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A Review Over Panoramic Image Stitching Techniques

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Abstract: Using digital images at present are increased rapidly in many fields such as in solving big problems, with the extraordinary appearance of them in all areas of life, in medicine, agriculture, industry, the Internet, and others, where their use is extensive and is considered a source of information for technological progress. One of the important use is stitching the images, also called mosaic images. The stitching images means a grouping of images for the same sense with the overlapping areas to be a panoramic image of high resolution and wide width. With the modification and development of the algorithms used in this field in recent years, it has become one of the essential branches of image processing. There are many applications of stitching, used in maps and satellites, knowledge and positioning, etc. So this summary article will provide a set of image stitching techniques and investigate its use in terms of advantages, disadvantages, and accuracy for each one of them with comparative studies of several research papers in this field for the period of years (2017 – 2020). Therefore, this article may be useful for researchers working in this field to benefit and develop stitching algorithms in terms of discovering features and matching them to create a useful, problem-free, and high-resolution panoramic image.

Keywords: Panoramic Image, Feature Matching, Image Blending, Images stitching, Alignment Quality, Image Mosaic.

1. Introduction:

Nowadays, the development of cameras and multimedia technology is increased rapidly. Also, there is a dramatic increase in the use of huge images and videos among peoples. Smart cameras used in recent time in a wide range, smart camera is a combination of three parts in one package (cameras, computer vision programs, and image processing). Smart cameras also called intelligent cameras used to hand the users for processing the images by providing microprocessors that control the camera instead of using a separate processor or PC.

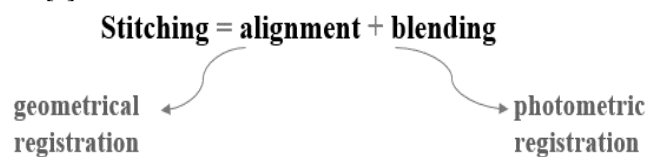
The field of computer vision has increased meteorically, with the introduction of a wide range of techniques to perform such tasks. These tasks include motion analysis, reconstruction of the scene, image restore, and image matching. This study focused on various image matching techniques and feature detection algorithms. We have compared their performance and how it affects the accuracy of the stitching process. Some algorithms/techniques might work better with certain data sets, whereas others do not analyze the same datasets as efficiently. Therefore, some algorithms are useful for a particular application, whereas others have different applications in image processing and computer vision applications.



Image stitching is the method by which many images are merged to create a separate high-resolution panorama or photograph. If two overlapping images are present, the image stitching consists of a mosaic of both images into one frame [1].

In panoramic stitching, an image set will have a logical amount of overlap to prevail over the deformation of a lens and must contain sufficient measurable features, if the images are taken from different places, then it may associate with parallax errors. Blind stitching can be done using feature-based alignment methods. However, it can produce an erroneous result. To overcome the parallax errors, we can use a large camera system in a fixed disclosure [2].

Panoramic image mosaicking works through many images by stitching the pictures into a composite image with a much wider view from an ordinary camera. The collection from an image may include digital more or two images taken at different times, from different sensors or other points of view from a single scene [3]



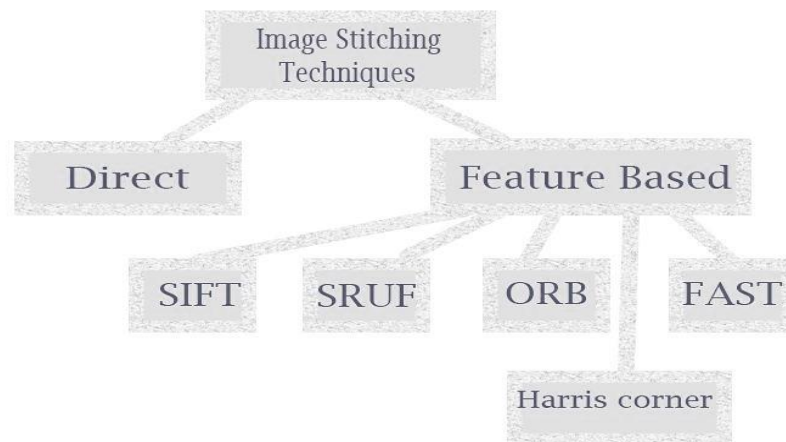
Where the Image alignment algorithms may be appropriate for the creation of mosaic, summarization, and video stabilization, help to discover the correspondence relationships among images with varying degrees of overlap. The algorithms of creation panorama determine the alignment by using registration algorithms to blend the images seamlessly, it taking care to deal with potential problems such as blurring or ghosting caused by parallax and scene movement as well as varying image exposures. Techniques of image alignment were applied at the beginning to build seamless panoramas from simple handheld cameras [4], the alignment process starts by finding the suited mathematical model to correspond the pixels coordinates between two images, estimation the alignment will be easier when a roughly known panning angle, The most straightforward technique is to try all possible alignments exhaustively.

Image Blending executes the adjustment figured out in image calibration as remapping of the images, color correction between images. Images are merged to create a seamless large image. The seam while stitching can be reduced with gain adjustment; it minimizes the difference between the intensities of the overlapping pixels of the two images. Alpha feathering and Gaussian pyramid are the two well-known methods of blending [5]. In these cases where well-aligned image pixels are present with only a difference in intensity between two images, then alpha blending works extremely well. The Gaussian pyramid is another popular approach where images at two different frequency bands are merged and then filtered together.

