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A Survey on Image Mosaicing Techniques

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***Abstract*— Image Mosaicing is a method of assembling multiple overlapping images of the same scene into a larger image. The output of the image mosaic will be the union of two input images. Image-mosaicing algorithms are used for obtaining a mosaiced image. There are five steps used in image mosaicing which includes; Feature extraction, Image registration, Computing homography, Warping and Blending. Feature extraction is an Image mosaicing technique which is done by using various corner detection algorithm. This corner detection algorithm produces an efficient and informative output mosaiced image. Importance of Image mosaicing can be seen in the field of medical imaging, computer vision, data from satellites, military automatic target recognition.**

***Index Terms* — Image Registration, Warping ,Corner, Homography, Blending.**

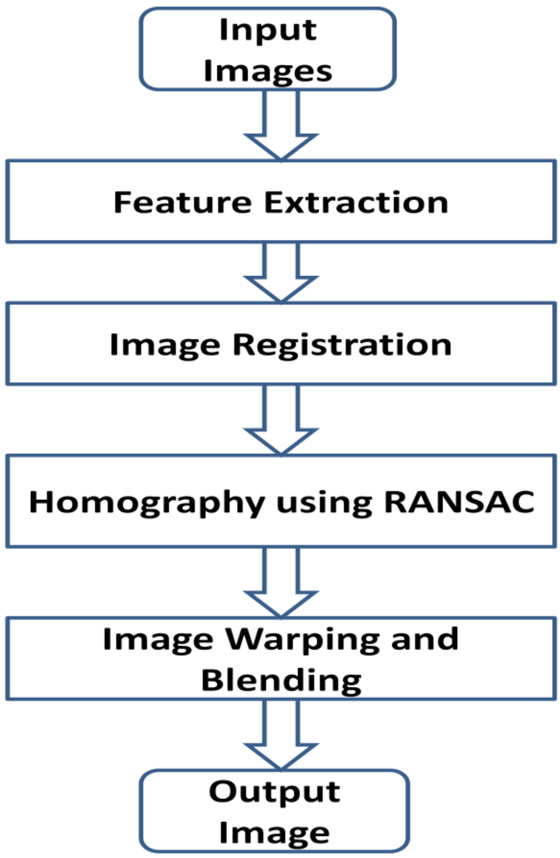
I.INTRODUCTION

Image mosaicing is the stitching of multiple correlated images to generate a larger wide-angle image of a scene. Mosaicing could be regarded as a special case of scene reconstruction where the images are related to planar homography only. An Image Mosaic is a synthetic composition generated from a sequence of images and it can be obtained by understanding geometric relationships between images. The geometric relations are the coordinate systems that relates the different image coordinate systems. The appropriate transformations is applied via of a warping operation than by merging the overlapping regions of warped images. In image mosaicing two input images are taken and this images are fused to form a single large image. This merged single image is the output mosaiced image.

The first step in Image Mosaicing is feature extraction. In feature extraction, features are detected in both input images. Image registration refers to the geometric alignment of a set of images. The different sets of data may consist of two or more digital images taken of a single scene from different sensors at different time or from different viewpoints. In image registration the geometric correspondence between the images is established so that they may be transformed, compared and analyzed in a common reference frame. This is of practical importance in many fields, including remote sensing, computer vision, medical imaging. Registration methods can be loosely divided into the following classes: algorithms that use image pixel values directly, e.g., correlation methods [2];algorithms that use the frequency domain, e.g., Fast Fourier transform based (FFT-based) methods [3];algorithms that use low level features such as edges and corners, e.g., Feature based methods [4];and algorithms that use high-level features such as identified parts of image objects, relations between image features, for e.g., Graph-theoretic methods[4].The next step, following registration, is image warping which includes correcting distorted images and it can also be used for creative purposes. The images are placed appropriately on the bigger canvas using registration transformations to get the output mosaiced image. The quality of the mosaiced image and the time efficiency of the algorithm used are given most importance in image mosaicing.

Image Blending is the technique which modifies the image gray levels in the vicinity of a boundary to obtain a smooth transition between images by removing these seams and creating a blended image. Blend modes are used to blend two layers into each other.

