a reasonable timeframe is paramount. Consequently, in our current research, we have carefully selected and evaluated algorithms that are most suitable

for both image processing and analysis tasks. Our study is relevant to researchers in the field of computer science. For example, works such as [1-3] investigate mosaic creation by selecting images acquired from the air and processing them for surveillance purposes. Similarly, research studies such as [4-6] focus on using mosaic creation algorithms to process images captured from surveillance cameras. Furthermore, the utilization of algorithms such as FAST and FREAK for rapid image processing and mosaic creation is explored in studies like [7-8].

In the second part of this paper, we discuss the algorithms utilized for large-scale image creation and mosaic generation, as well as our own implementation efforts. In the third section, we provide a detailed description of the comparative results obtained from these experiments.

II. RESEARCH METHODOLOGY

In this section, we will provide a detailed explanation of the algorithms utilized for the creation of large-scale images or mosaics at both the mosaic creation stage and the subsequent refinement stage, focusing on the principles and procedures of their application (Fig. 1).

By elucidating the intricacies of these algorithms, we aim to establish a direct correlation between the outcomes

Manuscript received March 27, 2024; Revised May 14, 2024; Accepted May 20, 2024. (ID No. JMIS-24M-03-008)

Corresponding Author (*): Tserennadmid Tumurbaatar, tserennadmid@seas.num.edu.mn

¹Department of Information and Computer Sciences, School of Engineering and Applied Sciences, National University of Mongolia, Ulaanbaatar, Mongolia, nyamkhagva@num.edu.mn, tserennadmid@seas.num.edu.mn

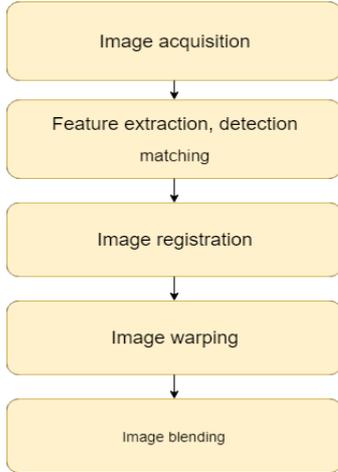


Fig. 1. Mosaic steps [9].

of mosaic creation and the algorithms utilized for both refinement and optimization.

2.1. MSER (Maximally Stable Extremal Regions)

MSER is an algorithm that identifies stable regions within an image. Its primary function is to locate corresponding points between two or more identical or similar objects obtained from different perspectives. The core operation of the MSER algorithm revolves around identifying regions that remain stable across different scales. It achieves this by iteratively segmenting the image into multiple smaller regions and merging adjacent regions until the resulting area reaches a maximum size, with each region bounded by a minimum and maximum threshold. The rate of area growth is monitored, and when it reaches zero, it indicates the presence of an extremal region [10].

2.2. SURF (Speeded Up Robust Features)

SURF is an algorithm widely utilized for both detecting and describing salient features within images, known as blobs. The detection of these salient features relies on the computation of the Hessian matrix. The Hessian matrix is calculated at each pixel location to measure local variations in intensity, with a detector selecting salient points by identifying local maxima [11]. Additionally, the Hessian matrix is employed in scale selection for images. For a given pixel (x, y) , the Hessian matrix $H(x, \sigma)$ is represented as follows at scale σ .

$$\mathcal{H}(\mathbf{x}, \sigma) = \begin{bmatrix} L_{xx}(\mathbf{x}, \sigma) & L_{xy}(\mathbf{x}, \sigma) \\ L_{xy}(\mathbf{x}, \sigma) & L_{yy}(\mathbf{x}, \sigma) \end{bmatrix}. \quad (1)$$

Here, $L(x, \sigma)$ represents the convolution with the second derivative of the Gaussian at point x , where a Gaussian function with a standard deviation of σ is convolved at the given position (x, σ) .