In the rest of this paper, the image stitching techniques and methods are explained in sections two and three. Related works introduced in section four, and section five present some of the alignment quality tools. Summarization of challenges faces the image stitching is introduced in section six, where the application of stitching is summarized in section seven. Finally comparison analysis present in section eight.

2. Image Stitching Techniques

The feature-based techniques and direct are the two general methods that were used to characterized techniques used for Image stitching as shown in Figure 1.

**Figure****1:** Type of Image stitching techniques

2.1 Direct Technique

The direct technique is dependent on the comparison of pixel intensities of the images and it decreases total differences among overlapping pixels, each pixel intensity of the image is compared with another, properties of the direct technique are [5]:

Advantage

- Minimizes the number of absolute pixel overlap variations.
- Optimum use of the image content and details.
- This technique can evaluate the input of each pixel in the image.

Disadvantage

- The technique is very complicated.
- Do not change the scale and rotation of the image.
- The convergence range is limited.

Direct Method uses all pixel information. It updates the homographic estimate to minimize a cost function specific. Phase correlation is often used to assess the few tomography parameters [2], [3], Table 1 gives more details. All current direct methods are limited to single-level image processing, or the scene is almost flat, and there is no difference in parallax.

Table 1: Comparison of different direct methods [6]

Approach	Principal	Moving object	Pre-processing	Advantage	weakness
Peleg et al.	Optical flow			Fast. determine the cumulative error.	Accuracy decreases
Levin et al.	Gradient weighting	✓	✓	Seamless.	The input image should be aligned.
Jia and Tang	Locally aligning			Precise alignment.	Distortion.
Uyttendaele et al.	Graph structure	✓		Has the ability to remove ghosting due to moving objects.	Complex calculation.
Ziti and COoperstock	Depth and color	✓		determine a specific degree of depth	Complex calculation.

				discontinuity.	
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2.2 Features Based Technique

Features-based techniques are aimed at determining a relationship between the images based on extracting different features. The key of a few cost feature points in a pair of images is compared to the entire features on the more image using one of their local descriptors [7]. Properties of image stitching focusing on feature-based techniques are:

Advantages

- For any type of scene occurring in the image, its reliability is higher.
- This method is high-speed and can recognize the panorama by automatically detecting the relationship between adjacent image sets.
- These features are suitable for fully automatic panoramic stitching.
- Feature-based techniques depend on the accurate detection of image features.

Disadvantages

- Feature-based techniques lack discrimination ability.
- Loss data interpretability such as PSA.

Approach	Principal	Parallax	Advantage	weakness
AutoStitch	Simple Sparse feature matching.		Auto method.	Restricted to one plane
Gao et al.	Dual-homograph.		Two planes	one tomography
Lin et al	Multi-affine.	✓	determine small parallax.	one affine.
Zaragoza et al.	Mesh-based		Multiple transformations	Local distortion
Liu and Chin	Insert more appropriate correspondence based on pixels.	✓	determine the images that have a specific degree of parallax, and wide-baseline.	Complex calculation.
Chang et al.	Local hybrid transformation model.		Various transformations between overlapping and non-overlapping regions.	Restricted to vertical or parallel images.
Li et al.	Quasi tomography		Reduce distortion.	Limited to parallel images
Zhang and Liu.	Hypotheses of warping	✓	Effective and robust stitching.	Not reusable knowledge about alignment
Lin et al.	Seam-driven	✓	Optimization seam, reduce ghosting	Iterative operations and complicated calculation
Herrmann et al.	Prior constraints.		Single registration, and determine the images	Limited to images contain

			with moving objects.	
Chen and Chuang	Coarse-to-fine scheme.	✓	Scale and rotation correction.	Local distortion.
Zhang et al.	Various prior constraints and optimization terms.		Address the wide-baseline images.	The complicated calculation, local distortion.

Table 2: Comparison of different Feature-based methods [6]

The main steps for image stitching are extract features, registration, and image blending. Feature-based methods are used to match different shapes between images such as points, lines, etc. The key features of a reliable detector include image invariance for noise, scaling, translation, and rotation conversion [3]. Researchers suggested many techniques for detect features, like Harris, Scale-Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF), Features from Accelerated Segment Test (FAST), PCA-SIFT, and ORB techniques.

2.2.1 SIFT Detector

SIFT calculates the local image descriptor of each key point based on the value of the image gradient and the direction of each point of the image sample in the area centered on the key point, The SIFT algorithm is used to extract color picture feature points[3]. Invariant illumination, affinity, and projection transition features can be extracted by the SIFT algorithm. It helps to reduce the number of matching characteristics, increase the speed and precision of matching feature points, balance the feature points by measuring similarity, and use Euclidean distance to calculate the similitude of two images. Get the most important points in the image, and find the next two main points in another image[8].

