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Comparative Study of Feature Matching Algorithms

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Abstract

In this paper, a comparative study on eight feature matching algorithms: SIFT, ORB, KAZE, AKAZE, Dense SIFT, DAISY, BRISK and FREAK were presented. Feature matching is an important aspect of computer vision used for key point detection and matching across im- ages to perform tasks such as object recognition. Each importantly has different features and performance metrics, making them suitable for cer- tain uses. I have evaluated these algorithms with two main criteria: the computation time, and the number of key points matched between two images. Based on the experimental results, there appear to be substantial performance differences among these algorithms that reveal key features of their relative strengths and weaknesses. This performance analysis will help choose which algorithm to use based on requirements like speed and accuracy.

In future work, I will apply this analysis to different data sets and fur- ther discuss the advantages and disadvantages of each feature-matching algorithm in other application scenarios.

Keywords: *Feature Detection • SIFT (Scale-Invariant Feature Trans- form) • ORB (Oriented FAST and Rotated BRIEF) • KAZE • AKAZE (Accelerated-KAZE) • Dense SIFT • DAISY (Dense Adaptive Scale- Invariant Descriptor) • BRISK (Binary Robust Invariant Scalable Key- points) • FREAK (Fast Retina Key point).*

INTRODUCTION

Feature matching is a fundamental -task in computer vision. Finding and match- ing key points (distinctive points or patterns between various images) is the aim of feature matching. The two main steps in this procedure are feature description and feature detection.

Finding key points in a picture that remain constant despite changes in illumi- nation, rotation, and scaling is known as feature detection. In contrast, feature description computes a vector representation (descriptor) for every key point, which may be utilized for key point matching across various images. For feature matching we have multiple types of algorithm in which SIFT is the oldest one.

Scale-Invariant Feature Transform (SIFT) algorithm was developed by David Lowe in the late 1990s and early 2000s. The initial concept was introduced in 1999, and a more refined version was published in 2004 in the paper "Distinctive Image Features from Scale-Invariant Keypoints." It is used to detects key points in an image using a Difference of Gaussian (DoG) method across multiple scales to ensure scale invariance. Each key point is localized and refined to remove low-contrast points and an orientation is assigned based on local image gradi- ents. Descriptors are created by sampling gradient magnitudes and orientations around the key points, resulting in a 128-dimensional vector for each key point. These descriptors are then used to match key points between images, ensuring robustness to scale and rotation.

ORB (Oriented FAST and Rotated BRIEF) was introduced in 2011 by Ethan Rublee, Vincent Rabaud, Kurt Konolige, and Gary Bradski in their paper "ORB: An efficient alternative to SIFT or SURF." It detects key points using the FAST (Features from Accelerated Segment Test) algorithm, which identifies corners in the image. It assigns an orientation to each key point and creates binary de- scriptors using the BRIEF (Binary Robust Independent Elementary Features) method. The key points are matched between images using Hamming distance, providing a fast and efficient alternative to SIFT with lower computational cost.

KAZE (pronounced kah-zeh) was introduced by Pablo Fernández Alcantar- illa, Adrien Bartoli, and Andrew J. Davison in 2012. Their work, titled "KAZE Features," was presented at the European Conference on Computer Vision (ECCV). It detects key points using

nonlinear diffusion filtering to preserve edge details and fine structures in images. It assigns orientations to key points based on lo- cal gradients and creates descriptors for matching.
Introduced in 2012 by Pablo Fernández Alcantarilla and colleagues, KAZE offers a balance between compu- tational efficiency and robustness, addressing limitations of previous algorithms by enhancing feature detection quality.

AKAZE (Accelerated-KAZE) was introduced in 2013 by Pablo Fernández Alcantarilla, Jesús Nuevo, and Adrien Bartoli. It was developed as an optimiza- tion of the original KAZE (KAZE Features) algorithm. It computes descriptors using a modified Local Difference Binary (LDB) method, ensuring robust match- ing across different images. The motivation behind AKAZE was to enhance the computational efficiency of KAZE while maintaining or improving its robustness and accuracy in feature detection and description.

