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Image Stitching Algorithms - A Review

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ABSTRACT
Image stitching is the process of combining two or more images of the same scene as a single larger image. Image stitching is needed in many applications like video stabilization, video summarization, video compression, panorama creation. The effectiveness of image stitching depends on the overlap removal, matching of the intensity of images, the techniques used for blending the image. In this paper, the various techniques devised earlier for the image stitching and their applications in the relative places has been reviewed.

Keywords
Image stitching, GIST-Gradient-domain Image Stitching, RANSAC-Random Sample Consensus, Bundle Adjustment.

1. INTRODUCTION
Image Stitching is an inevitable process in application like making Panoramas, Video Compression , Object Removal , Object Insertion and Video Stabilization. It is a process which can be described as follows: Suppose there are two images I1 and I2, with some common parts, W. You want to combine the two Images into a single Image with the Common parts being overlapped [1]. This is the process what you exactly call the Image Stitching. But the process does not end just by combining the two images. The Angle of projection of light on the images are different, the intensity of pixels are different , exposure towards light is different and the alignments of the pictures are different. Hence you need to adjust each and every feature of the two images to a such that they look exactly like a single image taken from the same angle of the camera. The final output the image should be such that the final output image should be like the original image. the final image formed out of the two or more input images should be creaseless, that is the line joining the images should be invisible to the viewer. It should have smooth edges non-varying intensity and high resolution.

2. VARIOUS IMAGE STITCHING ALGORITHMS
Image stitching in simple language is to combine two or more than two images to form a single combined image [2]. The concern comes when you have to remove the intensity difference among the pixels of the images, to remove the false edges which come after joining the images and to provide a smoothness in the combined image. There are main two ways in which you can do image stitching:

2.1 Intensity based comparison
This is a direct method. In this method , Intensity of the pixels of the images is compared and then a modulus difference of pixels are taken in a place where images are overlapping, which can also be defined in terms of the cost function which are discussed in the later sections. In this method, the value varies where the scale and rotation of the images varies.

2.2 .Feature-based Technique
Feature-based techniques are mainly deal with optimization of feature correspondence and are vulnerable to local minima in the function to be optimized. These methods frequently rely on an accurate *a priori* map which can easily be obtained from architectural drawings, manual measurement, which can fail to account for the presence of objects like, pen or notebook, or the issues related to dynamics of the robot and human interaction with the environment. In feature-based techniques, the alternative of which features to employ is oftentimes depends on the sensors and encumber to a specific application area. In this section the focus is on the work proposed by Vlandon et al;(2005)[3] on the Image stitching and blending. they had described three basic steps in which the whole process of Image stitching is carried out. the steps are described as follows:

Image Registration: This is an image processing technique in which multiple images are aligned to form a single integrated image [4]. This step is helpful in overcoming the issues image rotation, scale, and skew which are some common problem that occurs when overlapping edges.[4]

Overlap Removal: The job of overlap removal is to adapt the layout rendered by representative graph drawing techniques so that nodes of non-zero width and height do not overlap.This process removes the overlap region giving the final output image a good smooth effect

Image Blending: Image Blending is defined as the influence of input images in the final combined output image.

2.3 Coherent Image Joining using Slope-Field
In this method of Image stitching, slope that is the change in the intensity between the points of the images are taken into consideration to combine two images. When two or more images are combined to form a single image, the quality produced by the final combined image is directly dependent on the similarities the stitched image shows towards the images input and the quality of the crease produced due to the stitched image. the final image produced should be seamless to give a better experience to the viewers.

In this topic, the focus is on the work done by the Anat Levin, Assaf Zomet, Shmuel Peleg and Yair Weiss (2004)[5]. To measure the quality of the composition of the images cost functions are defined to evaluate the same. In the cost functions defined, slope areas are defined to find the similarities of the output images to the input images and the profile of the line formed due to stitching.

The efficiency of an image stitching algorithm depends on the cost functions. Optimized the cost function, better is the algorithm.

There are several approaches to stitch the image under the gradient domain. Popular among them is the GIST algorithm, GIST- Gradient-domain Seamless stitching. Two versions of GIST are mentioned in this review-GIST1 and GIST2.