2.2.2 SURF Detector

This algorithm is used based on multi-dimensional space theory and acceleration calculations using fast matrix approximation and Hessian's definition of "integrated images". SURF uses three steps to discover features; matching, description, and disclosure. SURF speeds up the SIFT detection process by monitoring the quality of the detected points. It focuses more on speeding up the matching process. Near the low dimensional features[9], the Hessian matrix is used for greatly increasing the matching velocity. This algorithm is widely used in all fields of computer vision professionals. SURF has proven efficacy and durability in the localization and stabilization of unchanged features.

The adoption of the highly optimized SURF algorithm on the SIFT algorithm is also similar in general steps [10].

An improved algorithm is proposed by using (improved SURF Algorithm) to solve the above problems.

2.2.3 Detector (FAST Corner)

A SUSAN corner-based algorithm FAST was presented as a detector, where it is very fast, high quality, accurate, and ideal for applications with real-time frame rates. A further property of the FAST operator is its rotational and scale invariance. Its efficiency is better than many other algorithms, including operator SIFT [11].

2.2.4 Detector (Harris Corner)

Harris algorithm is a point extract algorithm based on the algorithm of Moravec, to get all the corners in the image. The Harris detector looks at the average directional strength. The intensity changes in the

small specific area around an interesting point called the window. If the window is flat, then there is no change in intensity in all directions when it is changed. In the case of existing an edge region, then the intensity will not be changed along the direction of the edge. From the other side, the intensity will be changed significantly in all directions. So, this detector is a mathematical way to calculate the type of region (edge, flat, or corner). Also, finding the correct angle points concerning weak edges is very difficult [3].

2.2.5 Detector (ORB)

The ORB is a fast binary descriptor based on BRIEF key points and FAST detectors. BRIEF is a new feature descriptor that uses a smooth image patch binary test between pixels. Its performance is similar to SIFT in terms of lighting, blurring, and enhanced distortion. Its efficiency is close to SIFT in terms of light airtightness, Blurring, and distortion. More efficient comparison and very low memory. It can be seen by experiments how ORB operates in several cases in two orders of magnitude faster than SIFT. Performance is tested in many real-world applications, such as object detection patches and motion monitoring [7], An improved algorithm is proposed by using (improved PCA-ORB Algorithm) to solve the above problems.

Table 3 shows all the characteristics advantages and disadvantages of using technologies based on Discover features.

Table 3: Comparing the use of feature detection techniques.

<i>Ref.</i>	<i>Year of Publication</i>	<i>Feature detector techniques</i>	<i>Characteristics</i>
(Qu et al.) & (Song) & (Zahra, H.et al.). [14] [10] [12]	2018 &2020	SIFT	<p>Advantages:</p> <ul style="list-style-type: none"> • Maintain to feature Unchanged for scaling and rotation. • It has a strong resistance to light and noise. • In detecting image features and matching their use is very wide. • it has strong anti-noise ability and SIFT has good robustness • The fastest of four algorithms significantly improved the performance of the work • A Gaussian variation is used in the feature extraction stage. <p>Disadvantages:</p> <ul style="list-style-type: none"> • High cost. • Large computational burden. • The main problem for remote sensing images is their low controllability in the number of features; Lack of attention to the quality and distribution of extracted features. • Gaussian filter does not maintain object limits or smooth the information and noise of the same level at all scales.
Ma et al & (T. Zhang et al.) [15] [8]	2019 & 2020	SURF	<p>Advantages:</p> <ul style="list-style-type: none"> • A fast and robust SIFT algorithm for feature extraction • It is superior in terms of repeatability, uniqueness, and robustness to related approaches. • in the speed of calculation