Dense SIFT (Scale-Invariant Feature Transform) is an extension of the orig- inal SIFT algorithm developed by David Lowe. Dense SIFT computes SIFT de- scriptors at regular intervals across the image, ensuring comprehensive feature coverage but at a higher computational cost.

DAISY (Dense adaptive scale invariant descriptor) algorithm was introduced by Tola et al in 2008 as a method to capture local image patterns robustly across different scales and rotations. DAISY computes histograms of gradient orienta- tions in local regions around each pixel, forming a descriptor that is invariant to local geometric transformations.

BRISK (Binary Robust Invariant Scalable Keypoints) was developed by Ste- fan Leutenegger et al in 2011 as a feature detection and description algorithm in computer vision. It was designed to provide a fast and efficient alternative to existing methods like SIFT and SURF, suited for real-time applications. BRISK detects key points using a scale-space pyramid and an AGAST (Adaptive and Generic Accelerated Segment Test) corner detector, which is robust to varying image conditions. It computes binary descriptors based on intensity comparisons of predetermined pixel pairs, optimizing for speed and memory efficiency. BRISK achieves a balance between feature detection speed and matching accuracy.

FREAK (Fast Retina Key point) was introduced by Alahi et al. in 2012 as a fast and efficient feature descriptor for computer vision applications. Inspired by the human retina's structure, FREAK generates binary descriptors using intensity comparisons within a retinal sampling pattern around key points. This approach allows for rapid descriptor computation and matching using Hamming distance, making FREAK well-suited for real-time applications on devices with limited computational resources.

METHODOLOGY

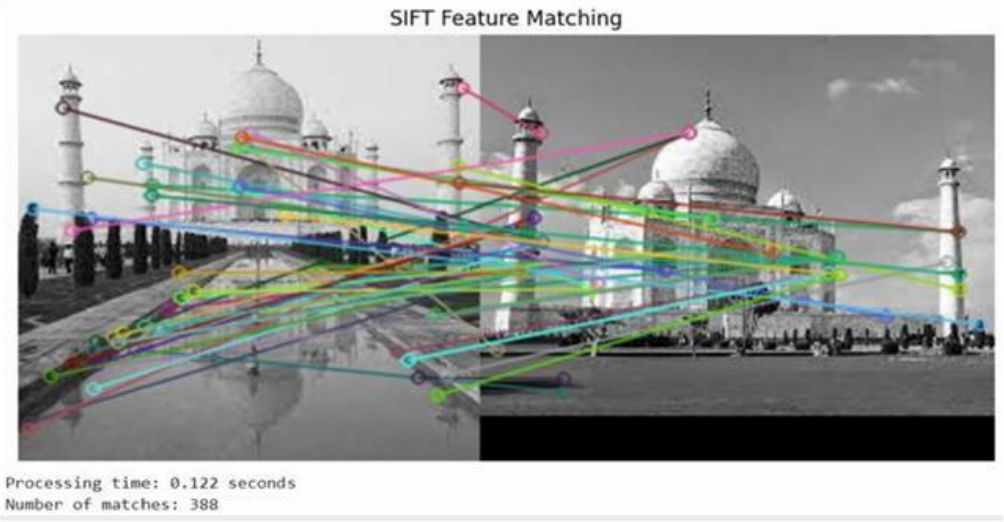
The above comparative analysis of different algorithms was done on two images of the Taj Mahal, to analyze the time taken for feature detection and description, and the number of key points matched.

I have used OpenCV and scikit-image libraries to implement these algorithms. The experiments were conducted on a standard desktop computer. The images were converted to grayscale to simplify the computation.

RESULT

Table 1 Comparative analysis of algorithms with time taken and features matched

Algorithm used	Time taken to perform the algorithm	Total number of matches
SIFT	0.122 seconds	388
ORB	0.012 seconds	126
KAZE	0.110 seconds	281
AKAZE	0.023 seconds	161
Dense SIFT	0.219 seconds	841
DAISY	0.212 seconds	625
BRISK	0.082 seconds	218
FREAK	0.097 seconds	130