A. *Image Mosaicing Model*



II.FEATURE EXTRACTION

The first step in image mosaic process is feature detection. Features are the elements in the two input images to be matched. For images to be matched they are taken inside an

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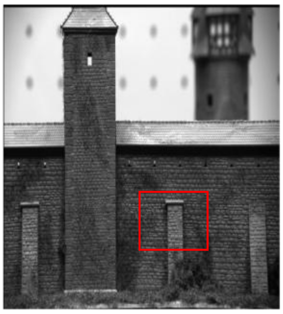
image patches. These image patches are groups of pixel in images. Patch matching is done for the input images. It is clearly explained below as follows:-



Patch-Matching.Fig-1: Input Image-1

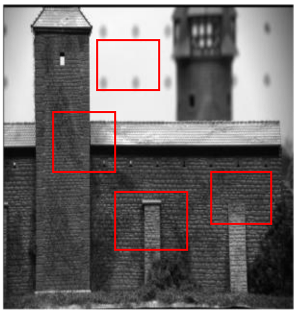
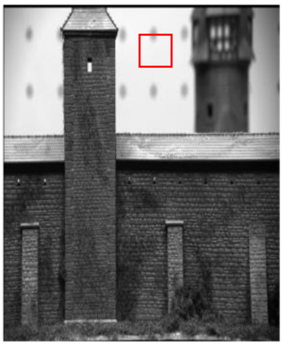


Fig-2: Input Image-2



Patch-Matching.Fig-3: Input Image-1

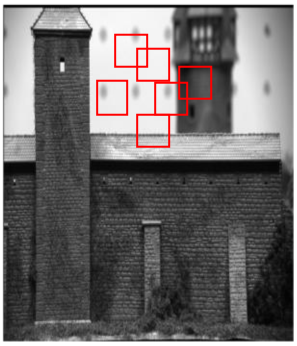


Fig-4: Input Image-2

In the above examples so given,fig1and fig2 gives a good patch match because there is one patch in fig2 which looks exactly similar to the patch so given in fig1.When we consider fig3 and fig4,here it's a bad patch match as there are many similar patches in fig4 which are looking similar to the patch so given in fig3.So,exact feature matching cannot be done because intensities are slightly equal here.

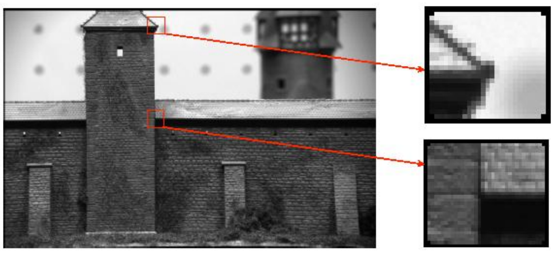


Fig-5: Corners (Junction of Contours.)

To provide a better feature matching for image pairs corners are matched to give quantitative measurement. Corners are good features to match. The features of corners are that they are more stable features over changes of viewpoint. The other most important feature of corner is that if there is a corner in an image than it's neighborhood will show an abrupt change in intensity. Corners are detected in images by applying corner detection algorithms. Some of the corner detection algorithms are Harris Corner detection Algorithm, SIFT corner detection algorithm(Scale Invariant Feature Transform),the machine learning based FAST algorithm, Speeded-up robust feature(SURF).

A. *Harris Algorithm:*

Harris corner detection is a point feature extracting algorithm based on Moravec algorithm based by C. Harris and M.J Stephens in 1988.A local detecting window in image is designed. The average variation in intensity that results by shifting the window by a small amount in different direction is determined. At this point the centre point of the window is extracted as corner point. We can easily recognize the point by looking at intensity values within a small window. Shifting the window in any direction gives a large change in appearance. Harris corner detector is used for corner detection. On shifting the window if it's a flat region than it will show no change of intensity in all direction. If an edge region is found than there will be no change of intensity along the edge direction. But if a corner is found than there will be a significant change of intensity in all direction. Harris corner detector gives a mathematical approach for determining whether the region is flat, edge or corner..Harris corner technique detects more features and it is rotational invariant and scale variant. For the change of intensity for the shift [u, v]:

$$E(u,v) = \sum_{x,y} w(x,y)[I(x+u,y+v) - I(x,y)]^2$$

Where w(x, y) is a window function ,I(x + u, y + v) is the shifted intensity and I(x, y) is the intensity of the individual pixel. Harris corner algorithm is given below as:

1. For each pixel (x, y) in the image calculate the autocorrelation matrix M as;
$$M = \sum_{x,y} \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$
2. For each pixel of image has Gaussian filtering, get new matrix M, and discrete two-dimensional zero-mean Gaussian function as :-
$$Gauss = \exp(-u^2+v^2)/2\delta^2$$
3. Calculating the corners measure for each pixel (x, y,), we get;
$$R = \{I_x^2 x I_y^2 - (I_x^2 I_y^2)\} - k\{I_x^2 + I_y^2\}^2$$
4. Choose the local maximum point. Harris method considers that the feature points are the pixel value which corresponding with the local maximum interest point.
5. Set the threshold T, detect corner points.