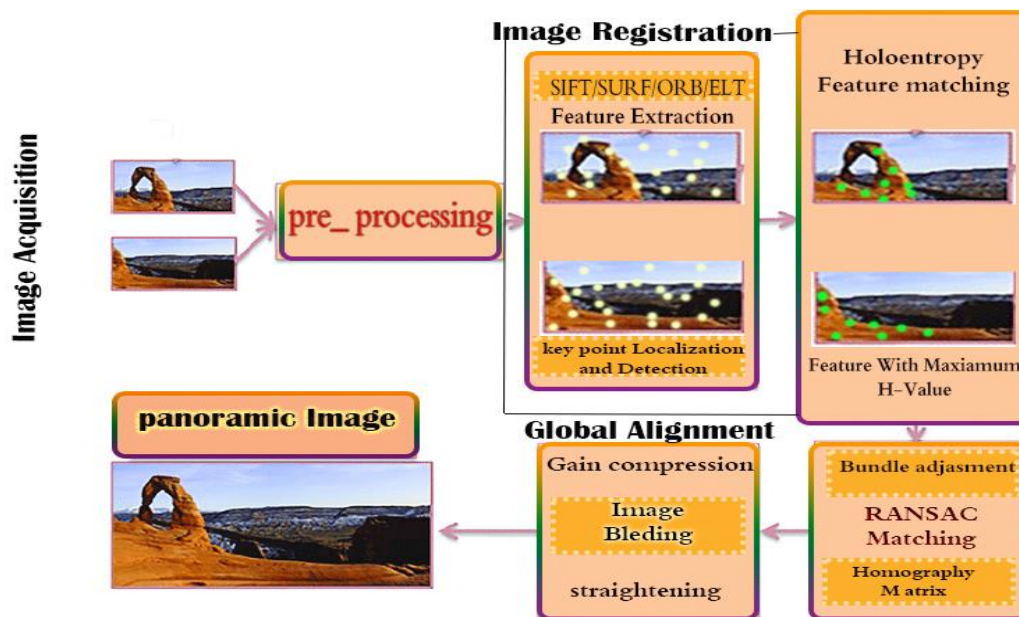
			<ul style="list-style-type: none"> reducing the computational cost <p>Disadvantages:</p> <ul style="list-style-type: none"> High feature descriptor dimension. Huge quantity of calculations. Poor precision when the rotation angle and the viewing angle are too wide.
(Setiawan et al.) [11]	2020	FAST	<p>Advantages:</p> <ul style="list-style-type: none"> It determines the intensity weighted centroid of the patch with a located corner at the centre. The orientation represented by the vector direction from the centroid to the located corner point. Enhance the rotation invariance by calculating moments. <p>Disadvantages:</p> <ul style="list-style-type: none"> Does not compute the orientation and is a rotation variant.
(Mistry & Patel) & (Setiawan et al.) [3] [11]	2016&2020	Harris Corner	<p>Advantages:</p> <ul style="list-style-type: none"> high accuracy in detecting corners The application is done to get the highest number of points. <p>Disadvantages:</p> <ul style="list-style-type: none"> It requires a relatively longer extraction and matching time.
(Ma et al & M. Wang et al & Zhu et al) [15] [16] [17]	2019 & 2017 & 2020	ORB	<p>Advantages:</p> <ul style="list-style-type: none"> By using the algorithm, the feature points will be improved to obtain the feature points in which the distribution is uniform A rotation matrix is computed using the orientation of the patch and then the BRIEF descriptors. Reduces the computational cost and reduces the dimension in subsequent feature point matching. Stitching speed is much faster than that of Sift and Surf. The algorithm is robust to the external parameters of the camera. <p>Disadvantages:</p> <ul style="list-style-type: none"> It does not contain the scale threshold property and has a high mismatch rate.

[18]. Compare performance on different image distortions for the matched assessments using SURF, ORB, BRIEF, and SIFT. Using 812 images that underwent transformations and were matched by using several different detection devices. The results of this study are:

- The BRIEF algorithm was very poor in performance in terms of image matching that is not clear for each detector.
- In terms of horizontal and vertical rotation, the performance of **SURF and ORB** is much better.
- In the images that have been tampered with, **SIFT and SURF** in terms of image matching are good.
- In terms of different trends in image matching, **ORB, and SURF, BRIEF, and SIFT** will work in the same classifications for matching.
- In terms of matching displaced and changing images, **ORB** is a very poor performance.
- Regarding blurred images, the performance of ORB, SIFT, and BRIEF, SURF is weak.

3. Image Stitching Methods

There are three main phases of the stitching algorithms: image acquisition, image blending, and image registration and composing. The image stitching process goes through several stages and algorithms in terms of feature extraction, matching, elimination of external values, and building a panoramic image, as shown in Figure 2.



3.2 - Image pre-processing

During digital hardware image acquisition, multiple interferences are acquired in the original image, such as blur, noise, scaling, rotation, warping, and segmentation. etc., Thus, the picture acquired quality cannot fulfill the expected quality. To ensure accurate pixel-level calibration between images, an original image, as image DE noising, image correction, should be pre-processed efficiently and accurately. The main goal of image pre-processing is to minimize alignment difficulty. The precision of the image pre-processing step directly affects the consistency of the final stitch image [8]. N images with significant brightness variations in the image set must be optically recorded. The image brightness correction will change the entire image series to a similar level of brightness [10].

3.3 -Image Registration

The image register is the next step after images are acquired. The origin of the image-stitching algorithm is image registration. The aim of this stage is to separating images and seeking

geometric correspondence. If the matching points in the two images are sufficient, then after the process of extracting the feature points and matching them the image pair is used as a matching image[8]. Without proper registration, the final performance panorama is not composed correctly. This begins by loading and then processing the images from the database through a loop to detect and extract features, geometric estimation, and available matching. Feature detect and extract are designed to select certain points like the corners and edges of an image rather than looking at the whole image. As previously explained in a feature-based technique.

After extracting features for pair of an image, the next step is to match the feature extracted. The highest feature points of an image in the overlapping areas indicate that their representation in the reference image has changed. The corresponding feature with the reference image displays a changed image[9]. It will find many vital points and descriptions for each image. The matching process uses descriptor data to compare matching points on the image. This step is intended to compare the best features of an image with the other image. Then if the features of the input images match, to achieve accurate feature matching, the locations of the identical features will be identified as matched pairs. Angles are useful points of interest that must be matched because angles are more detectable features of perspective changes. This is done through the use of one of the matching algorithms, including Brute Force (BF), Fast Library for Approximate Nearest Neighbors (FLANN), and K-Nearest Neighbors matcher (KNN)[19].