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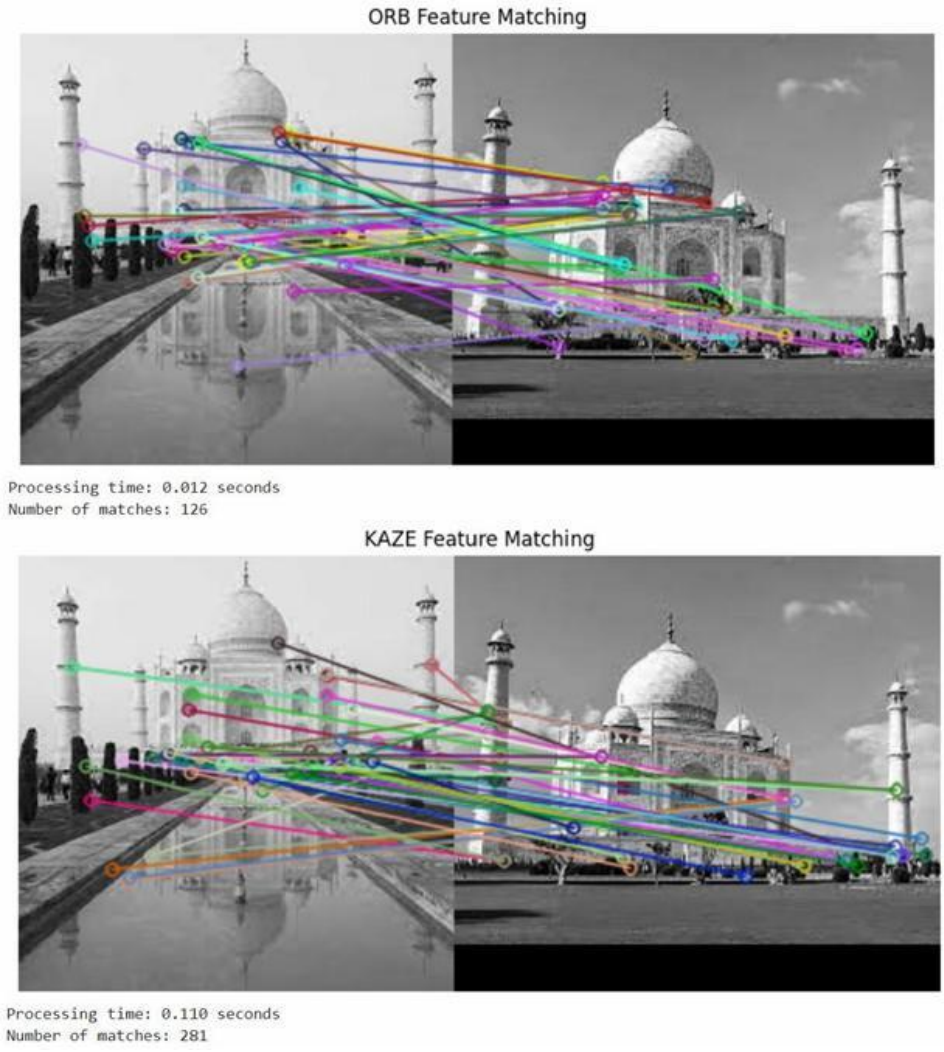

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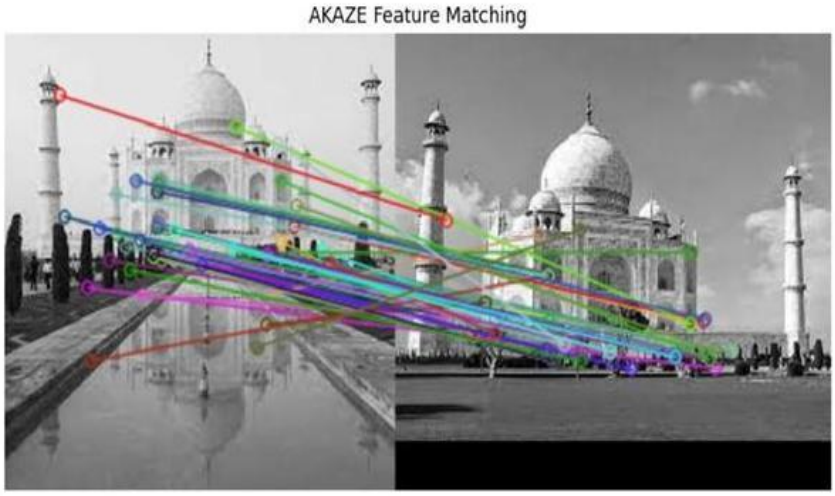

