Integrating the Traffic Images to make Composite Image with Wide Field of View using SIFT Features

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بسم الله الرحمن الرحيم

In the name of Almighty Allah,

The most Beneficent, the most Merciful

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Final Approval

This is to certify that we have read the thesis submitted by **Miss Maria Wahab,** Reg No **343-FBAS/MSCS/F07.** It is our judgment that this thesis is of sufficient standard to warrant its acceptance by International Islamic University, Islamabad for the degree of **Master of Science in Computer Science**.

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Dedication

To my late Father.

His words of inspiration and encouragement in pursuit of excellence, still linger on.

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As a Partial Fulfillment of the Requirement for the Award of the

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Declaration

I hereby declare that this research, neither in part nor in full, has been copied from any source, except where cited; hence, acknowledged. It is further declared that this research, in its entirety, is a product of my personal efforts, under the sincere guidance of my supervisor *Mr.Asim Munir*. No portion of the work being presented herein, has been submitted to any other university, institute, or seat of learning, in support to any piece of writing for bestowment of any other degree of qualification.

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Project In Brief

Project Title:	Integrating the Traffic images to make composite image with wide field of view using SIFT features
Undertaken By:	Maria Wahab
Supervised By:	Mr. Asim Munir
Tool Used:	MATLAB© 7.6
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Abstract

Image stitching is one of the important techniques in the field of computer vision. It involves taking two or more images and generates a single image having higher resolution and more information about the scene. A huge number of techniques have been proposed but some challenges are still there. This research concerns the problem of automatic image stitching mainly includes traffic images. The major challenges of image stitching process are image registration and image blending. The main focus of this research is on blending. For automatic and accurate registration of images, SIFT feature extraction and matching is done.

For blending purpose a technique is proposed which is based on pixel replacement. Compensation of pixels in the overlap region is done. So it blends the image seamlessly and deals with the ghost appearance problem. This technique is less complicated as compare to other deghosting algorithms and produces significant results. As a final point, the experimental results show that the efficiency of proposed method is more than "average weighted blending method" for traffic images (with both moving vehicles and motionless vehicles).

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Chapter 1

Introduction

1 Introduction

Image stitching is a process of combining multiple images to get a high-resolution image. The input images must have some overlap region. The reason of why one would want to stitch images is to get a single seamless image with wide field of view.

Registration and stitching of images has been a wide field of interest for several years. Initially it was done manually. The need for mosaicing increased when satellite images were sent back to earth. In recent years the stitching of images and its application has become an active area of research.

Fig 1.1 Input images with overlap region

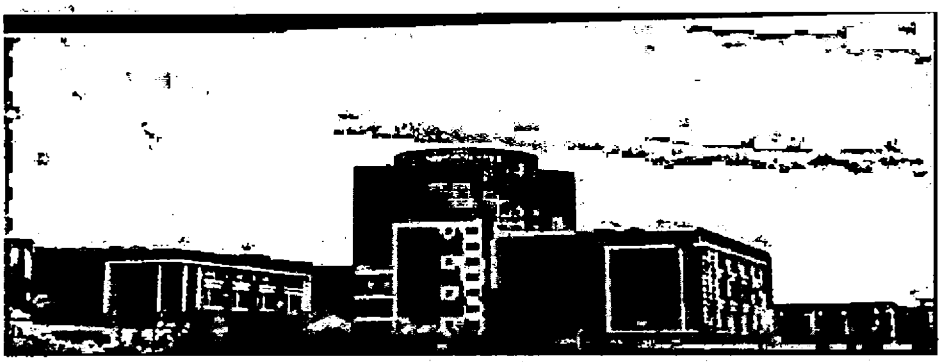


Fig 1.2 Stitched image

1.1 Motivation

The inspiration is to generate a mosaic image automatically without taking any input from user. Image matching and transformation should be robust and accurate so that the input images can be well aligned. Furthermore, the final mosaic image should be blended so well that there is no visible seam. Beside this, the problem of ghost appearance in case of moving objects in input images should be eliminated.

The image stitching process can be divided in to three main categories:

- Image acquisition
- Image registration
- Image blending

During image acquisition process images are captured carefully, in such a way that there is some overlap region in images. As overlap region, illumination differences, camera pan (rotation) etc in input images can have big impacts on resultant panorama.

Image registration is another important task in image stitching. It involves matching features and applying geometric transformation.

Image blending involves the adjustment of pixels in the overlap region that can cause seam in the mosaic. Compensation of exposure difference is done during blending.

1.2 Challenges in Image Stitching

Different techniques and models have been designed to implement this process but still there are some problems that need to be solved.

- Image acquisition, so that overlap region should be there in them.
- Registration problems may occur due to change in rotation or scale in the images.
- Due to illumination difference in input images discontinuity can occur in the final image. So in order to avoid it the overlap region should be treated carefully.
- Ghost appearance problem can occur when moving objects are there in the input images.

The whole image stitching process mostly depends on registration of images. It involves matching of the overlap regions of images and geometric transformation of them. It is very tricky step because of the involvement of rotation, translation, scale and illumination differences in input images. So error free registration is a demanding task of image stitching process.

Blending is an important task after registration. When images are being stitched they need to get blend well to make the transition region smooth.

Blending will be effected poorly due to parallax. Because of this parallax effect, image looks blurry or ghosted. Ghost appearance means anything that should not be in image plane but is there. The ghost effect can be caused by small scene motion like waving tree branches or large-scale scene motion like moving people or vehicles [1].

Fig 1.3 Stitched image with ghost appearance problem

Different techniques have been studied for image stitching process and a new method for blending is proposed. The proposed method produces better seamless and de-ghosted results, moreover it is simple and robust .Accurate results are produced as it is feature based method.

The proposed method applied on traffic images, as traffic image is a challenging task to stitch because of moving vehicles.

Rest of the thesis is organized like this.

Chapter 2 is titled as "Image stitching" in which different steps for stitching process are discussed in detail.

Chapters 3 named as "Literature survey" where different research papers are included that help in analysis of different techniques for image stitching.

Chapter 4 titled as "Research methodology", describes the proposed method in detail.

Chapter 5 describes the results of proposed method hence titled "Experimental results". Different image pairs for traffic images are used for test purpose.

Conclusions and future work are discussed in Chapter 6 titled "Conclusions and Future work".

Chapter 2

Image stitching

2 Image stitching

Image stitching is the process that merges two or more images together, which have some overlapped region, to generate a high resolution image containing more details after expanding field of view.

The field of view (FOV) of human eye is 135x200 degrees; a normal camera can give FOV of 50x35 degrees while a mosaic image can give the FOV of 360x180 degrees. So the image stitching enables us to have an image with immense field of view and with more details of the scene as the field of view is greater than both human eye and a camera.

Fig 2.1 Camera FOV

Fig 2.2 Human eye FOV

Fig 2.3 Panoramic mosaic FOV

Image stitching combines a number of images in to a composite image. The quality of stitching is expressed by measuring correspondence between adjacent images that form the composite image and the visibility of seam between stitched images.

The entire process can be expressed as:

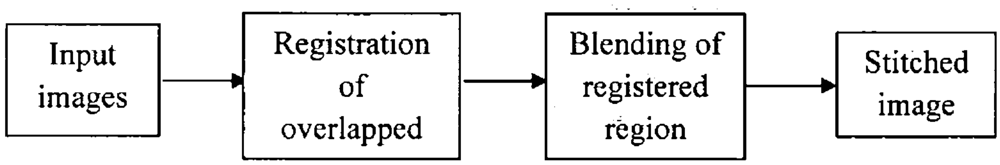


Figure 2.4 Representation of stitching process

2.1 Registration of Overlapped Region

Registration of overlapped area involves feature matching or using direct alignment method and then estimating geometric transformation between images.

Two methods for image matching are available: correlation based method and feature-based method.

2.1.1 Correlation-Based Method

This method involves pixel-to-pixel matching i-e measuring the correlation of windows from two images. It involves all the pixels of an image, grouped as a window. The template window is compared against the search region and similarity is measured.

But this method is not so reliable because vague results may occur when search region expands. Practically, this method is slow. [2]

2.1.2 Feature-Based Method

Other method for image registration is feature-based. This method involves the extraction of features and then performs matching. This method finds the correspondence between features of different images and then finds the geometric transformations. Features can be points, lines, contours etc. [1]

2.1.2.1 Introduction to SIFT Features

These are local image features and are invariant to rotation, scale, translation and illumination [3]. There are four steps in this algorithm, given below:

i. Scale-Space Extrema Detection

Image is convolved repeatedly with Gaussian filter at different scale i-e σ to produce 1st octave. Images of same size (vertical) form an octave. Any number of images in an octave is possible and any number of octaves can be obtained however it is suggested that four octaves and five images in each octave are enough to get required results [4].
The adjacent images are than subtracted to produce difference of Gaussian DOG images. Image is than down sampled by a factor of 2 to produce next octave.