1. **BF matcher:** the descriptor takes all possibilities and finds the best matches in the initial set, the descriptor takes one feature and matches any other feature to the second set employ a separation figuring through measure distance with all other features of the second image[19].
2. **FLANN matcher:** A custom algorithm library can demonstrate high-dimensional features and fast neighbor search in large data sets. FLANN uses a random KD tree algorithm and k-means tree algorithm to perform priority search. The random KD has a good ability to find the closest points to an input point in any KD tree by searching many trees in parallel [19]. Using the characteristics of the search tree can rapidly remove part of the search space. The priority search K-means tree algorithm divides the data into regions and regroups each region until there are more than M items in each leaf node. Then, it randomly selects the initial center, so for large data sets, it runs faster than the BF matcher.
3. **KNN matcher:** Display the best match of k, where k is determined by the customer. It stacks two images on a horizontal plane and draws lines from the first image to the second image, showing the best match [19].

3.4 - Good Matching Operation

The incorrect matching of images may have a great impact on the results of the geometric transformation model. To increase recording speed and precision, RANSAC is the acronym of "Random Sample Consensus". This filtering algorithm was published by Fischler and Bolles in 1981[20] It is a non-deterministic algorithm because it doesn't ensure to return of acceptable results, the probabilities of success increases if more iteration is made to discard the false matches. RANSAC is an iterative method used by a group of observed data, which contains outliers for estimating the parameters of a mathematical model and for finding the best-fit results.

3.5-Image blending

The last step of the stitching algorithm is image blending and composing. Images are merged to create a seamless large image, once all images are aligned, the seam while stitching can be reduced with gain adjustment. It minimizes the difference between the intensities of the overlapping pixels of the two images. Alpha feathering and Gaussian pyramid are the two well-

known methods of blending. In the cases where well-aligned image pixels are present with only a difference in intensity between two images, then alpha blending works extremely well [5]. The Gaussian pyramid is another popular approach where images at two different frequency bands are merged and then filtered from the center of one image to another image correctly stitched image as shown in Figure 4 and incorrectly stitched image as shown in Figure 5

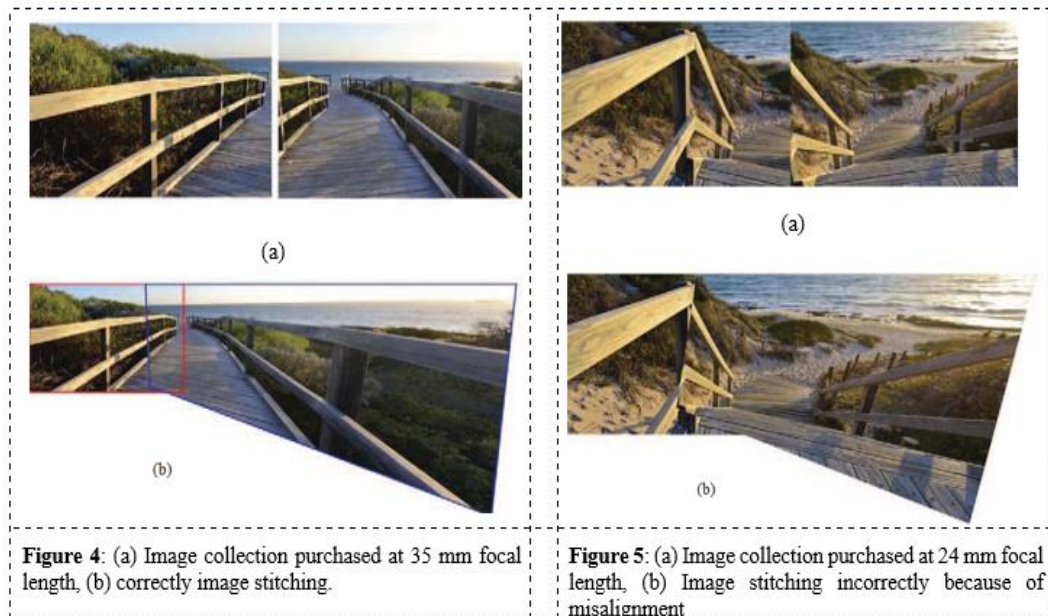


Figure 4: (a) Image collection purchased at 35 mm focal length, (b) correctly image stitching.

Figure 5: (a) Image collection purchased at 24 mm focal length, (b) Image stitching incorrectly because of misalignment

4. Related Works

In this section, different techniques for image stitching are considered and analyzed. We present a study on feature detection and matching techniques to obtain a panorama image.

(Zhu et al.2020) They used PCA-ORB feature matching where it solving several problems related to image stitching such as the process of huge data, reduce stitching time, and reduce the mismatching rate. This algorithm benefits from the advantages of the ORB and the PCA algorithm, where they merged them into one algorithm, thereby improving the stitching speed. The results of the algorithm showed

that it reduces the amplitude of the feature descriptor and uses the KNN algorithm to make it coincide with the feature point. Then, the RANSAC algorithm of robust matching is used to eliminate unmatched matching points. Lastly, the inverse algorithm is used to perform fading. The resulting images are fused.

Based on ensuring the stitching quality, this algorithm consumes less time than the PCA-SIFT algorithm and is a reliable image-stitching algorithm [17].

(T. Zhang et al.2020) The author proposes an improved SURF algorithm. The feature points are extracted through the Hessian matrix, and then the circular neighborhood of the feature points is used for feature description. Each wave point is used to discover a descriptor for every feature point; As RANSAC can be used to get rid of all unwanted or unmatched points. In comparison to the conventional SURF algorithm, this algorithm benefits from good speed, full use, and higher accuracy of grey information and detailed information [21].

