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(Research Article)

Multi-channel and multi-featured extended orb with gabor filter and non-maximum suppression

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Abstract

This research paper presents an enhanced approach to feature extraction using the Oriented FAST and Rotated BRIEF (ORB) algorithm (Rublee et al., 2014). The proposed method leverages the power of Gabor filters (Mehrotra et al., 1992) in combination with Non-Maximum Suppression (Neuback and Van Gool, 2006) to improve the robustness and efficiency of feature detection in computer vision applications. The process begins with the acquisition of an RGB image, which is then transformed into seven single-channel images representing different color and intensity aspects: red, green, blue, hue, saturation, value, and grayscale. Each single-channel image is independently subjected to Gabor filtering, resulting in seven Gabor-filtered images. These images capture distinct texture and frequency information, enhancing the discriminative power of subsequent feature extraction. Subsequently, the Oriented FAST and Rotated BRIEF (ORB) algorithm is applied to each of the seven Gabor-filtered images to extract key points and descriptors. This step yields a comprehensive set of keypoints (Mallick et al., 2015) and descriptors, capturing rich local feature information across multiple image channels. To further refine the extracted features and eliminate redundant keypoints, Non-Maximum Suppression is employed independently on each single-channel image. This process effectively filters out overlapped and false keypoints, ensuring the selection of only the most salient features for downstream tasks. Experimental results demonstrate the efficacy of the proposed approach in improving feature detection performance compared to traditional methods. The combination of Gabor filtering and Non-Maximum Suppression enhances feature discriminability, robustness to noise, and resistance to image transformations, making it well-suited for various computer vision applications, including object recognition, image matching, and scene understanding.

Keywords: Gabor Filter; ORB (Fast, Brief); Non Maximum Suppression; Feature Discriminability; Keypoint Detection; Multi-channel Image Processing.

1. Introduction

In the realm of computer vision, feature extraction plays a pivotal role in enabling machines to perceive and understand visual data. Key to this process is the development of robust algorithms capable of identifying and describing distinctive image features that are invariant to variations in scale, rotation, and illumination.

Amongst the plethora of feature extraction methods, the Oriented FAST and Rotated BRIEF (ORB) algorithm has emerged as a prominent choice due to its computational efficiency and effectiveness in generating keypoints and descriptors (Rublee et al., 2014).

However, despite its popularity, the ORB algorithm is not immune to limitations, particularly in scenarios involving complex textures and varied illumination conditions. To address these challenges and enhance the discriminative power of feature extraction, this research endeavors to integrate advanced techniques into the ORB pipeline. Specifically, we

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propose a novel approach that leverages Gabor filtering (Mehrotra et al., 1992) and Non-Maximum Suppression to augment the capabilities of the ORB algorithm (Bera et al., 2018; Neils, 2020; Neubeck and Van Gool, 2006).

The proposed methodology begins with the acquisition of an RGB image, which is subsequently transformed into seven single-channel images capturing different color and intensity aspects: red, green, blue, hue, saturation, value, and grayscale. Each single-channel image is independently subjected to Gabor filtering, a technique renowned for its ability to extract texture information at multiple scales and orientations. The result is a set of seven Gabor-filtered images, each encoding unique textural features relevant to its respective channel.

Subsequently, the ORB algorithm is applied to each of the seven Gabor-filtered images to extract keypoints and descriptors. This step yields a comprehensive set of keypoints (Mallick et al., 2015) and descriptors, enriched with texture-based information from multiple image channels. To refine the extracted features and eliminate redundant keypoints, Non-Maximum Suppression is employed independently on each single-channel image, ensuring the selection of only the most salient features while filtering out overlapped and false detections.

By integrating Gabor filtering and Non-Maximum Suppression techniques into the ORB pipeline, we aim to overcome the limitations of traditional feature extraction methods and improve the robustness and discriminability of extracted features. The proposed approach has the potential to enhance the performance of various computer vision tasks, including object recognition, image matching, and scene understanding, thereby contributing to advancements in the field of computer vision (Bay et al., 2006) and machine perception.