- **Scale-space in SIFT**

  In order to get invariance to scale, SIFT works in scale space. Here it means to get Gaussian blurred images at different scales, than resize the original image to half and repeat the process again.

- **Scale**

  In scale space image is convolved with Gaussian operator i-e

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \quad (1)$$

Here σ is scale parameter in other words it is the amount of blur. If its value for one image is σ then it will be kσ for next image where **k** is constant. When image is convolved with Gaussian for first time, it uses value for σ as$\sigma = sqrt(2)$. [18]

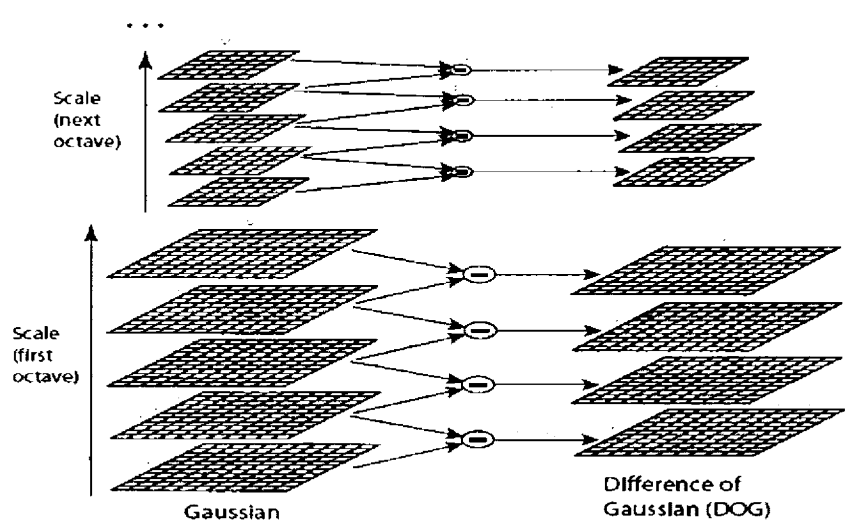


Fig 2.5 Gaussian and Difference of Gaussian images

To extract local maxima, a point is compared with its 8 neighbours at equal scale and 9 neighbours at neighbouring scale. This point will be extrema if its value is greater or less than these 26 points.

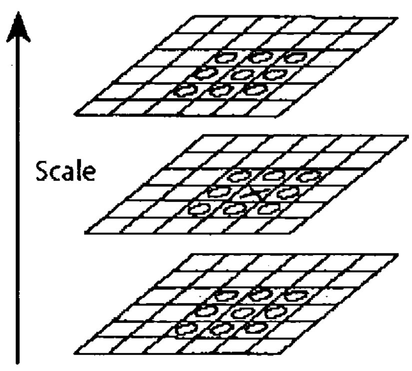


Fig 2.6 Scale-Space Extrema

ii. Key point Localization

The key point detected in above step is not exactly a pixel but is present near any pixel. So to get this sub pixel location Taylor expansion is used.

As a large number of key points are detected. In this step the points with low contrast or poorly localized on edge are rejected as they are not useful as features.

Low contrast key points are eliminated by computing intensity magnitude for each key point using Taylor expansion. If it is greater than certain value than this key point will be discarded.

Key points that are poorly localized along the edge are supposed to be rejected. So Hessian matrix is used to calculate weather the key point is at corner or not. [4]

iii. Orientation Assignment

Furthermore, gradient magnitude and direction is calculated for all pixels in neighbouring region of every key point and orientation histogram is formed. The highest peak from this histogram is assigned to create key point with that orientation. In this way invariance to rotation is achieved.

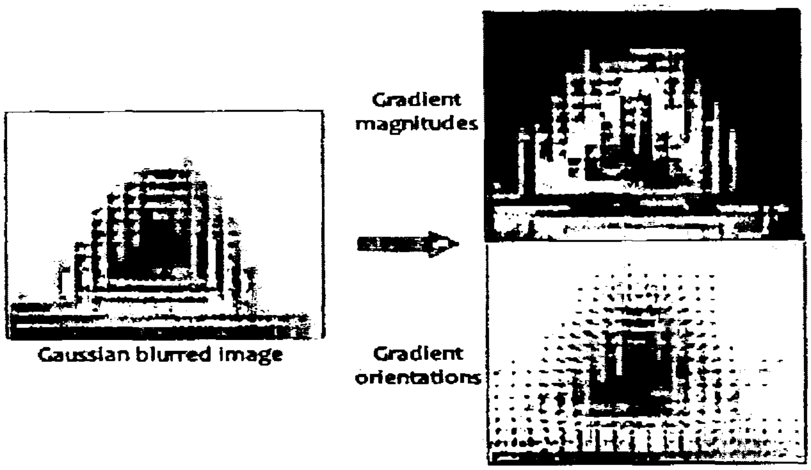


Fig 2.7 Gradient magnitude & orientation

iv. Key Point Descriptor

Descriptor provides the means for comparing image or image regions. A 16x16 window is taken around each key point and this window is further divided into sixteen 4x4 windows. Orientation Histogram is computed over 8 directions in each window. So as a result 4x4x8=128 dimension feature vector is obtained.

These key point descriptors are invariant to remaining variations like illumination, noise etc.

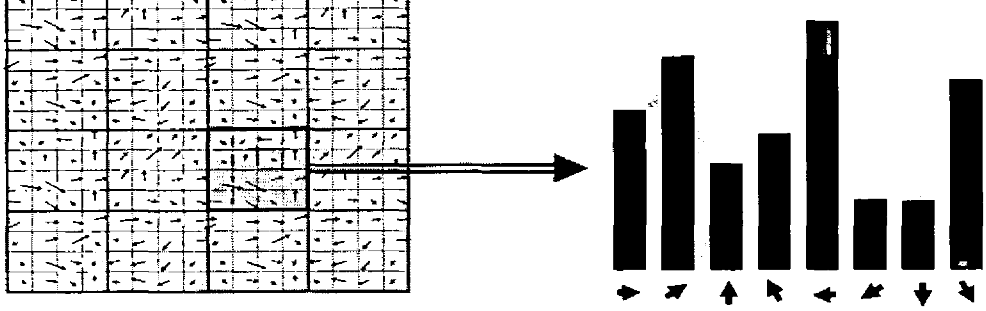


Fig 2.8 Gradient Histogram

2.1.2.2 Advantages of SIFT Features

The advantages of using SIFT features are given below

i. SIFT features are invariant to scale, rotation, translation, zoom and partially invariant to illumination difference.
ii. These features allow correct object recognition as they give low probability of mismatch.
iii. The extraction is fast so can be used for real time applications.
iv. These features can be used in applications like object recognition, image stitching, gesture recognition, video tracking and many more.

2.1.3 Feature Matching

After feature extraction, next step is feature matching. Features are matched from all images in order to get corresponding features. Different algorithms can be used for feature matching.

Simple method is to take features from one image and compare the Euclidean distance of these features with all other image's features, but it is somewhat complicated. Some other algorithms can be used that are based on nearest neighbour search or binary search like kd-tree, best bin first (BBF) etc. [1]

2.1.4 Geometric Transformation

For geometric transformation, motion parameters are estimated after feature matching. This is because we need to develop mathematical relationship that maps pixel coordinates from one image to other. The geometric transformation describes camera motion while capturing two images. Many of the motion parameters are there e.g. affine, similarity, translation, projective transformation etc.

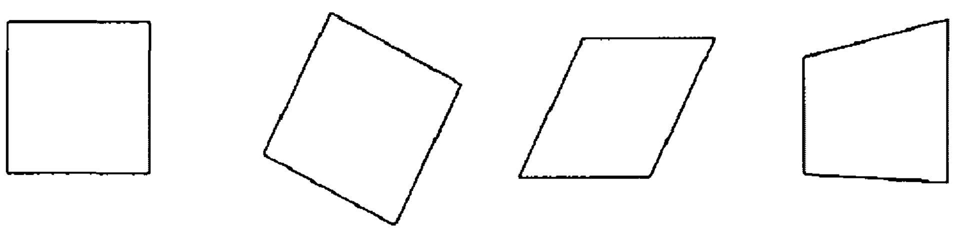


Fig 2.9 Rigid, Affine, Projective Transformations

2.1.4.1 Rigid Transformation

It includes rotation and translation. This transformation preserves the distances between every pair of points e-g if u and v are two points that transformed to $u'$and v', the distance from u' to v' should remain the same as it is from u to v.