(Jatmiko & Prini,2020) Authors suggested many steps to stitching underwater images, which is at the first taking an image frame, determine a key point based on the Binary Robust Invariant Scalable

Keypoints (BRISK), feature matching using Random Sample Consensus (RANSAC), homographic estimation, and perspective warping. The result proved that the suggested algorithm has the ability to stitching underwater images and produce the best matching, even the less detected key points [22].

(J. Li & Liu, 2020) The authors focus on finding the edge points. This is achieved by developing the cuckoo algorithm which is improved the edge detection, comparing extracted feature points when using the SIFT algorithm and edge points are made. improved the ISIFT algorithm proposed is the highest in matching accuracy and matching time, while the matching accuracy and matching the time of HSIFT algorithm is better than BSIFT and SIFT, and BSIFT is better than SIFT [23].

(Hoang et al, 2020) The authors suggested the algorithm (A-KAZE) to deal with complex calculations and time-consuming issues during uncontrolled image welding. In the case of image registration, the overlap area between the input images is estimated, so this area (KNN) algorithm extract and collate only the feature points. Image stitching builds a binary tree model that does not match two matching images. Compared to conventional approaches, our program significantly reduces the computational time for matching unrelated image pairs and speeds up image registration and stitching. Also, the binary tree PIN model reduces preamble distortion. Experimental results show that using the same method, the number of feature points that pop up in nearly overlapping areas is about 0.3-0.6 times that of the entire image, significantly reducing feature extraction and matching calculations. Compared to the whole image matching method, our method takes only one-third of the time to find all matching images [24].

(Caparas et al, 2020) proposed an algorithm for auto image stitching based on features. Five steps are proposed to achieve the image stitching. image registration is the first step, while the second step focuses on detecting and extract features by using the SIFT algorithm. The algorithm used for matching the features in the third step was K-nearest neighbor. Estimate Homograph based on the RANSAC is the fourth step. Finally, the weighted matrix is used for blend images. This method is tested by comparing the image stitched similarity with the reference image, similarity was up to 12-18%. This is because

high-quality images (i.e. high number of pixels) have thousands of features - hence, thousands of key points while low-quality images may have only a few hundred [25].

(Qi et al, 2019) The authors suggested an improved SURF feature extraction method. The retrieval and recording of images is the center of the image stitching, which contributes directly to the quality of the

stitching. Tackling the issue of unequal distribution images and image stitching, In this proposed, the BRIEF operator in the ORB algorithm performs the rotation shift-invariance. The European pull distance was later used to measure, the similarity and the KNN algorithm are used to calculate the rough feature matching. Finally, the distance threshold is used to delete the corresponding pair with a larger distance, and the RANSAC algorithm is then used for cleaning. Experiments show that the algorithm proposed is good in real-time, powerful, and precise [26].

(Vijayan & Kp, 2019) The author proposes a new method for the extraction of drift facilities. Drowsiness during driving is one of the main problems of road traffic accidents. Physical or mental fatigue can lead to driver drowsiness, the sedative effect of multiple drugs, drug abuse, melanocytes, or certain diseases, such as obstructive sleep apnea. It was developed by combining the previous two methods (such as S and FLAN). The features extracted from the face using the screening feature extraction technology will be deleted, and the features will be extracted using Extron matching. SIFT matches have been compared with FLANN. Experimental results show that the improved features are

extracted and matched with the FLANN-SIFT combination. It has also been proven that FLANN with the SIFT method reduces fake emails. One of the challenges remains. When the driver uses sunglasses, this function will disappear. Solving this problem may help expand his work. In all other facial conditions and for lighting changes [27].

(Qu et al, 2019) The authors proposed a new photo mosaic algorithm based on the proposed A-KAZE features to use the A-KAZE algorithm in terms of rotational stability, luminance stability, velocity, and stability. Get rid of stitching lines with the optimized Laplacian algorithm for multi-precision fusion, get better fitting lines, and combine images with the multi-resolution fusion algorithm to get a satisfactory high-resolution smooth image to do. The proposed seam algorithm is faster and more robust than traditional SIFT algorithms [12].

(Shreevastava et al.,2019) A mismatching point elimination algorithm based on the angle cosine and RANSAC algorithms is suggested to resolve the issue of many mismatches and low accuracy in the ORB algorithm. Experiments show that as regards the original ORB algorithm, the improved algorithm greatly increases the accuracy, and the time efficiency is superior to the mainstream algorithm SIFT and SURF, which can be applied to some applications with high precision and real-time requirements[28].

(Ane Delphin et al., 2018) The author proposes a seamless image-stitching scheme that works well under a variety of lighting conditions. The proposed mosaic scheme is based on hole entropy sieving SIFT feature matching, eliminating mosaic issues related to the scale, rotation, and zoom effects of mosaic images. The proposed system uses the RANSAC image-matching standard to select outliers and outliers that represent keyframes that contain important visual content: Minkowski distance-based image-stitching and paired distance-based stitching. Use horizontal and vertical square gradient values to calculate performance. The proposed seamless splicing method is evaluated based on the matrix, horizontal squared gradient value (HSGV), and vertical squared gradient value (VSGV) [29].