2.3. FREAK (Fast Retina Keypoint)

The FREAK algorithm is utilized for robust feature detection and is particularly adept at discerning human-eye-like patterns. This methodology focuses on identifying regions of interest that are densely populated and employs a novel approach to selecting salient points. By initially performing a coarse-level shift and subsequently refining the search space with specific thresholds, the algorithm achieves nuanced feature extraction within the human eye's operational range (Fig. 2) [10]. Advantage: Identifying significant features regardless of image size and resolution.

2.4. Proposed Methodology

Since the phase of feature detection from the image plays an important role in mosaicking, we aim to extract a certain number of features with the best possible results in this proposed method. In other words, when detecting features from an image, not for the whole image, but by dividing the images to be mosaicked into regions, selecting the features in that region with a threshold value (over 6,000) and matching the next image to be mosaicked with the corresponding region. Higher threshold values result in fewer keypoints being detected, but they tend to be more reliable and robust. This can help reduce computational overhead and improve the quality of the keypoints detected.

If the number of features in the states is less than 50, considering the images being mosaicked, it continues by moving to the next state. The fewer keypoints may be suitable for specific applications where computational efficiency is paramount. We chosen 50 in this work (Fig. 3).

For instance, the illustration above demonstrates the division of two images into regions and the subsequent connection of these regions for feature matching, indicated by straight lines (Fig. 4).

III. EXPERIMENTAL RESULTS

The study was conducted using a dataset consisting of 150 images captured by a drone provided by Sensefly

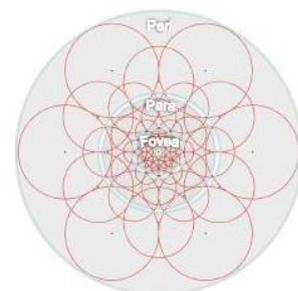


Fig. 2. Model of the FREAK algorithm.

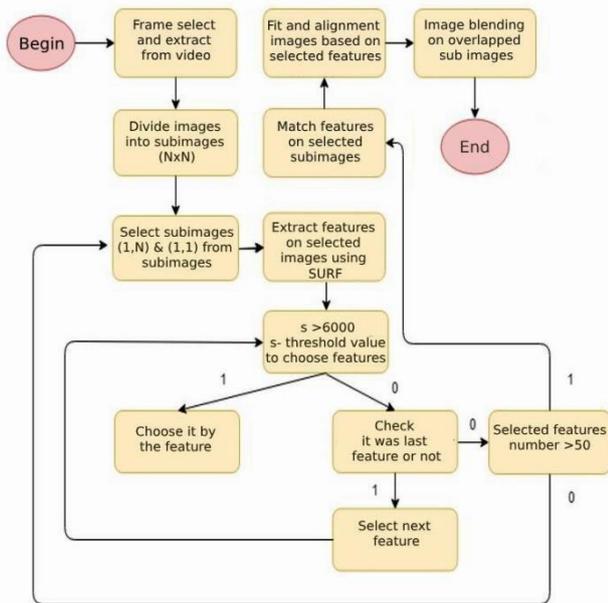


Fig. 3. Block diagram of the proposed methodology.

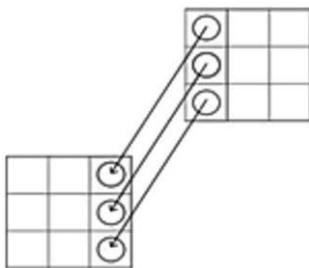


Fig. 4. Model for comparing key points of mosaicked images.

company [12], and the next data we created, we intended to create one image from 100 pieces of images, with 10×10 grid position. In the primary section denoted as A within the results section, a comprehensive comparison was conducted, analyzing the performance of various feature detection and extraction algorithms applied to the images (detection+extraction). Subsequently, in the section B, our proposed methodology was evaluated in comparison to the traditional approach of full-image feature detection utilized in previous research studies.

3.1. Comparison of Results of MSER, FREAK, and SURF Algorithms in Terms of Image Processing and Analysis

For image processing and analysis, MSER, SURF, and FREAK algorithms were incorporated using the provided table format (Tables 1 and Table 2) and they evaluated based on the following criteria. The following two metrics are used to evaluate the resulting image compared to the original image.