It preserves angle between the points also. All rigid transformations are affine transformations. [5]

2.1.4.2 Affine Transformation

It is the transformation which preserves straight lines means the points lying on the line will still lay there after transformation. Translation, rotation and similarity transformations are all affme transformations.

2.1.4.3 Projective Transformation

This transformation maps a point from one image plane to other image plane. It is also called Homography and it operates on homogeneous coordinates. Affine transformations are the subset of projective transformation. Straight lines remain straight under this transformation.

If $x = (u, v,1)^T$ are the homogeneous coordinates of one image and $x' = (u', v', 1)^T$ are the homogeneous coordinates of other image then projective transformation will be

$$x = Hx' \tag{2}$$

$$H=\begin{bmatrix} h_0 & h_1 & h_2 \\ h_3 & h_4 & h_5 \\ h_6 & h_7 & h_8 \end{bmatrix} \tag{3}$$

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} h_0 & h_1 & h_2 \\ h_3 & h_4 & h_5 \\ h_6 & h_7 & h_8 \end{bmatrix} X \begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} \tag{4}$$

Where, H is the 3x3 Homography matrix. To determine the Homography matrix we require four pairs of corresponding points. When it is applied to every pixel, the new image will be the warped image of original image.

After correct estimation of Homography matrix, projective transformation could be like this:

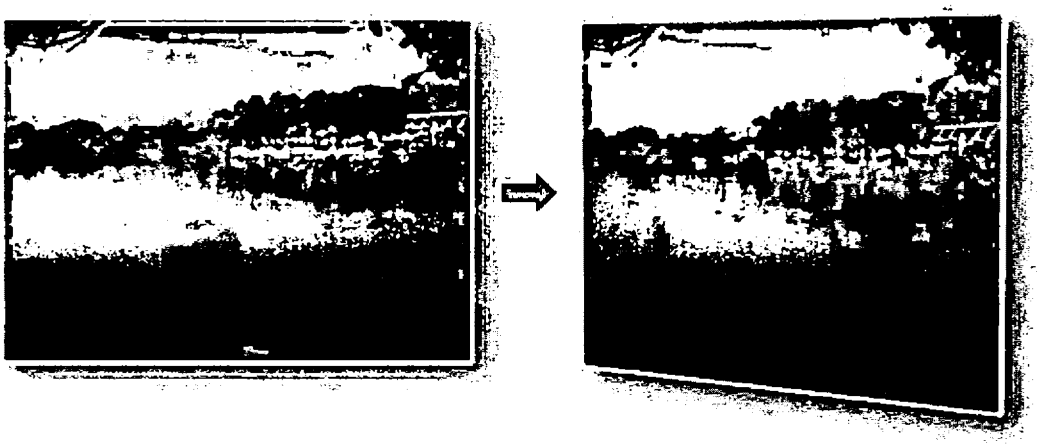


Fig 2.10 Transformation after Homography

Final projection will be probably like the image given as:

Fig 2.11 Final projection

2.1.5 RANSAC (RANdom SAmple Consenses)

RANSAC is an algorithm that selects inliers from the set of observed data that contains outliers also. Here inliers are the data that fits to a certain model and outliers doesn't fit to a certain model. It is an iterative method which produces results with certain probability, and probability depends on number of iterations performed.

While using RANSAC for feature based image stitching we can find the transformation that best transforms the points in the first image to the points in the second image.

Four features are randomly selected from 1st image. Then Homography is calculated on their basis. Remaining features are transformed with Homography. The transformed features are then compared with the matching features of 2nd image to remove outliers. This process will continue until the removal of outliers keeping largest set of inliers.

2.2 Blending of Registered Region

This is a very important step after registration as it gives a final look to mosaic .After the images are stitched, they need to be blended so that stitching become seamless.
Seam is an abrupt change in an image that can occur due to illumination change or due to registration errors in the images. Different methods can be used for blending purpose like Feathering, Pyramid image blending, Average weighted method etc.

Chapter 3

Literature Survey

3 Literature Survey

A number of published research papers were studied and an analysis of some relevant research is given below.

3.1 An implementation on recognizing panoramas [6]

SIFT features are extracted from two images by using Lowe's method. Feature matching is done by using the same method. Homography matrix is calculated to make them stitch. To get strong Homography matrix between two images RANSAC algorithm is applied. RANSAC algorithm will produce best matches i-e inliers and outliers will be removed.

After Homography matrix calculation images are ready to be stitched together. First transform the image using this Homography matrix through *imtransform* function. A mask is applied on overlap area for image blending.

Cansin Yildiz gave some interesting results regarding RANSAC algorithm through observation. According to him if too small or too high threshold value is used, than there are good chances to get best four matches. Means there should be a single proper threshold value and based on the empirical observation, this proper threshold value is 1.

The number of times RANSAC run doesn't affect the result. If it doesn't produce four best matches at 1.000 loops than it can't produce best matches at 100 loops also.

Limitation:

This implementation give remarkable results on two image stitching, but cannot work for wide panoramas because of linear behavior of Homography matrix.

Fig 3.1 Resultant image

3.2 An algorithm for image stitching and blending [7]

In this paper Rankov et al. proposes an image stitching method applied on microscopy imaging for clinical studies. The algorithm is automated and is based on cross correlation.
Image matching is done by sliding the image over the composite image and gets the proper point of correlation when equal dimensional images are to be stitched. Extract a strip from one image and correlate it with other image.0 to 1 value can be obtained from correlation and 1 will be the appropriate correlation.

In order to make image seamless, gradient blending method is applied. This algorithm determines the contribution of new image and composite image at every pixel in overlap region. A lookup table is created which has the information about the share of intensities of overlap regions; this information is a weighting factor at each pixel. A mask is created for overlapped image, where weighting (α) is the distance from image edge.
Blended image pixels:

$$N(x,y) = \alpha I(x,y) + (1-\alpha)C(x,y) \quad (5)$$

Where
$C(x,y)$=composite image pixels (before placing new), $I(x,y)$=new image pixel
$N(x,y)$=new composite image

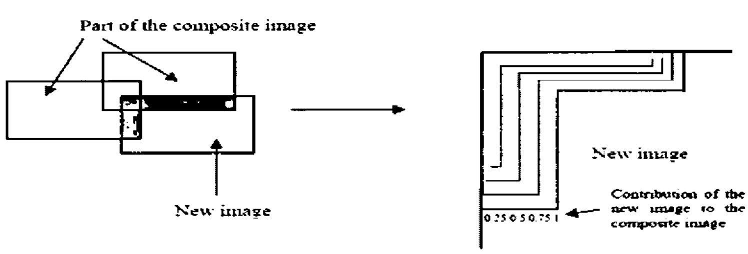


Fig 3.2 Blending intensities of overlapping images

This approach is applied on RGB, 16 bit and 8 bit grayscale images. For RGB images blending algorithm is applied on three bands.

Limitations:

This method is applied only on microscopy images so don't give surety of its application on other types of images. And this method searches the whole image to get best correlation point, so is slow.

3.3 The implementation of an image stitching algorithm based on feature extraction [8]

The method proposed in this paper is based on feature extraction. A new method is proposed by Zhuang et al. for image stitching that combines feature extraction and edge detection. Image edge detection is done by using edge detection algorithm based on canny operator. After edge detection, get the edge points and record their coordinates. Singular points are detected and are used to match images by singular point location. The matching location is than separated in to rough match and exact match. Rough match will find out the corresponding features and exact match will find out the exact overlap location.

For rough match determination, the distance between randomly chosen feature points is calculated by use of threshold. Transform the images and for exact match determination, the area around that particular point is searched because this area is supposed to have the exact match point. A search window is created around the feature points in both images and correlation is calculated to get the overlap region. This overlap area will be used to stitch image.
Final step is the restoration of stitched image from original and gradual integration is made to get the smooth transition of edges.

Advantages:

According to author this method will reduce the redundancies in feature points and hence reduce complexity. It improves the efficiency of algorithm by edge detection and feature point combination.

Limitations:

It requires improvements for complex images due to noise and edge similarities during detection. No method is given to treat ghost appearance problem.