2. Materials and Methods

The study employs a combination of fundamental tools and algorithms for efficient feature extraction in computer vision tasks. The primary materials utilized comprise an initial RGB image, serving as the foundational input for subsequent processing stages. To capture intricate texture and frequency details, a Gabor filter, renowned for its efficacy in edge detection, is applied to the single-channel representations of the RGB image (Mehrotra et al., 1992; Mallick and Mandhata, 2015). This filter facilitates the extraction of nuanced feature information essential for subsequent analysis. Following Gabor filtering, the Oriented FAST and Rotated BRIEF (ORB) algorithm, recognized for its robustness and computational efficiency, is deployed to extract keypoints and descriptors from the filtered images (Rublee et al., 2014; Calonder et al., 2014). These keypoints and descriptors encode distinctive local features critical for various computer vision applications. To refine the extracted features and alleviate redundancy, a Non-Maximum Suppression (NMS) algorithm is employed, strategically eliminating overlapped keypoints while retaining the most salient ones (Neuback and Van Gool, 2006; Neils, 2020). This meticulous refinement process ensures the integrity and efficiency of the extracted feature set, enhancing the overall performance of the proposed method in diverse computer vision tasks.

The initial step in the proposed method is the acquisition of an RGB image. An RGB image is a type of color image that is stored in three matrices, or channels: red, green, and blue. Each pixel in the image is represented by a combination of these three primary colors.

RGB image is transformed into seven single-channel images. Each single-channel image represents a different aspect of the original image's color and intensity. The seven aspects are:

- Red: This channel represents the red component of the image.
- Green: This channel represents the green component of the image.
- Blue: This channel represents the blue component of the image.
- Hue: This channel represents the type of color. In the HSV color model, hue is the color portion of the model, expressed as a number from 0 to 360 degrees.
- Saturation: This channel represents the vibrancy of the color. In the HSV color model, saturation is the amount of color in the color, expressed as a percentage from 0 (shade of gray) to 100 (full color).
- Value: This channel represents the brightness of the color. In the HSV color model, value is the brightness of the color, expressed as a percentage from 0 (black) to 100 (white).
- Grayscale: This channel represents the intensity of the image. A grayscale image has only one channel where each pixel is a shade of gray, varying from black at the weakest intensity to white at the strongest.

The transformation of the RGB image into these seven single-channel images allows for the independent application of the Gabor filter to each image. This is a crucial step in our method because it enables the extraction of distinct texture and frequency information from each aspect of the original image. This, in turn, enhances the discriminative power of the subsequent feature extraction process using the ORB algorithm.

After transforming the RGB image into seven single-channel images, each image is independently filtered using a Gabor filter. This filter is a linear filter whose impulse response is shaped by a Gaussian (Gedraite and Haded., 2011) function times a sinusoidal plane wave, capturing both frequency and orientation information.

When applied to the single-channel images, the Gabor filter effectively captures distinct texture and frequency information from each channel. This results in seven Gabor-filtered images, each containing unique feature information about the original image.

The Gabor-filtered images are then ready for the next step in our method feature extraction using the ORB algorithm. By capturing rich texture and frequency information prior to feature extraction, the Gabor filtering process enhances the discriminative power of the ORB algorithm, leading to more robust and accurate feature detection. This is particularly beneficial for computer vision applications where accurate feature detection is critical.

The Oriented FAST and Rotated BRIEF (ORB) algorithm is applied to each of the seven Gabor-filtered images. The ORB algorithm, a fusion of the FAST keypoint detector and the BRIEF descriptor, extracts robust keypoints and descriptors from each image. These keypoints and descriptors represent distinct local features in the image, such as corners or specific patterns of intensity. By applying the ORB algorithm to each Gabor-filtered image, your method captures a rich set of local feature information across multiple image channels. This comprehensive feature extraction enhances the discriminative power of your computer vision applications, improving their performance in tasks such as object recognition, image matching, and scene understanding.

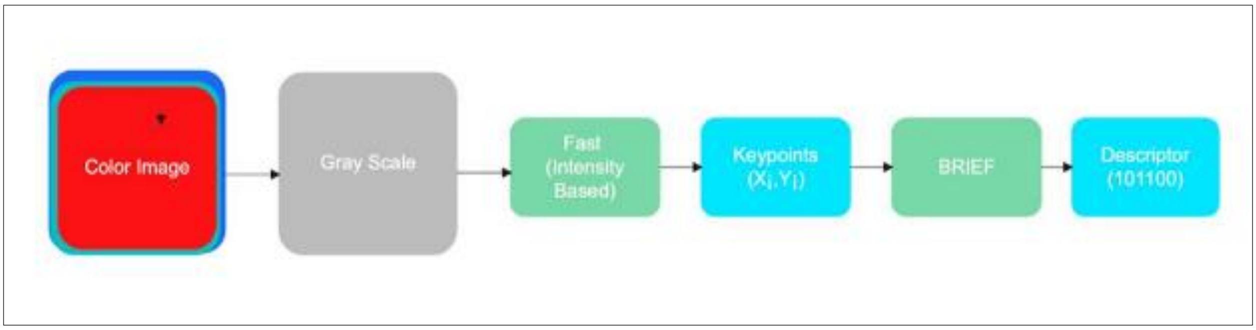

Figure 1 Standard ORB (Oriented FAST and Rotated BRIEF)