2.3.1 GIST1 versus GIST2

GIST1 minimizes the false edges of the stitched image to compute the cost function Cp. Here Cp is the cost function computed by finding the dissimilarity between the first differential coefficient of the input image to that of the combined output image. The second term of the equation 1 removes the false stitched.[5]

Dissimilarities between the stitched image can be measured as D_s, where D_s is:

$$D_s=\sum(d_i) + \sum(g_i) \quad (1)$$

where,
d_i=dissimilarity of combined image to the input image
g_i=slope of inconsistency in the overlap region

GIST2 compute the derivative of the input images.[5] In this method , first, the partial derivative of the input images are computed with respect to the coordinated here dealing with. Suppose if here dealing with the x and y coordinates, then partial derivative with respect to x and y coordinates are calculated as-

$$\text{Partial derivative in x-coordinate}=\partial I_i/\partial x \quad (2)$$

$$\text{Partial derivative in y-coordinate}=\partial I_i/\partial y \quad (3)$$

where, I_i goes from 1 to n number of images

Then after partial derivative of images are stitched in their respective domain as-

$$F_x=(\text{Image stitched in x- domain}) \quad (4)$$

$$F_y=(\text{Image stitched in y- domain}) \quad (5)$$

and function F is formed by F_x and F_y as-

$$F=(F_x,F_y) \quad (6)$$

Finally , a composite image whose gradient is closest to the gradient of F has been found out.

The choice to use GIST1 or GIST2 depends on the requirements and the Images here available with. If the input has images which cannot give a perfect seam due to some particular reasons like inconsistencies in the image, the best option is to use GIST1. GIST1 can overrule over the misaligned images due to the poor geometry of images.

2.4 Seamless Image-Stitching Using Wavelet Transform

Here the focus is on the wavelet-based algorithm proposed by Guangquan et al (2005)[6] in which they designed a new function-defining energy for differing frequency subbands of waves of the image representing multi- resolution. better the algorithm is, more optimized is the energy function. The benefit of this algorithm is that it can produce an effective result even in the cases where the images are badly misaligned[7].

2.5 Seamless Image-stitching deforming the structure

Daeho Lee et al (2015)[8] proposed an algorithm which makes use of the previous algorithms like Speeded-up Robust Features(SURF)[9] for feature detection, RANSAC[10] and Approximate Nearest Neighbour(ANN)[7] for feature matching [4]. Correlation between the images is found out by using homographic similarities.[12] Double Seam Selection is used to reduce the structure misalignment. Multiband Blending algorithm is used for removing the difference in the intensity of the images.

2.6 Panoramic Image Stitching

Panorama recognition is based on the Feature matching between the images, feature extraction from the images , image stitching, bundle adjustment and multiband blending.In particular, the focus is on the work done by the M. Brown and D. G. Lowe (2003)[13]. They had proposed an algorithm for panorama making which is fully automatic in nature. Their algorithm requires recognition which is a part of panorama join up. Before their algorithm was proposed, panorama making was limited to the number and the sequence of the images . The algorithm was devised in five steps which are summarized as follows:

Feature matching step extract and match the SIFT (Scale-Invariant Feature Transformation) among images. This extracting and matching of the features is done by using the k-nearest neighbor algorithm using k-d trees to find the approximate neighbors. The time complexity of this algorithm is the Big-O of *n*log(n).*

This step gives panorama by matching and overlapping the connected set of images. There is a popular algorithm RANSAC-Random Sample Consensus, which is used to select a homographic compatible set of inliers among the images.[14]

RANSAC Inliers are defined as the set of geometrically consistent features for all pair of potentially matching images. RANSAC Outliers are defined as the set of inconsistent features within the overlapping areas for all pair of potentially matching images. This step is purely probabilistic. The idea of this model is to make a comparison in the probabilities between the outliers and inliers which is generated by the false edge detection. A pairwise match is established between the images which then leads to the panoramic sequence as connected images. The advantage of this model is that it is helpful in recognizing multiple possible panoramas which can be obtained given a set of images along with rejecting the noise in the image which does not match to any of the images in the set.

The best matching image is selected in each step and it is then added to the Bundle one by one. Image stitching algorithm is carried out while adding the image to the bundle, with the same rotation and focal length as the image to which it is matched. Each feature is projected into all the image in which its matching is done. Camera parameters play an important role in this model.

This was developed by BURT and ADELSON, which blend the frequencies depending upon their amplitude. If the frequencies are low, they will be blended over the large spatial range and vice versa.

3. SOME COMMON PROBLEMS FACED DURING IMAGE STITCHING

i. Parallax-handling: This is the most common challenge during image stitching. Many algorithms came into the light to solve this problem. Some of them are listed in table 1. Many algorithms are proposed to remove the significant amount of parallax from the images during image stitching

ii. Ghosting Effect: This also is one of the common problems in the image stitching algorithm. Some of the algorithms to solve this problem are listed in the table below.