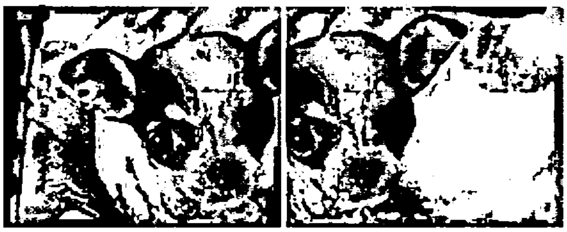


Fig 3.3 Experimental images

Fig 3.4 Edge detection

Fig 3.5 Edge stitching

Fig 3.6 Result of Image stitching

3.4 Automatic panorama stitching using invariant features [9]

In this method Brown et al. has formulated stitching as a multi-image matching problem and used invariant local features to find matches between all of the images. This method is insensitive to ordering, orientation, scale, illumination and noise of input images.

The methods for automatic image alignment and stitching have two broad categories:

1. Direct 2.Feature based

For automatic panorama stitching, invariant feature based approach is used because it enables reliable matching of panoramic image sequences despite rotation, zoom and illumination changes.

The basic step in panoramic recognition is to extract and match SIFT features from all of the images. By assuming the rotation of camera about its optical centre, pair wise Homography is obtained.

$$\tilde{u}_i = H_{ij}\tilde{u}_j \quad (6)$$

Images with large number of matches between them will be identified.After extracting the features from n images they will be matched. Each feature is matched to its k nearest neighbours in feature space.

Next step is to find all matching (i-e overlapped) images. Each image can match every other one, so it is necessary to match each image with smaller number of images.

RANSAC (random sample consensus) is an estimation procedure that uses a minimal set of randomly sampled correspondences to estimate image transformation parameters and finds the solution that has best consensus with the data. In this technique a set of feature correspondence is selected and Homography H is computed between them using direct linear transformation (DLT) method. It is repeated with a number of trials and a solution that has maximum number of inliers is selected.

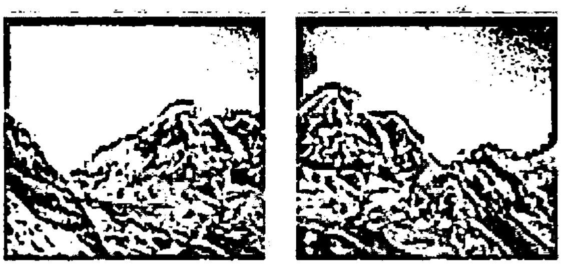


Fig 3.7 original images

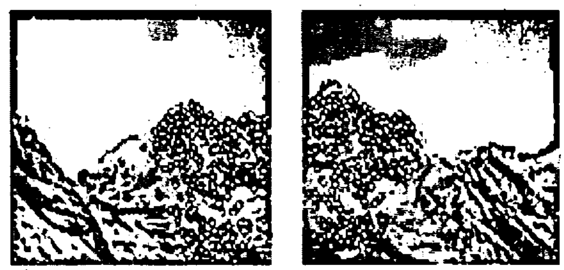


Fig 3.8 SIFT matches

Fig 3.9 Images aligned according to Homography

After that the probabilistic model for image match verification is applied to compare the probabilities that this set of inliers/outliers was generated by correct image match or by false image match. Bundle adjustment is performed for images alignment which optimises the parameters of camera.

To solve for photometric parameter namely gain between images, the error function is defined over all images which is the sum of gain normalised intensity errors for all overlapping pixels.

After gain compensation some image edges are visible. So, multi-band blending algorithm is used to blend low frequencies over a large spatial range and high frequencies over a short range yields seamless panorama.

Advantages:

This method gives automatic image stitching despite of rotation, translation and zoom.

Limitation:

No method is given to identify the moving objects in the scene.

3.5 An algorithm for seamless image stitching and its application [10]

A four step algorithm based on SIFT features is a new approach proposed by Xing et al. to eliminate the seam between adjacent images. The preliminary step is feature matching. To extract SIFT features algorithm applies a four-stage filtering approach

1. Scale-space extremum detection
2. Key point localization
3. Orientation assignment
4. Key point descriptor

Homography calculation is the following step. H is a 3x3 matrix and to calculate H Direct Linearity Transformation (DLT) is used and four pairs' interest points from image 2 to image 1 are required.3rd step is image stitching. The coordinates of image 2 are recorded after transformation and stitch two images directly. This method can avoid unnecessary calculation.

To eliminate the seam of the stitched image a method is given in the paper which doesn't need the camera parameters and can detect seam correctly. It processes the transition region. The transition region is computed and gives a weight function to make stitched image smooth. The weight function is applied on the transition region to eliminate the seam. Weight function can be denoted as the following formula:

$$S = \left(1 - w(x)\right) * I1(x, y) + w(x) * I2(x, y) \quad (7)$$

$$w(x) = \sin(x * \pi/(2 * d)) \quad (8)$$

The images after stitching using the method based on SIFT features with obvious seam and seam elimination results are shown in the figures.

Limitation:

This method produce ghost appearance problem when there is moving object in the overlap region of input images.

Fig 3.10 original images

Fig 3.11 stitching result with seam

Fig 3.12 after smoothing the transition

3.6 Automatic image stitching using SIFT [11]

This method is proposed by Yangfang et al. for image stitching and is based on invariant features to fully automatic stitching. The method can be applied to image sequences including noisy (non-related) images.

The entire algorithm can be described as:

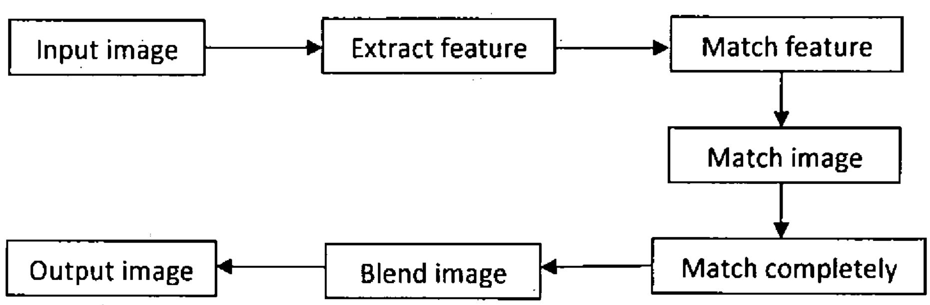


Fig 3.13 Stitching algorithm

After extracting the SIFT features, features are matched by building a K-D tree to find k nearest neighbours. Based on feature matches, a modified RANSAC is described to match further.

From RANSAC, set of inliers features can be found. Than to compare, the probabilities of inliers or outliers are generated by correct or false image match, probabilistic model is used. In this way the matching relationship between the images can be verified and also the interfere images (that doesn't belong to panorama images) will be rejected.

The key problem is to eliminate the accumulated error between the images, so bundle adjustment is used.

After implementing the above steps stitched image is produced, which has obvious seam in overlapping region. So average weighed method is applied which is simple and fast for blending.

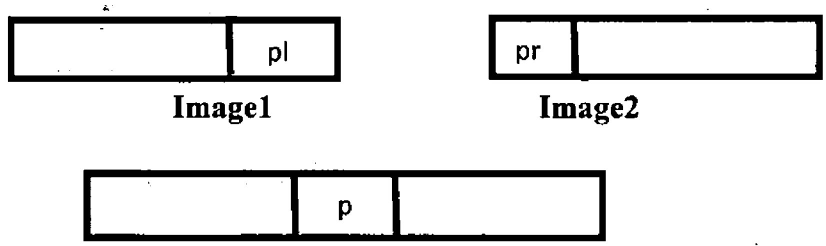


Fig 3.14 Blending the overlap region

In the average weighted blending, the values of features in overlap region are equal to the weighted average values of matching images. This is given below;

$$p = \frac{dl}{dl+dr} pl + \frac{dr}{dl+dr} pr \qquad (9)$$

So it ensures smooth translation between the overlap regions.

Limitations:

This technique also has some deficiencies like noise can appear in low contrast images and ghost appearance problem is not solved also.