(Win & Kitjaidure, 2018) The author proposes a system for stitching biomedical images. The system uses a feature-based methodology to propose an image-based mosaic system. This system is used to stitch biomedical images with the same partial overlap area. The proposed system aims to stitch high-resolution images with a short processing time. The design of the system divided into five stages: pre-processing, feature extraction, feature matching, homographic estimation, and image stitching. In the feature detection stage, a method based on ORB features is used. The proposed methodology has been improved in terms of performance and accuracy. This method is compared to many different feature detectors, Harris Corner Detector, SIFT, and SURF technology. In the experiment, the ORB approach had stronger results on the detection rate of the right key points and processing time than other feature-based approaches [30].

(M. Wang et al., 2017) the authors address that the SIFT and SURF features face a problem of long time-consuming. The authors proposed a new image-stitching algorithm by using ORB features (Oriented FAST and Rotated BRIEF) to solve the time problem. FAST is used to extract the ORB feature points with directional information, described by BRIEF. Feature extracting and matching. Also, the false matching points were removed by using the RANSAC algorithm. Lastly, the image blending speeds up by using the weighted average method. The authors proved that the results of image stitching by using the proposed algorithm have the same effect as that of the SIFT and SURF algorithms [16].

(Mistry & Patel, 2016) The author proposed an image registration mechanism used in this proposal as a feature-based approach using the corner detection algorithm HARRIS feature detection. RANSAC is also used to remove outliers from both images and process the algorithm for image stitching to create the panoramic stitched frame [3].

5. Evaluation of Image Alignment Quality

1. **Root mean square error (RMSE):** the first measure to evaluate the alignment accuracy of the stitched images is the root mean squared error (RMSE) [31].

$$\text{RMSE}(\mathbf{I}_{\text{tar}}, \mathbf{I}_{\text{ref}}) = \sqrt{\sum \pi \frac{1}{N} (\mathbf{1} \cdot \mathbf{0} - \text{NCC}(\mathcal{P}, \text{ref}))} \quad (1)$$

2. **Peak Signal to Noise Ratio (PSNR):** is an engineering term for the ratio between the maximum possible power of a signal and the power of a corrupting image that affects the fidelity of its representation [32].

$$\text{PSNR} = 10 \log_{10} \left(\frac{\text{MAX}_1^2}{\text{MSE}} \right) \quad (2)$$

Where MAX₁ is the maximum gray level value represent the image, the pixels are 255. MSE has defined as for a picture I of M / N and its loud approximation K:

$$\text{MSE} = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (I(x, y) - K(x, y))^2 \quad (3)$$

3. **Structural Similarity Index (SSIM):** The approximation is based on the sensory model, which takes into account changes in the input of the image structure. It has a powerful ability to measure data loss that occurs during image degradation. However, SSIM also requires reference images. Also, it is easy to calculate and fit different images [32].

$$\text{SSIM}(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (4)$$

4. **Difference Of Edge Map (DoEM):** It determines the average value of brightness in the local edge difference map and divides it into the entire average value. It judges whether the brightness difference plays an essential role in proportion. When generating points, the ratio of brightness change and displacement estimation will be dynamically adjusted as the differential graph changes. DoEM is defined by the following equation:

$$\text{DoEM} = e^{-\frac{\sigma^2}{c_4}} \left(\frac{\mu_e e^{-\frac{\mu_c}{c_1}} + \mu_a e^{-\frac{\mu_a}{c_2}}}{\mu_e + \mu_a} \right) + \left(1 + e^{-\frac{\sigma^2}{c_4}} \right) e^{-\frac{\sigma^2}{c_3}}, \quad (5)$$

However, this is not appropriate for evaluating the stitching series a method is proposed for evaluating stitched images [30]. The geometric and photometric accuracy of the stitched images was evaluated using SSIM, SAM (spectral angular mapper), and IMR (intensity magnitude ratio).

There are other performance evaluations, such as (NIQUE, PIQUE, etc.)

6. Challenges of Image Stitching

- Images corrupted by noise.
- indexing a large number of images.
- High image resolution.
- presence of parallax and scene motion [25]
- Several issues were produced between cameras due to the angle and exposure, such as wide baseline, large parallax, and variation in illumination.
- Low-texture overlapping regions [6].
- Blurring image.
- uneven distribution of picture features and stitching of images.

- Color mismatches correction.
- Correcting differences in exposure, white point, and vignette between the individual images.
- The evidence of an uncertain or noisy image: Often it damages the image because of the difference in the acquisition and transmission process caused by noise, the extraction features will have minimal cost through successive filtering methods and methods.
- Effective index for large image collection.
- Another problem that is often repeated in the process of creating mosaic images is the deletion of visible seams [34].
- If the multiple-image is aligned, it will be a problem with amplification and accumulation Error [35].
- How to treat parallax, How to consistently stitch the left and right panorama, how to take care of disparity during stitching.
- The stereo image-stitching task.
- Illumination, Scale, Deformation, Occlusion, Background Clutter, Motion, Local Ambiguity, Texture Gradient, Shading, Shape from Texture Etc.