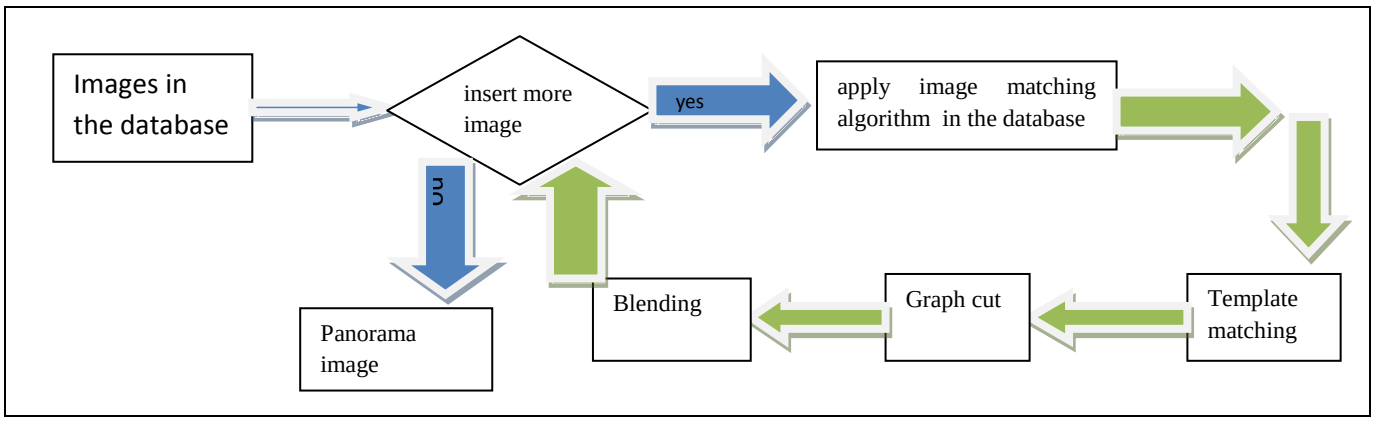

Fig 1. Diagram showing the steps followed in panoramic image stitching.

Table 1:Algorithms for Image Stitching

S. No.	Algorithm	Description	Shortcomings
1.	Parallax-tolerant Image Stitching Algorithm[15]	• This algorithm requires the alignment of images in a way that they can be stitched along a common local origin. • Images with large parallax can be efficiently stitched.	• The method fails with the images having very large parallax and when the images are full of salient features. In that case, the method does not work as no non-salient features exist.
2.	Automated Image Stitching algorithm for microscopic images[16]	• This algorithm is based on the feature extraction . First SURF [17] is used for feature extraction, which is then followed by Histogram Equalization method for image preprocessing. • It can stitch both common images as well as microscopic images. • Enhanced SURF[18] is immune to viewpoint [19], rotation, zooming, and blurred image.[20] • Support multiple formats of the image.	• Images with parallax can not be handled by this algorithm. For that, the need of reference to the specialized algorithms for parallax handling is there.
3.	Perspective preserving distortion for image stitching[21]	• It is the combination of the local transformation of projection and similar transformation with regard to space, of nonoverlapping regions into	• The algorithm has not taken into consideration of more transformations like reflection,

		nonoverlapping regions. • The accuracy of alignments and less distortion with respect to projection and maintenance of multi-perspective view.	rotation, and rotation on the local geometries. This area is the scope for the development of this algorithm.
4.	Using adaptive normalization for image stitching[22]	• It normalizes the image locally, adjusting the contrast, associate local statistics to the image, done using Wallis Filtering. • This algorithm is simpler as compared to other algorithms as well computationally efficient and stable.	• The algorithm works well as a whole, but to achieve the best result, it requires different stitching methods for different constituents of the images, which can increase the complexity of the algorithm.
5.	Projection interpolation image stitching[23]	• Calculates the homography matrix and then it's inverse. • The inverse matrix is decomposed and then interpolated into sub-matrixes, which is then composed into new one.[24] • Warped image is converted into a new matrix. • Local alignment is improved and geometric structure is preserved. • Ghost effect is removed. • Parallax error is minimized.	• Images with larger parallax, more affine transformations can not be handled by this algorithm.
6.	Dominant plane homography for Parallax handling of image stitching[25]	• Larger parallax problem found in image stitching algorithm is handled as- • Matching points are selected as pairs and the cost of clusters are measured. • Standard seam cutting method is modified to obtain a valid seam. • Global distortion of the image is accepted as compared to the local distortion.	• Cannot handle when the image does not contain larger parallax and is full of salient features. For this method to work, images should contain at least non-salient features.

4. CONCLUSION

Methods for an efficient image stitching has been discussed. Image stitching can be done in either the gradient domain or in the intensity domain. both of the methods devised by the nobles has been summarized here with a brief description on each of them. Final it has been concluded that the choice of a particular image stitching algorithm depends on the type of application required. For example, in panorama making algorithm, need to use the algorithm which can provide the final output using multiple input images and have multiple overlapping among the images. Two gradient domain algorithms are mentioned-GIST1 and GIST2, which has their own advantages and disadvantages. Recently developed algorithms make use of the previous algorithms to make an efficient result.[26]

5. FUTURE SCOPE

Image Stitching has always been an open field for research. New algorithms are coming to make the work clear and less tedious for the programmers to work upon. In this era of 3-D imaging and videos, image stitching is an inevitable task. Panoramic images are the most common application of image stitching. Hence, there is a large scope for research in this field.

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