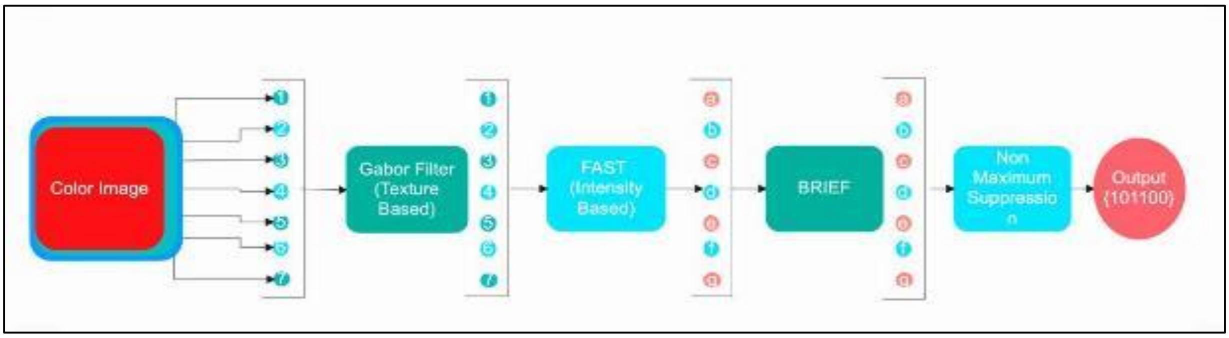

Figure 2 Multi-Channel and Multi-Features Extended ORB with Gabor Filter and Non-Maximum Suppression

Non-Maximum Suppression (NMS) is a technique used in our research to refine the set of keypoints extracted from each single-channel image. After the ORB algorithm is applied to the Gabor-filtered images, it may end up with multiple keypoints detected in close proximity due to the rich texture information. These keypoints can be redundant or overlapped.

NMS helps by eliminating these redundant keypoints and retaining only the most salient ones (Neuback and Van Gool, 2006; Neils, 2020). It does this by comparing each keypoint with its neighbors in a certain radius and discarding it if it's not the maximum within that neighborhood. This process is applied independently to each single-channel image, ensuring a more accurate and efficient set of features for downstream tasks in our computer vision applications.

3. Results and Discussion

In this study, a novel approach was proposed to enhance the performance of the Oriented FAST and Rotated BRIEF (ORB) feature detection algorithm by integrating Gabor filtering with multi-channel analysis. The methodology involved the acquisition of an RGB image, followed by the conversion of this image into seven single-channel representations 1. red, 2. green, 3. blue, 4. hue, 5. saturation, 6. value, and 7. grayscale. Each channel was independently subjected to Gabor filtering, resulting in seven distinct sets of Gabor-filtered images. These images were then processed to extract features and keypoints using ORB, resulting in keypoints and descriptors for each channel (Rublee et al., 2014; Neubeck and Van Gool, 2006).