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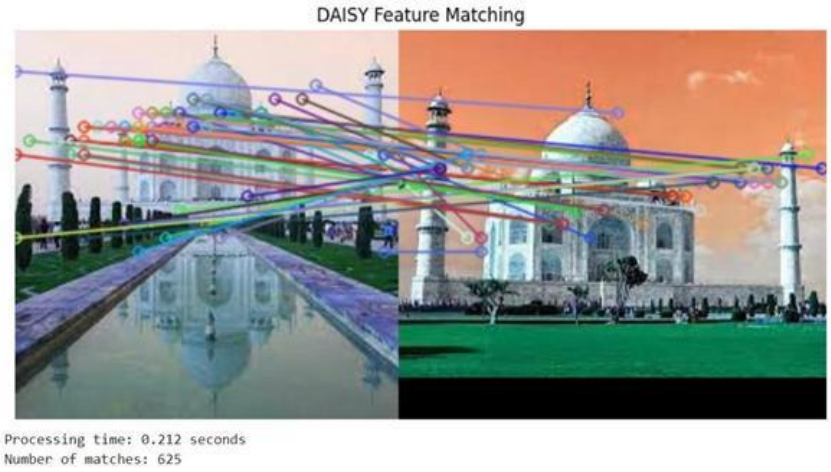

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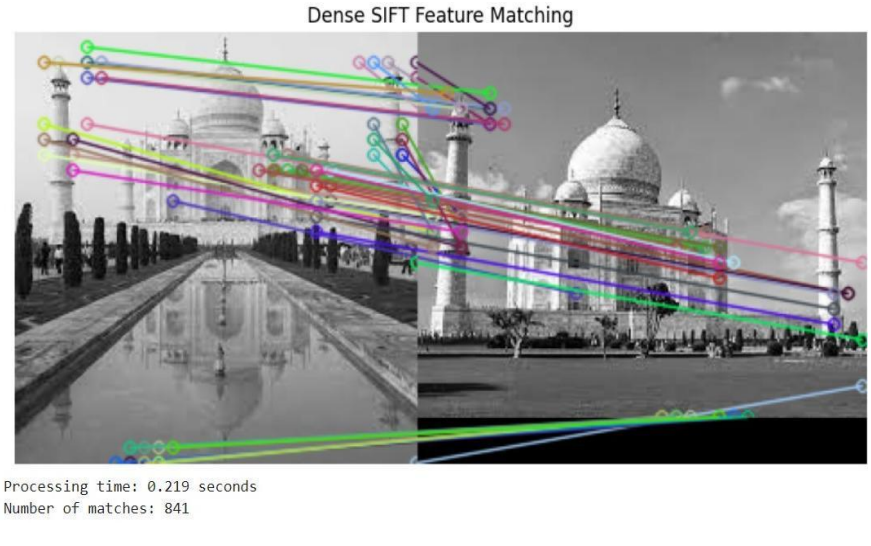

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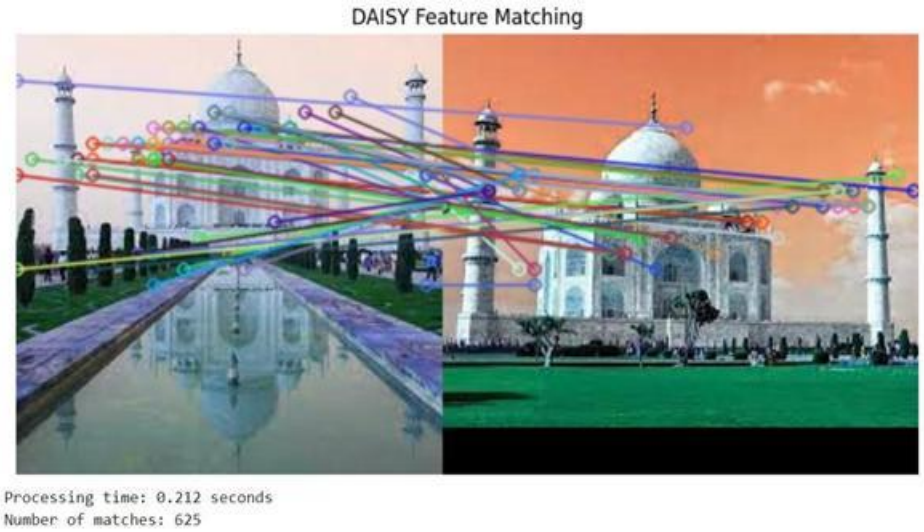