B. *SIFT Algorithm*

SIFT Algorithm is Scale Invariant Feature Transform. SIFT is an corner detection algorithm which detects features in an image which can be used to identify similar objects in other images. SIFT produces key-point-descriptors which are the image features. When checking for an image match two set of key-point descriptors are given as input to the Nearest Neighbor Search(NNS) and produces a closely matching key-point descriptors. SIFT has four computational phases which includes: Scale-space construction, Scale-space extrema detection, key-point localization, orientation assignment and defining key-point descriptors. The first phase identifies the potential interest points. It searches over all scales and image locations by using a difference-of Gaussian function. For all the interest points so found in phase one, location and scale is determined. Key-points are selected based on their stability. A stable key-point should be resistant to image distortion. In Orientation assignment SIFT algorithm computes the direction of gradients around the stable key-points. One or more orientations are assigned to each key-point based on local image gradient directions. For a set of input frames SIFT extracts features. Image matching is done using Best Bin First(BBF) algorithm for estimating initial matching points between input frames. To remove the undesired corners which do not belong to the overlapped area, RANSAC algorithm is used. It removes the false matches in the image pairs. Reprojection of frames are done by defining its size, length, width. Stitching is done finally to obtain a final output mosaic image. In stitching, each pixel in every frame of the scene is checked whether it belongs to the warped second frame. If so, then that pixel is assigned the value of the corresponding pixel from the first frame. SIFT algorithm is both rotational invariant and scale invariant. SIFT is very suitable for object detection in images with high resolution. It is a robust algorithm for image comparision though it is slow. The running time of a SIFT algorithm is large as it takes more time to compare two images.

C. *FAST Algorithm:*

FAST is a corner detector algorithm founded by Trajkovic and Hedley in 1998.The detection of corner was prioritized over edges in FAST as corners were found to be the good features to be matched because it shows a two dimensional intensity change, and thus well distinguished from the neighboring points. According to Trajkovic and Hedley the corner detector should satisfy the following criteria:-

1. The detected positions should be consistent, insensitive to the variation of noise, and they should not move when multiple images are acquired of the same scene.
2. Accuracy; Corners should be detected as close as possible to the correct positions.
3. Speed; The corner detector should be fast enough.

FAST incremented the computational speed required in the detection of corners. This corner detector uses a corner response function(CRF) that gives a numerical value for the corner strength based on the image intensities in the local neighborhood.CRF was computed over the image and corners which were treated as local maxima of the CRF.A multi-grid technique is used to improve the computational speed of the algorithm and also for the suppression of false corners being detected. FAST is an accurate and fast algorithm that yields good localization (positional accuracy) and high point reliability.

D. *SURF Algorithm:*

The Speed-up Robust Feature detector (SURF) uses three feature detection steps namely; Detection, Description and Matching. SURF speeded-up the SHIFT's detection process by keeping in view of the quality of the detected points. It gives more focus on speeding-up the matching step. The Hessian matrix is used along with descriptors low dimensionality to significantly increase the matching speed. SURF is widely used in the computer vision community. SURF has proven its efficiency and robustness in the invariant feature localization.

II.COMPUTING HOMOGRAPHY

A. *RANSAC Algorithm:*

Homography is the third step of Image mosaicing. In homography undesired corners which do not belong to the overlapping area are removed. RANSAC algorithm is used to perform homography. RANSAC is an abbreviation for "RANdom Sample Consensus." It is an iterative method to estimate parameters of a mathematical model from a set of observed data which contains outliers. It is a non deterministic algorithm in the sense that it produces a reasonable result only with a certain probability, with this probability increasing as more iterations are allowed. The algorithm was first published by Fischler and Bolles. RANSAC algorithm is used for fitting of models in presence of many available data outliners in a robust manner. Given a fitting problem with parameters considering the following assumptions.

1. Parameters can be estimated from N data items.
2. Available data items are totally M.
3. The probability of a randomly selected data item being part of a good model is P_g.
4.The probability that the algorithm will exit without finding a good fit if one exists is $P_{fail.}$

Then, the algorithm:

1. Selects N data items at random.
2. Estimates parameter x.
3. Finds how many data items (of M) fit the model with parameter vector x within a user given tolerance. Call this K.
4. If K is big enough, accept fit and exit with success.
5. Repeat 1.4 L times.
6. Fail if you get here.

How big K has to be depends on what percentage of the data we think belongs to the structure being fit and how many structures we have in the image. If there are multiple structures than, after a successful fit, remove the fit data and redo RANSAC.

We can find L by the following formulae:

P_{fail} = Probability of L consecutive failures.

P_{fail} = (Probability that a given trial is a failure) L.

P_{fail} = (1 - Probability that a given trial is a success)L.

P_{fail} = (1-(Probability that a random data item fits the model)N)L.

$P_{fail} = (1-(P_g)^N)^L$

L = $log(Pfail)/\ log(1-(Pg)N)$

B. *Homography:*

Homography is mapping between two spaces which often used to represent the correspondence between two images of the same scene. It's widely useful for images where multiple images are taken from a rotating camera having a fixed camera centre ultimately warped together to produce a panoramic view.