- Mean Square Error (MSE): Measures the average squared error.

Table 1. Results between generated and reference images (Fig. 5(a)).

Algorithm	MSE	PSNR
MSER+FREAK	53.4852	30.8485
MSER+SURF	53.1403	30.9560
SURF+SURF	52.1775	30.6381

Table 2. Results between generated and reference images (Fig. 5(b)).

Algorithm	MSE	PSNR
MSER+FREAK	115.9947	27.4864
MSER+SURF	115.2506	27.6332
SURF+SURF	112.1387	27.5144

- Peak Signal-to-Noise Ratio (PSNR): Measures the ratio between the maximum possible power of a signal and the power of corrupting noise.

Evaluation results are shown in Tables 1 and Table 2.

By the comparison result, we decided to choose combination of (SURF+SURF). In Fig. 6, we illustrate the difference between the reference image and the generated image. Due to the small difference, the comparison appears dominantly black. To show this difference, we



(a)

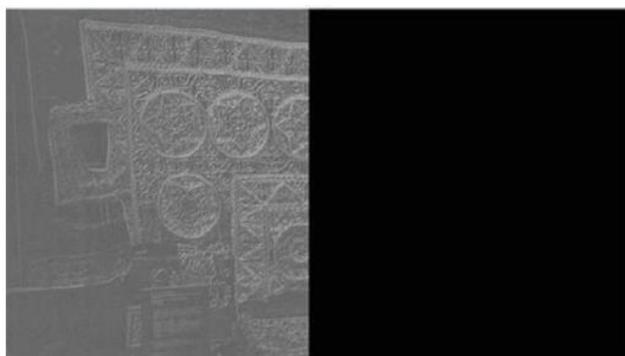


(b)

Fig. 5. Result images using the proposed methodology.



(a)



(b)

Fig. 6. Differences between original and created images.

performed histogram equalization on the left side. As mentioned above, when the number of features in the given image increased, the calculation time increased and the running time slowed down. For Fig. 7, the graph below shows the relationship between the number of features detected and the running time when the mosaiced images overlap by 10%, 25%, and 50%.

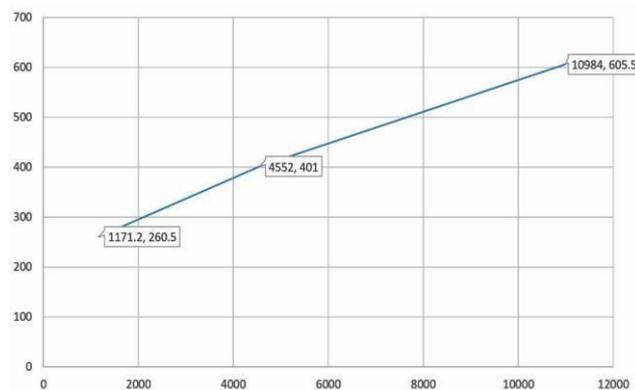


Fig. 7. Relation between number of features and runtime (Fig. 5(a))

3.2. Санал болгож буй арга болон бүтэн зургийн хувьд SURF алгоритмийг хэрэглэсэн аргын үр дүнгийн харьцуулалт

Considering the more favorable results observed in the previous section's analysis, we have opted for the SURF+SURF variant. Utilizing our approach of segmenting the entire image into specific regions and conducting feature comparisons among them, the following results have been obtained.

As illustrated in Fig. 8, there has been a significant reduction in processing time, decreasing from 605.5 seconds to 120.2 seconds. Furthermore, Table 3 suggests that the comparison estimates closely align with the previous results.

IV. CONCLUSION

Within this study, various mosaicing methods were evaluated and compared for their applicability in the research domain of "monitoring plant growth using digital image processing." Notably, the SURF algorithm demonstrated superior performance. Subsequently, we devised a novel approach wherein the image was partitioned into regions, and the SURF algorithm was applied to these regions. This strategic segmentation not only reduced computational complexity but also led to a significant reduction in processing time, averaging a threefold decrease. Importantly, this optimization did not compromise the quality or integrity of the final mosaicked image.