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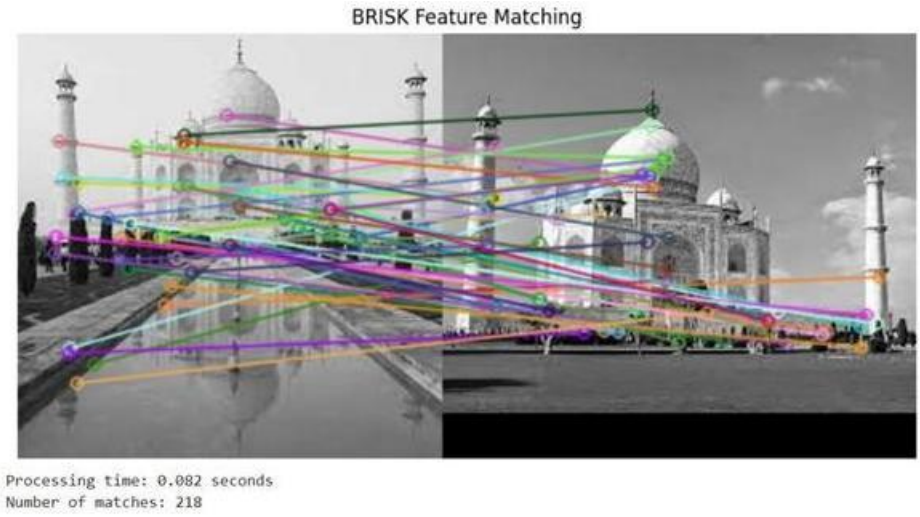

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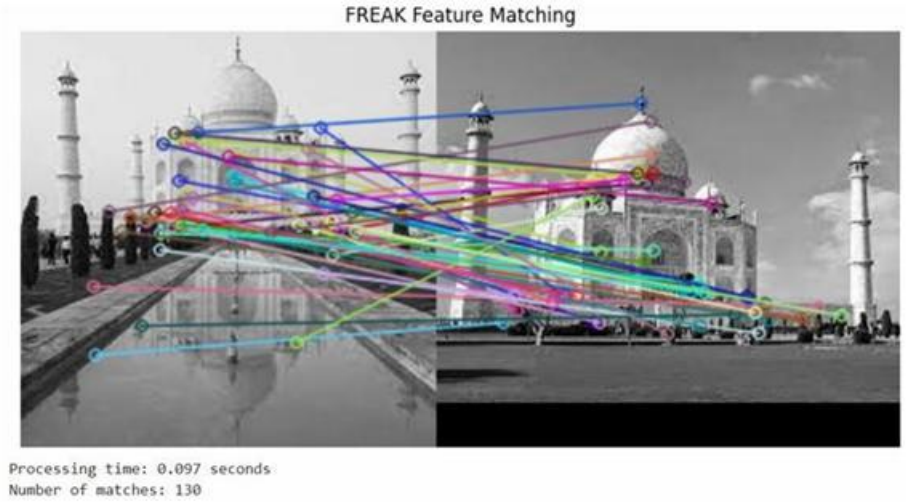

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CONCLUSION

Above analysis indicates that ORB and AKAZE are the fastest algorithm but has fewer matches compared to others for the given set of images. SIFT , Dense SIFT and DAISY provide a high number of matches but are computationally more expensive, DAISY is effective for dense feature extraction but slower. AKAZE offer a balance between speed and accuracy. DAISY is effective for dense feature extraction but slower. BRISK and FREAK are good alternatives for binary descriptors with reasonable speed and matching accuracy.

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