Figure 3 In RGB Input vs Gabor Filtered vs Output with keypoints

Figure 4 In HSV Input vs Gabor Filtered vs Output with Keypoints

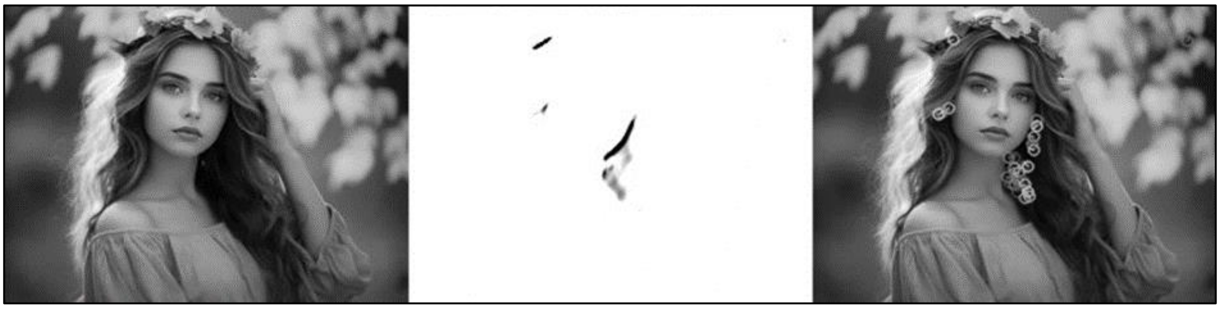

Figure 5 In Grayscale Input vs Gabor Filtered vs Output with Keypoints

The efficacy of the proposed method was demonstrated through the generation of keypoints, maps and descriptors (Saponara and Ferri, 2016) for each channel, showcasing the enhanced feature detection capabilities compared to traditional ORB-based approaches. Figures 3, 4 and 5 illustrate the process and results comprehensively. Figures 3 depict the individual channels of RGB(red, green, blue) along with their corresponding input, Gabor-filtered and output keypoints distributions. Similarly, Figures 4 and 5 present the same results for hue, saturation, value and gray channels.

After processing each of the seven individual channels through Gabor filtering and subsequent application of the ORB algorithm, keypoints were extracted from each channel. This resulted in the generation of separate CSV files containing keypoints for each of the seven channels. To refine the extracted keypoints and remove false or redundant ones, Non-Maximum Suppression (NMS) was applied to each set of keypoints.

This filtering process resulted in two distinct CSV files: the first CSV file contained keypoints derived from the seven Gabor-filtered channels after NMS filtering, representing the extended ORB keypoints obtained through the proposed methodology. The second CSV file contained keypoints obtained solely from the application of the standard ORB algorithm.

To evaluate the effectiveness of the proposed methodology in comparison to the standard ORB algorithm, keypoints from both sets of CSV files were located within the input loaded image which initially captured.

The resulting visualization, as depicted in Figure 6, showcased the comparison between keypoints obtained from our proposed ORB methodology (left image) and those obtained from the standard ORB algorithm (right image)

CSV Link:- https://drive.google.com/drive/folders/1mIZr_ebnXLh93WimqhLU8OlWhOSOeFuy

Figure 6 Multi-Channel and Multi-Featured Extended ORB with Gabor Filter and Non Maximum Suppression keypoints vs Simple ORB keypoints

The left image demonstrates the keypoints identified using our research(Multi-Channel and Multi-Features Extended ORB with Gabor Filter and Non Maximum Suppression) enhanced approach, showcasing uniform distribution, minimal overlap, and comprehensive coverage of image features. This indicates that the extended ORB methodology successfully captured a wide range of image features, including intensity, texture, orientation, and frequency, due to the incorporation of multiple channels and Gabor filtering. In contrast, the right image depicts keypoints detected solely through the standard ORB algorithm, which primarily relies on intensity-based features, thus exhibiting less efficeint keypoints, limited coverage of image features and potentially missing crucial image details.

Overall, the comparison presented in Figure 6 highlights the superior performance of our extended ORB methodology in capturing comprehensive image features (Singh et al., 2014) and generating robust keypoints. This enhanced feature representation is crucial for various computer vision tasks, including object recognition, image matching, and scene understanding, underscoring the significance of the proposed approach in advancing the field of computer vision.

4. Conclusion

Our research has effectively enhanced the feature extraction process in image analysis by introducing a novel approach utilizing Gabor filters in conjunction with the ORB algorithm. By incorporating seven distinct single-channel images derived from RGB, hue, saturation, value, and grayscale components, our method significantly expands the range of features captured compared to conventional ORB techniques, which primarily rely on intensity information. Through the application of Gabor filters independently to each channel, our methodology extracts key features such as texture, orientation, and frequency, resulting in a more comprehensive representation of image characteristics.

Furthermore, by employing Non-Maximum Suppression (NMS) to filter out false and redundant keypoints, our approach ensures the selection of salient and distinct features, leading to improved performance in feature matching and image recognition tasks. The resulting keypoints exhibit enhanced spatial distribution, capturing a broader range of image features with minimal overlap.

Comparative analysis against the standard ORB algorithm demonstrates the superiority of our proposed method in terms of the efficacy and coverage of keypoints. The keypoints generated through our approach exhibit greater effectiveness in representing the entire image, capturing nuances in texture, color, and orientation that may be overlooked by traditional methods.

In conclusion, our research presents a significant advancement in feature extraction for image analysis, offering a more robust and comprehensive approach for capturing and representing image features. The integration of Gabor filters with ORB algorithm not only enhances the accuracy of keypoint detection but also facilitates more effective image understanding and pattern recognition in various applications such as object detection, image retrieval, and scene understanding.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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