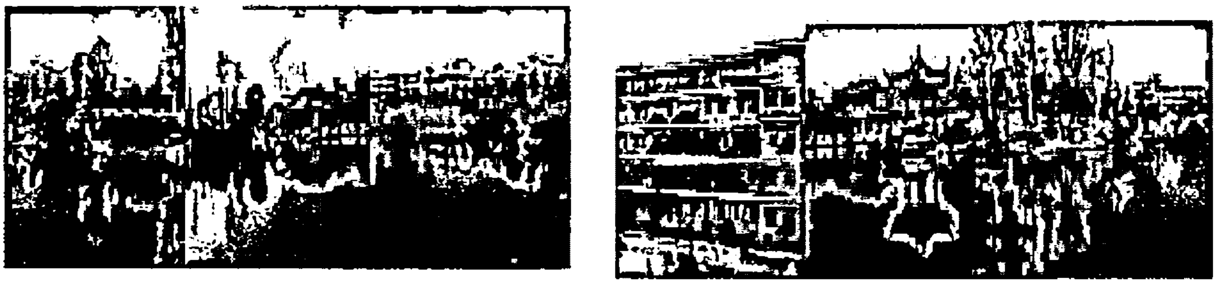


Fig 3.15 Image sequences including noisy image

Fig 3.16 Output panorama image

3.7 Image stitching of scenes with large misregistration [12]

In this paper Zheng et al. gave a technique to automatically stitch images with large mismatch contents. SIFT features are extracted and corresponding features are taken by comparing Euclidean distance. RANSAC algorithm is used to get inliers and projective matrix is calculated for transformation. Than Homography matrix is computed again by using correct matches through least square method to get correctly aligned image.

A mask blending method is proposed to blend the overlap region. Salient features are taken based on SUSAN (Smallest Univalue Segment Assimilating Nucleus) operator. It will place a circular mask around each pixel and the brightness of pixels within the mask is compared with central pixel. Than features are taken based on size, centroid and axis of symmetry of this area. Upper and lower bounds for the features made fixed, if the features get beyond the bounds threshold and radius got set and in this way averagely spread features are taken. Locations extracted are representing the change in view.

Features from overlap region are added, the region that contains more feature responses is top layer. Than a weight mask is applied to this top layer for blending. Its weight remains same at center and drops slowly to the edge of other layer.

Stitching results are compared with Panorama maker4 (commercial software) and the results are better with highly misregisterd images.

Limitation:

Moving objects in the images are not treated in this methodology.

Fig 3.17 Input images with large misalignment and matched features

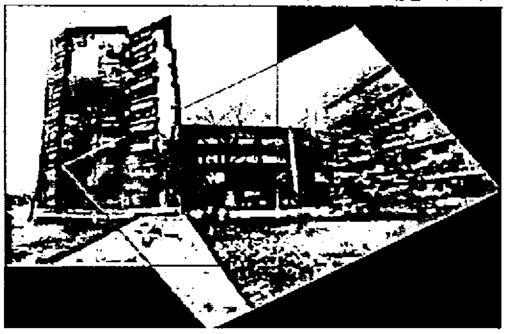


Fig 3.18 Corrected layout computed by best Perspective matrix

3.8 A Global Optimized Registration Algorithm for Image Stitching [13]

Overall steps for image stitching are described in this paper by Yong et al. are image sequencing, genetic searching, image registration and image fusion. Genetic algorithm will search for corresponding image blocks. It is effective because it is used to find maximum and minimum of some function.

The essential elements of this algorithm are chromosome representation, fitness function and genetic operators. Image registration is done using genetic algorithm. Chromosome is taken, which is the binary representation of image coordinates that consist of four parts, C= $[x_{11} \ldots\ldots x_{1m}, y_{11} \ldots . y_{1n}, x_{21} \ldots\ldots x_{2p}, y_{21} \ldots . y_{2p}]$, (m, n, p, q) is the number of genes. Than fitness function is computed which will calculate the measure of similarity. Fitness function will decide if an individual is good enough to survive and have a chance to multiply it in next generation .By using random sampling method, population is selected and fitness function computed. Crossing and mutation is done, as a result new observed region would be produced. These steps are iterated for many generations until satisfactory result found.

After registration for fusion fade in-out blending image fusion approach is designed to deal with surrounding light difference.

Advantages:

By using genetic algorithm, no need for yaw, pitch or roll angle adjustment but optimization is still needed. The experimental resulting images are seamless and give impression of very high resolution. So, genetic algorithm is able to solve image registration optimization problem. It will give more accurate result when more generations are produced.

Limitations:

In terms of orientation matching, accuracy and rotation improvements are needed. This technique doesn't work well if there is a moving object in overlap region of input images because ghost appearance problem can occur.

3.9 Automatic panorama image mosaic and ghost elimination [14]

This paper presented an automatic method for image stitching. For registration of images Yanli et.al used phase correlation method. Furthermore to get the robust registration of images median flow filters and modified RANSAC algorithm is used. Outliers are removed and Homography matrix is estimated to get images transformed. Bundle adjustment is used to eliminate the accumulated errors in the images. Weighted method is used to smooth the seam in stitched image.

$$I = w * I1(x,y) + (1-w) * I2(x,y) \quad (10)$$

$$w = \cos(\pi(x - x_{min}/(2x_{max} - x_{min})) \quad (11)$$

Where x_{max} and x_{min} are coordinates of overlap region.For de-ghosting purpose it will compute the position of moving object in overlap region. If it is nearer to the right bound than the region from left image up to that moving object will be taken as blending region and vice versa.

Limitations:

This method is not fully accurate as it uses the phase correlation for registration purpose.

Correlation process is not invariant to scale, translation and rotation as compare to feature based method. The method is complex in a sense that it will first compute the position of moving object and then eliminate the ghost.

3.10 Feature based image mosaicing [15]

The technique proposed by Mallick for image stitching in this paper is feature based and features are Harris corners. Harris corner detector is used to extract the corners and their corresponding matches are found through correlation. A relaxation based algorithm is used to find exact correspondence, based on the idea that a match is exact if other matches also exist in the neighborhood of that match.

Homography is estimated using RANSAC algorithm. Than non-linear Newton's method is used to refine the Homography estimation. For blending purpose difference of overlapping region is taken and this overlap region is divided in to two parts by drawing a curve. This curve is drawn along light intensity and a weight is applied to the pixels in this region, this result in to a seamless image. All this blending is done through dynamic programming.

Limitations:

This method doesn't show good results when applied on the stitching of more than four images. If there are moving objects in the scenes they will not recognize and will cause ghost to appear.

Fig 3.19 Resultant mosaic

3.11 A method for generation of panoramic view based on images acquired by a moving camera [16]

This technique is proposed by Sangle at al. he input images are captured by using rotation method i-e rotating the camera around its axis while its optical center is fixed. In order to align images SIFT features are extracted from all images and are matched. Features are matched using distance ratio method i-e the ratio of Euclidean distance of the neighboring features should be less than a threshold value. Image transformation is estimated by Homography matrix. Reference image is taken and other image is aligned according to this image.

Results are taken by applying SIFT algorithm on the images with size it has already.

Limitations:

This technique gives good results but is appropriate when the exposure difference between the images is very slight because no proper blending is used in this method. If moving object appear than there is no way to avoid ghost appearance.

Fig 3.20 Result of blending multiple images

3.12 Pipelines for image matching and recognition [17]

In this paper Simon describe various methods to make use of interest points for image matching and recognition. Interest points are the points that can be located across multiple views and these can be edges, corners, blob-like regions etc. Different interest point detection algorithms are available. An important thing one should consider about interest points is that they should be invariant to translation, rotation, scaling and affine deformation.

After interest point's detection, their matching is done. It means that the region around the interest point in both images should be same. So to get the local appearance, image descriptors are computed at each interest points. When interest points are to be matched, the descriptors are compared. In this way scale and orientation scalability is achieved. Pair-wise descriptors scale distance is compared between two images to get the match.

After getting the match points, the threshold method can be used to accept the best matches but in practice it doesn't give good results. So ratio test algorithm can be used to skip the outliers.

Matching interest point is time consuming so kd-trees can be used.Kd-tree is a data structure that can hold descriptors from an image and returns kth nearest neighbor and approximate nearest neighbor search is done to confirm whether it is the best match. For matching kd-tree is fast.

For geometric matching like affine, similarity or perspective matching, some approaches are there. For this purpose some set of parameters are computed. RANSAC algorithm can be used to compute transformation parameter matrix from matched points. It takes randomly a set of points and then computes the transformation, validate the transformation and record the best one.

The use of Bayesian statistics is an improvement in RANSAC algorithm. In some applications the transformation matrix calculated by RANSAC gives satisfactory results but in some applications it needs other algorithms to work with like Levenberg-Marquardt algorithm etc.

For recognition purpose descriptors can be used. Instead of kd-tree, bag of words approach may be used in which descriptors are divided in to domain and each one is given an index. So when a descriptor is computed it is mapped on to belonging index number. To divide the descriptor vector k-means clustering approach can be used.

To match these descriptors to millions of images in data base, inverted indexing method can be used. Locality sensitive hashing and min-hash techniques are good approaches to find nearest neighbors. For geometric verification of images i-e weather they are geometrically consistent or not, RANSAC algorithm will be used because bag of words approach doesn't have any information about the arrangement of points. So similarity, affine or projective transformations can be computed using this algorithm.