Given the efficacy demonstrated by our proposed methodology, we have elected to employ it in our ongoing research project.

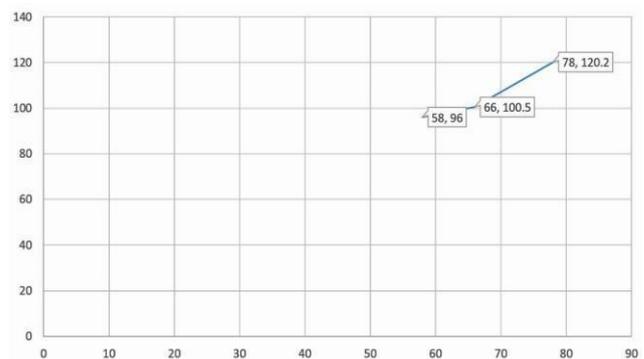


Fig. 8. Relation between number of features and runtime (Fig. 5 (a)) proposed methodology /150 sub-images/.

Table 3. Results between proposed and reference images.

Algorithm	MSE	PSNR
SURF+SURF (Fig. 5(a))	53.1532	30.6152
SURF+SURF (Fig. 5(b))	115.1874	27.1452

REFERENCES

- [1] E. Hadrović, D. Osmanković, and J. Velagić, "Aerial image mosaicing approach based on feature matching," in *59th International Symposium ELMAR*, 2017, pp. 177-180.
- [2] Y. Feng and S. Li, "Research on an image mosaic algorithm based on improved ORB feature combined with SURF" in *2018 Chinese Control and Decision Conference (CCDC)*, 2018, pp. 4809-4814.
- [3] J. Wang and J. Watada, "Panoramic image mosaic based on SURF algorithm using OpenCV," in *2015 IEEE 9th International Symposium on Intelligent Signal Processing (WISP) Proceedings*, 2015, pp. 1-6.
- [4] L. Yang, X. Wu, J. Zhai, and H. Li, "A research of feature-based image mosaic algorithm," in *4th International Congress on Image and Signal Processing*, 2011, pp. 846-849.
- [5] Z. Yang, D. Shen, and P. T. Yap, "Image mosaicking using SURF features of line segments," *PLOS ONE*, vol. 12, no. 3, e0173627, 2017.
- [6] X. L. Long, Q. Chen, and J. W. Bao, "Improvement of Image mosaic algorithm based on SURF," *Applied Mechanics and Materials*, vol. 427, pp. 1625-1630.
- [7] K. S. V. Prathap, S. A. K. Jilani, and P. R. Reddy "A real-time image mosaicing using FAST detector and FREAK desc-riptor," in *2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 2017, pp. 2413-2418.
- [8] S. Khachikian and M. Emadi, "Applying FAST & FREAK algorithms in selected object tracking," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 5, Jul. 2016.
- [9] P. Ghosh, Image mosaicing using feature detection algorithms, <http://ethesis.nitrkl.ac.in/7923/1/631.pdf>
- [10] G. Ganchimeg, "Methods for determining image similarity dimensions," *Conference of Mongolian Information Technology*, 2017
- [11] H. Bay, A. Ess, T. Tuytelaars, and L. Van Gool, "Speeded-up robust features (SURF)," *Computer Vision and Image Understanding*, vol. 110, no. 3, pp. 346-359, 2008.
- [12] SenseFly's Aerial Drone Image Dataset, https://agea-gle.com/resources/?filter_by=data-set

AUTHORS



Nyamlkhagva Sengee has received his B.S. degree from National University of Mongolia in 2013 and his M.S. and Ph.D. degrees in the Department of Computer Engineering from INJE University, Korea in 2008 and 2012, respectively. His research interests include medical image processing and analysis, contrast enhancement and image reconstruction algorithms.



Tserennadmid Tumurbaatar has received her B.S. in National University of Mongolia in 2003 and her M.S. in Mongolian University of Science and Technology in 2005. She received her Ph.D. degree from Inha University of Korea in 2017. Her research interests are image processing, computer vision and digital photogrammetry.