7. Application of Image Stitching

- Image stabilization features.
- Panoramas in maps and images of satellite with high-resolution.
- Images for medical solutions.
- High-resolution multiple images.
- Video stitching and object insertion [1].
- Used for global positioning and used by a robot for independent navigation [16].
- For games, like a war of tanks and other acquisition is used in computer games in a realistic playing environment.
- Used for default rear scan of the vehicle without blind spots To see drivers surrounding the vehicle without showing errors [36].
- Useful for remote sensing UAV, video summarization, surveillance applications
- [37].
- When you use an image pyramid, it is useful for several applications: such as image enhancement, image analysis, noise reduction [38].
- 360-degree cameras and photography in virtual reality [39].
- Image and video retargeting[15].
- Video stabilization, Video summarization, Video compression, Video matting, Panorama creation.
- There are many other applications such as tracking, object recognition, camera calibration, image registration, object classification, augmented reality, computer vision, 3-D reconstruction [40].

8. Comparative Analysis

The methods studied above are compared regarding advantages, disadvantages, techniques, and accuracy performance. Table 4 has displayed a comparative study among these methods.

Table 4: Comparative analysis of various image-stitching approaches

Ref.	Published year	A method in Feature Extraction	Method in Matching	Estimate the Homograph Matrix
(T. Zhang et al.) [8]	2020	Improved SURF	Hessian matrix	RANSAC
(Zhu et al.) [17]	2020	(PCA-ORB)	KNN	RANSAC
(Z. Li & Yin) [41]	2020	point features (LBD)& (LSR)	EDLines algorithm	RANSAC

(Jatmiko & Prini) [22]	2020	BRISK algorithm		RANSAC
(J. Li & Liu) [23]	2020	Improved SIFT	Cuckoo algorithm.	RANSAC
(Hoang et al.) [24]	2020	DCNN, Harris a study by Deep Learning	LF-Net CNN model	RANSAC
(Du et al.) [31]	2020	SIFT key region using SSM	SIFT	RANSAC
(Luo et al.) [29]	2020	SIFT in the VLFeat library.	line-point invariants or line-junction-line	RANSAC
(Caparas et al.) [25]	2020	SIFT	KNN	RANSAC
(Bakar et al.) [19]	2020	SIFT & SURF	BF & KNN & FLANN	RANSAC
(Y. Zhang et al.) [8]	2020	compare different feature SS-SIFT & SIFT & SURF selected SIFT	compare the feature points matching LPM & VFC	mTopKRP
(Qi et al.) [44]	2019	Improved SURF	KNN	RANSAC
(Vijayan & Kp) [27]	2019	SIFT	FLANN	RANSAC
(Shreevastava) [28]	2019	SIFT	Brute Force Matcher (BF)	RANSAC
(George & Vishnukumar) [45]	2019	SIFT	FLANN	RANSAC
(Qu et al.) [12]	2019	A-KAZE	KNN	RANSAC
(Ruan et al.) [44]	2019	SURF	Wavelet Transform	RANSAC
(Shu & Xiao) [48]	2018	Improved ORB	Brute Force Matcher (BF)	RANSAC
(Feng & Li.) [49]	2018	ORB+SURF	Laplacian Pyramid	RANSAC
(Win & Kitjaidure) [30]	2018	FAST + BRIEF	ORB	RANSAC
(Zou et al.) [50]	2017	SIFT	multi-band image	RANSAC
(M. Wang et al.) [16]	2017	OFAST	weighted average method	RANSAC
(J. Zhang et al.) [1]	2017	SIFT	weighted average by SIFT	RANSAC
(G. Wang et al.) [51]	2017	ORB	the edge matching	RANSAC

(Chen & Chuang) [52]	2016	SIFT	APAP	RANSAC
(Mistry & Patel)[3]	2016	HARRIS corner	Warping	RANSAC

Table 5 also summarized the accuracy of the image detection feature and its matching to obtain a more accurate panorama image

Table 5: Detection Feature and matching in image stitching

Image stitching techniques	Accuracy & Matching Rate (%)
SURF based Approach	95.99%
FAST based approach	50.74%
Harris corner detector based approach	94.68%
MSER based Approach	90.53%
For indoor scene the panoramic method SURF	92.9%
Experiment indoors Mosaic method SIFT	88.1%
For outdoor scene the panoramic method SURF	99.1%
In outdoor testing the mosaic method SIFT	92.1%
PCA-SIFT	90.12%
PCA-ORB	94.97%
SIFT	81.24%
BSIFT	86.42%
HSIFT	92.63%
ISIFT	97.1%
SIFT key region using SSM	92.0%
KAZE	88.11%
FLANN	93.412%
SIFT-SIFT	85.318%
SIFT-FLANN	93.412%
ORB + RANSAC	89.62%
ORB + elimination	94.57%

9. Conclusion

Image stitching is still a hot spot in many image processing, computer vision, computer graphics, software development, and other journals. Several challenges face image stitching still unsolved. Unfortunately, we did not found an appropriate algorithm that provides a panoramic image free of problems. Among many algorithms, the commonly used is the SIFT algorithm because of its speed and stability to rotation and scale. for that, it is not easy to define a specific method as an ideal method for specific purposes. However, the technological development of new techniques for image stitching will have tremendous and profitable applications and high accuracy.

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