3.13 Problem Identification

Ordinary images have limited field of view, while in some cases there is a need to get a broad field of view that contains more information. So, multiple images are taken to make a composite image. Like in surveillance systems or for systems where counting the number of vehicles is necessary, there is a need to stitch the traffic images to get a comprehensive view of traffic.

But after stitching the resultant mosaic is exposed with a seam due to intensity differences in two images. To get rid of the seam a proper blending method is needed. Moreover ghost appearance is a serious problem that occurs when there are moving objects in the input images.

Stitching has been complicated on traffic images due to their nature in terms of more area, resolution and ghost appearance (in case of moving vehicles). So it is a demanding task to stitch the traffic images to get a well blended and de-ghosted mosaic.

Chapter 4

Research Methodology

4 Research Methodology

The proposed technique is divided in to two major tasks, image registration and image blending. Many approaches are used for image stitching process including feature based and direct methods. Feature based method is more efficient because it works on features only. Hence it is less complicated than direct methods. The proposed technique is also feature based.

RANSAC has been used to get rid of outliers and for accurate Homography matrix estimation. Transformed images are then stitched [9].

For blending purpose new technique is proposed. The proposed technique will make resultant image seamless as well as will eliminate the ghost appearance Ghost is problems that occur when there are moving objects in images. This technique is simple as compare to traditional methods because those methods involve searching of moving objects in the overlap area and then eliminate the ghost. Unlike this complicated method, proposed method applies pixel replacement that not only minimizes the seam but eliminates the ghost. The description of proposed method is given below in image blending step.

4.1 Steps of Proposed Technique

Following steps has been followed to do the entire stitching procedure:

1. Image Acquisition

Data set is taken from net and some images are taken with a digital hand held camera. We capture 1st image, than panned the camera with a certain angle and capture 2nd image, in such a way that there should be some overlap region in both images. These images are taken as input images.

2. Image Registration

i. SIFT Feature Extraction

For registration of overlapped region in images, features are extracted and matched. We extracted SIFT features from the images because SIFT features are invariant to image rotation, translation and scale. [18]

Following steps are included.

- **Scale space extrema detection**

  The image is repeatedly convolved with the Guassian and differences of gaussian images (DoG) are taken.

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \quad (12)$$

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma) \quad (13)$$

  Where, $G(x, y, \sigma)$ is Gaussian, and $I(x, y)$ is input image. From these DoG images extremun are taken by comparing it with its 26 neighbours, at equal scale and neighbouring scale.

- **Key point localization**

  Points with low contrast or poorly localized along edge are discarded in this step. If the magnitude of the intensity of a key point in DoG image is less than 0.03 it is rejected. To get this Taylor Expansion is used.

$$D(x) = D + \frac{\partial D^T}{\partial x} x + \frac{1}{2} x^T \frac{\partial^2 D}{\partial x^2} x \quad (14)$$

- **Orientation assignment**

  Gradient magnitude and orientations are computed for all pixels around keypoint as:

$$m(x, y) = \sqrt{(L(x+1, y) - L(x-1, y))^2 + (L(x, y) + 1) - L(x, y-1)^2} \quad (15)$$

$$\theta(x, y) = \tan^{-1}((L(x, y+1) - L(x, y-1))/(L(x+1, y) - L(x-1, y))) \quad (16)$$

  An orientation Histogram is created and the highest peak is assigned to that keypoint. In this way rotation invariance is achieved.

- **Keypoint descriptor**

  The gradient magnitude and orientation is used to get descriptors. A 16x16 window is taken around each keypoint which is further divided in to 4x4. The 8 bin orientation histogram is created. The gradients are at the scale of keypoint and orientations are related to keypoint direction. The entries of all histograms are put in descriptor vector. So 4x4x8=128 elements are generated to form descriptor vector.

ii. Feature Matching

Key points with minimum Euclidean distance are considered as nearest neighbors. Then ratio of distance from the closest neighbor to the distance of second closest neighbor is taken, to get the correct match.

$$\frac{d_{1st-nearest}}{d_{2nd-nearest}} < threshold \tag{17}$$

The matches with distance ratio less than threshold are taken otherwise discarded. Threshold is 0.8, so only to keep matches with distance ratio less than 0.8. [18]

iii. Homography estimation via RANSAC

Homography matrix is computed using RANSAC algorithm to transform the coordinates of image according to second image. [4]

Homography matrix is a transformation matrix between two images;

$$p_b = H_{ab} p_a \tag{18}$$

Where, p_a and p_b are the points from imageA and imageB, respectively.

RANSAC loop works as follows:

i. Select four feature pairs randomly
ii. Compute Homography (H) ,using Direct Linear Transformation
iii. Compute inliers
iv. Repeat step 1

In this way it will keep largest set of inliers and remove the outliers. So transformation matrix can be calculated by using them.

iv. Transforming the Points

Homography is recomputed on all of the inliers. MATLAB function is used to transform points using Homography. Than image is transformed using `imtransform(im,tform)`. In this way first image is transformed with respect to Homography matrix and then is stitched to other image.

3. Image Stitching

After images are transformed, they got merged. So in this way first image will warp at the top of second image according to Homography matrix.

4. Image blending

i. Selection of overlap region

The overlap region in the stitched image is exposed with more brightness than the left and right region of the image because it contains the information from both images. So, in order to solve this brightness issue, this region first needs to be identified. To get the overlap region minimum of two transformed images is taken.

$$overlap = \min\,(transformed\ imageA, transformed\ imageB) \qquad (19)$$

By selecting the minimum intensity values from same location from both transformed images, overlap region is taken.

ii. Pixel replacement

When overlap region is extracted, the four corner coordinates of the extracted overlap region are taken, and with the help of these coordinates the corresponding region from imageA is taken.

Then the pixels of the overlap region of the stitched image are replaced with the pixels from imageA. As shown in fig 4.1.

$$\sum_{i=r}^{s}\sum_{j=t}^{u} Stitched(i,j) = \sum_{i=r}^{s}\sum_{j=t}^{u} overlapA(i,j) \quad (20)$$

Where $Stitched(i,j)$ is the image obtained after stitching and $overlapA(i,j)$ are the pixels from overlap region of imageA. And r, s, t, u represents overlap region of the stitched image and the same region extracted from imageA.

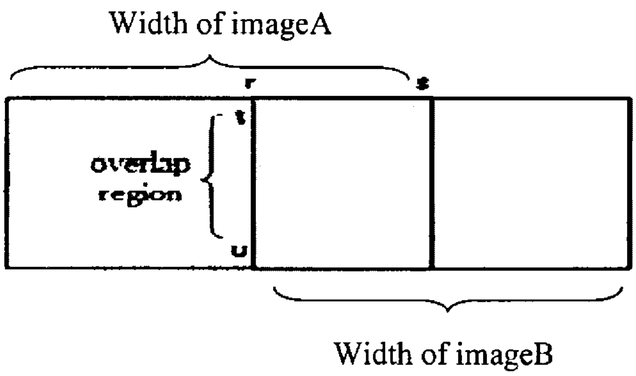


Fig 4.1 Stitched image with overlap region

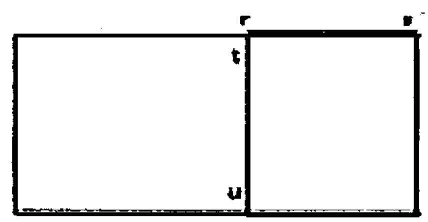


Fig 4.2 imageA with overlap region

Normally the overlap region contains pixels from both images, which is the cause for the ghost appearance problem and blurring. By selecting pixels from one image the overlap region will have the pixels from only one of the images, that helps in removal of ghost effect and thus brightness of overlap region is also compensated. So, this results in to a seamless and de-ghosted mosaic.