Let's take a situation of projection transformation of planes in images. We have two cameras C1 and C2 looking at a plane π in the world. Consider a point P on the plane π and its projections.
$P = (u1,v1,1)^T$ in image1 and $q= (u2,v2,1)^T$ in image2.
There exists a unique (up-to scale) 3 × 3 matrix H such that, for any point P:

$$q \equiv Hp \qquad \ldots\ldots\ldots \qquad (1)$$

(Here ≡ implies the left and right hand sides are proportional and those homogeneous coordinates are trivially equal.)

As mentioned earlier H only depends on the plane and the projection matrices of the two cameras and being a projective transformation matrix can be only defined up to a scale.

Lastly to say, as q and Hp are only proportional to each other so equivalently we have

$$Q \times Hp = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This H is a projective transformation of the plane, also referred to as a homography.
Since the matrix H has 8 DOF,4 point correspondences determine H.
Thus, H is estimated with a minimization scheme using:

$$h =(h11:h12:h13:h21:h22:h23:h31:h32:h33)^T \quad \ldots\ldots..(3)$$

N point correspondences give 2N linear constraints, using (2).
This results in a system of the form Bh = 0.
The following problem must then be solved:

$$\text{Minh} \|Bh\|2 \text{ subject to} \|h\| = 1 \quad \ldots\ldots\ldots\ldots(4)$$

The Homography Detection Algorithm using RANSAC scheme

1. First corners are detected in both images.
2. Variance normalized correlation is applied between corners, and pairs with a sufficiently high correlation score are collected to form a set of candidate matches.
3. Four points are selected from the set of candidate matches, and a homography is computed.
4. Pairs agreeing with the homography are selected. A pair (p, q), is considered to agree with a homography H, if for some threshold[2]:
   $$\text{Dist }(Hp, q) < \varepsilon$$
5. Steps 3 and 4 are repeated until a sufficient number of pairs are consistent with the computed homography.
6. Using all consistent correspondences, the homography is recomputed by solving (4).

III . IMAGE WARPING AND BLENDING

A. *Image Warping*

Image Warping is the process of digitally manipulating an image such that any shapes portrayed in the image have been significantly distorted. Warping may be used for correcting image distortion as well as for creative purposes (e.g., morphing).While an image can be transformed in various ways, pure warping means that points are mapped to points without changing the colors. This can be based mathematically on any function from part of the plane to the plane. If the function is injective the original can be reconstructed. If the function is a bijection any image can be inversely transformed.
The last step is to warp and blend all the input images to an output composite mosaic. Basically we can simply warp all the input images to a plane defined by one them known as composite panorama.

1. First we need to make out the output mosaic size by computing the range of warped image coordinates for each input image, as described earlier we can easily do this by mapping four corners of each source image forward and computing the minimum x, minimum y, maximum x and maximum y coordinates to determine the size of the output image. Finally x-offset and y-offset values specifying the offset of the reference image origin relative to the output panorama needs to be calculated.
2. The next step is to use the inverse warping as described above for mapping the pixels from each input image to the plane defined by the reference image, is there to perform the forward and inverse warping of points, respectively.

B. *Image Blending:*

The final step is to blend the pixels colors in the overlapped region to avoid the seams. Simplest available form is to use feathering ,which uses weighted averaging color values to blend the overlapping pixels. We generally use alpha factor often called alpha channel having the value 1 at the center pixel and becomes 0 after decreasing linearly to the border pixels. Where atleast two images overlap occurs in an output mosaic we will use the alpha values as follows to compute the color at a pixel in there, suppose there are two images,*I*1,*I*2,overlapping in the output image; each pixel (x, y) in image I_i is represented as $I_i(x, y) = (\alpha iR, \alpha iG, \alpha iB, \alpha j)$ where (R,G,B) are the color values at the pixel. We will compute the pixel value of (x, y) in the stitched output image as $[(\alpha 1R, \alpha 1G, \alpha 1B, \alpha 1) + (\alpha 2R, \alpha 2G, \alpha 2B, \alpha 2)]/(\alpha 1+\alpha 2)$.

IV. CONCLUSION

Image Mosaicing techniques have a long history and evaluation methodologies. In this paper, some of the popular algorithms have been vividly studied. Harris corner detection method is robust, and rotationally invariant. However, it is scale variant. The FAST algorithm is both rotation and scale invariant with improved execution time. But, its performance is poor in presence of noise. SIFT algorithm is rotation, scale invariant as well as more effective in presence of noise. It has highly distinctive features (sum of Eigen values after PCA). However, it suffers from illumination variation. The algorithm, SURF proves superior in terms of execution time and illumination invariance property.
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