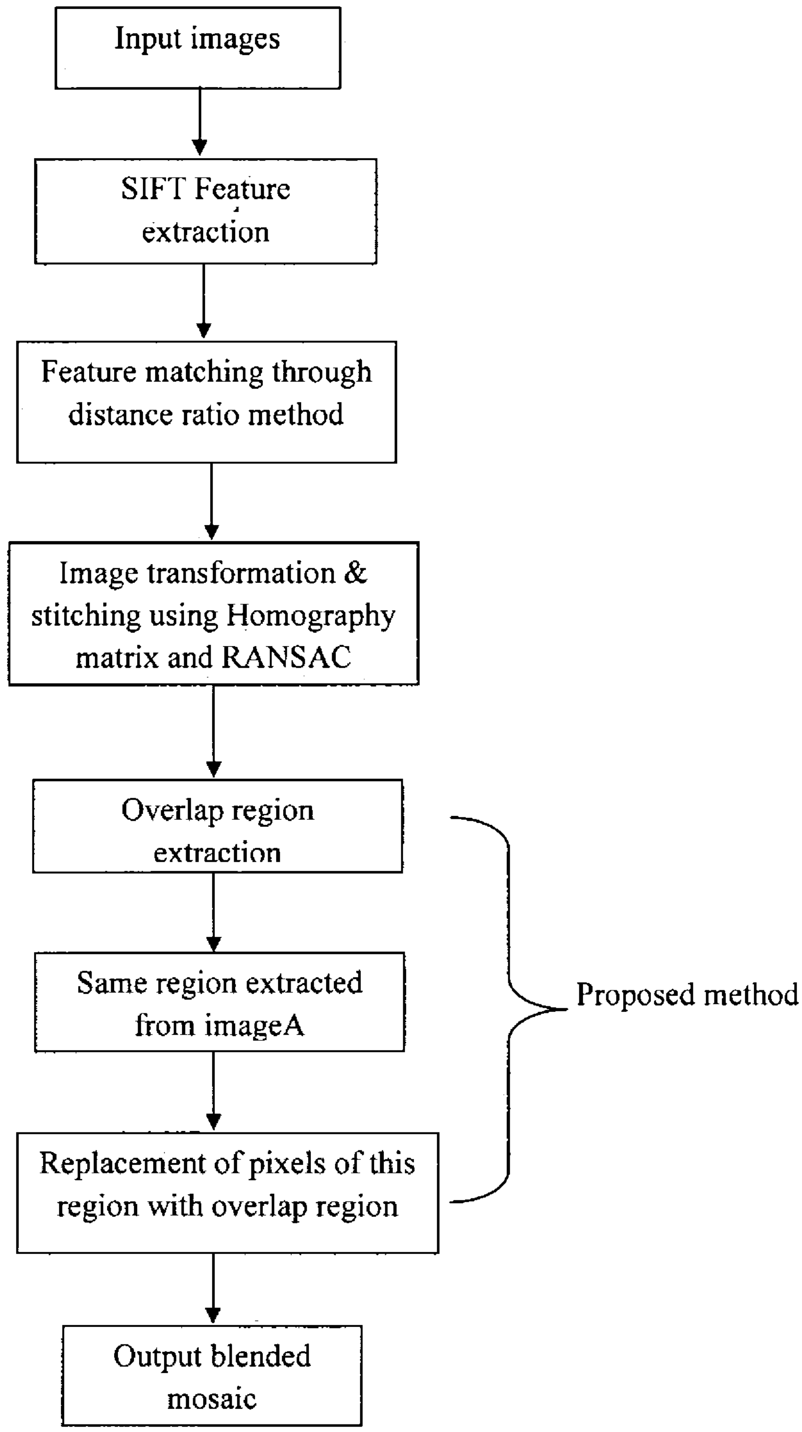


Fig 4.3 Block Diagram of Proposed Technique

Chapter 5

Experimental Results

5 Experimental Results

For experimental results different images are taken specifically Traffic images. Two pair of images are taken from web and rest are captured by using hand held digital camera (SONY).

Traffic images with moving vehicles and still vehicles are used for experiment. We have selected standard pair of images and then by using the method given in chapter4 following observations are found.

Example 1

5.1 Input images

The input images has overlap region. Size of both images is 892x592 .

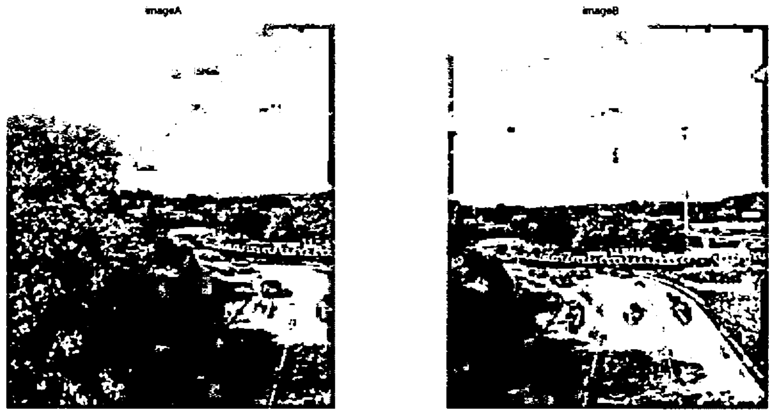


Fig 5.1 Input images, imageA & imageB

5.2 SIFT feature extraction

SIFT features are extracted from both images. 2185 and 1838 keypoints are found from imageA and imageB respectively.

A result of feature extraction is shown:

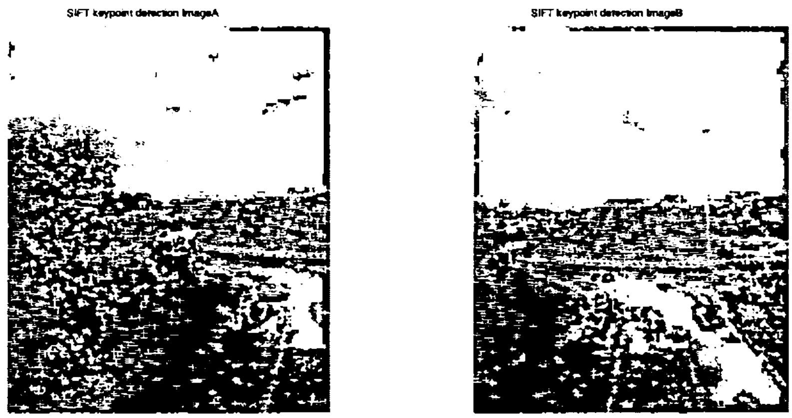


Fig 5.2 SIFT features extracted (from imageA & imageB)

5.3 Image matching

Features from both images are matched using distance ratio method. But some outliers will remain there.393 match points are found from both images.

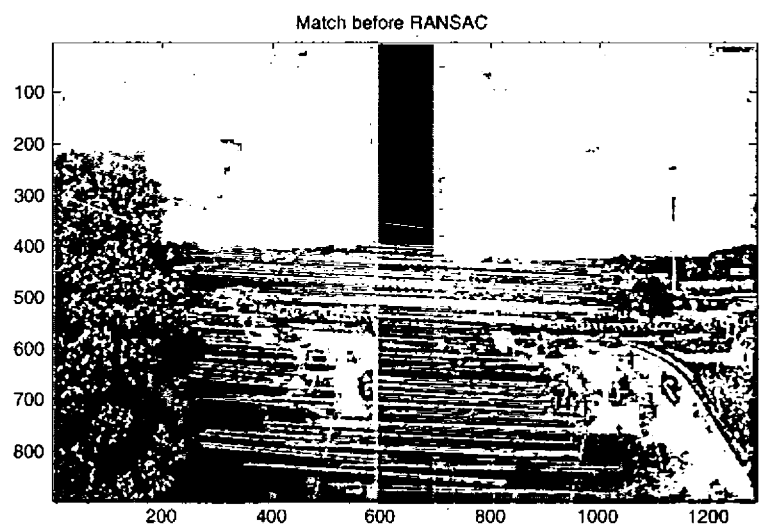


Fig 5.3 Feature matches before RANSAC

By using RANSAC (RANdom SAmple Consensus) algorithm the outliers are removed and a set of inliers can get.341 match points are found after RANSAC algorithm.

The inliers can be seen in the figure given.

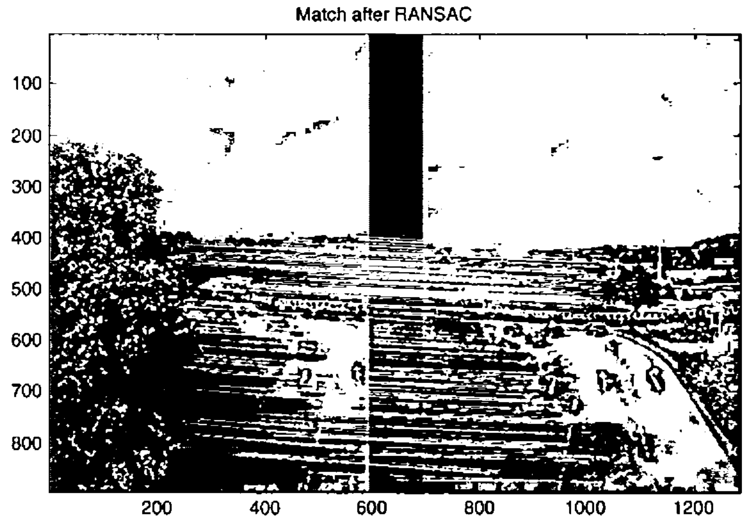


Fig 5.4 Feature matches after RANSAC

5.4 Image transformation

By using Homography matrix, transformation of imageB is done according to the coordinates of imageA. So the images are ready to get stitch.

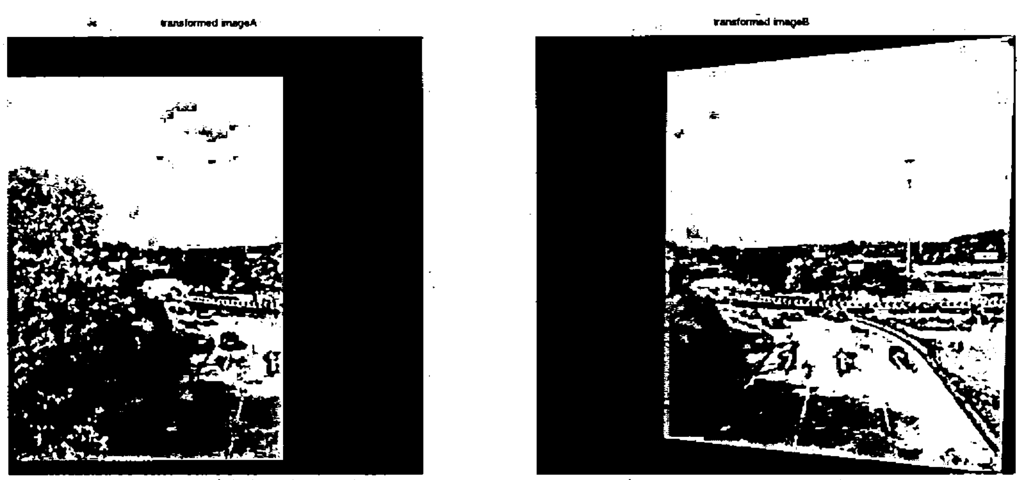


Fig 5.5 ImageB is transformed using Homography

After transformation both images are stitched and after stitching the resulting image has brighter overlap region. So it needs further processing.

Fig 5.6 Mosaic before blending

5.5 Image blending through proposed technique

After image is being stitched, it has obvious seam as shown in the figure below. For elimination of seam some blending technique can be used.

- The overlap region from stitched image is extracted.

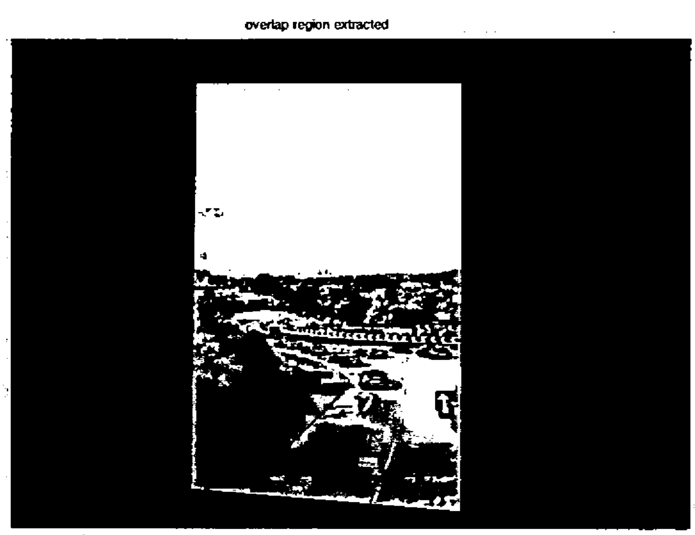


Fig 5.7 overlap region from stitched image

The same region is than extracted from imageA.

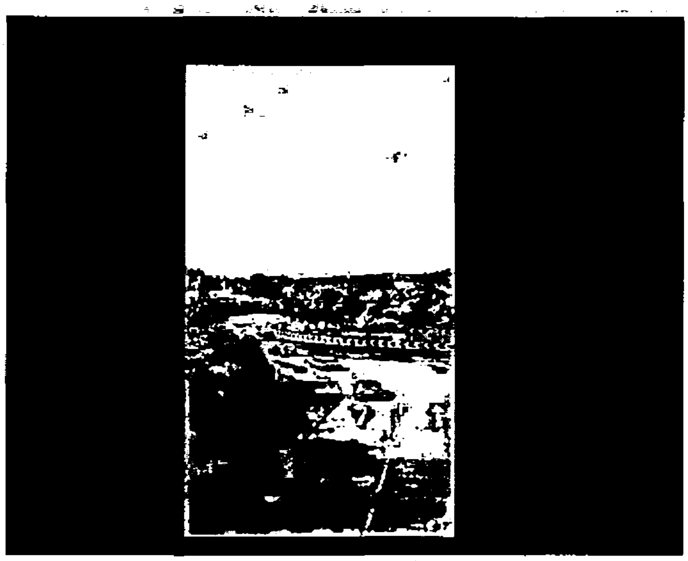


Fig 5.8 overlap region from imageA

Blending is done through pixel replacement i-e replacing the pixels of overlap poertion of mosaic with the pixels of imageA, which results in a seamless and de-ghosted image.the size of resultant mosaic is 1024x897.

Fig 5.9 Mosaic by proposed technique

5.6 Image blending through average weighted blending method

The blending is done using average blending method [11] .According to this method values in the overlap region are equal to the weighted average values of images.

And the result of this method is shown below:

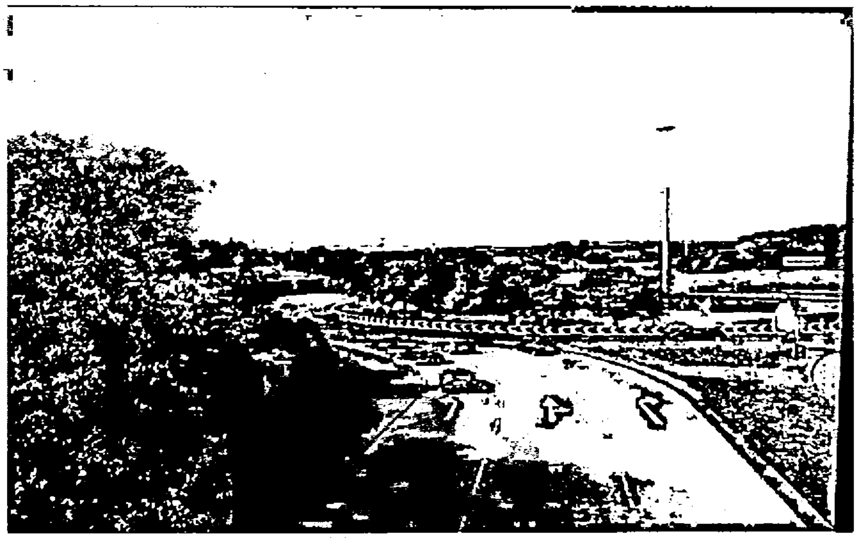


Fig 5.10 Mosaic by average weighted blending method

Fig 5.10 shows ghost appearance, moving vehicles are with dual appearance and are blurred also while Fig 5.9 shows a well blended image with no ghost appearance problem.

- **Example 2**
  The input images are of size 896x592.

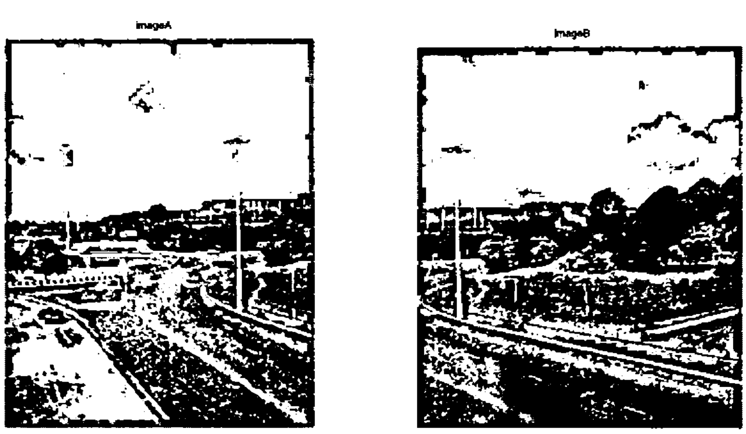


Fig 5.11 Input images, imageA & imageB

1624 and 2059 keypoints found from imageAand imageB respectively

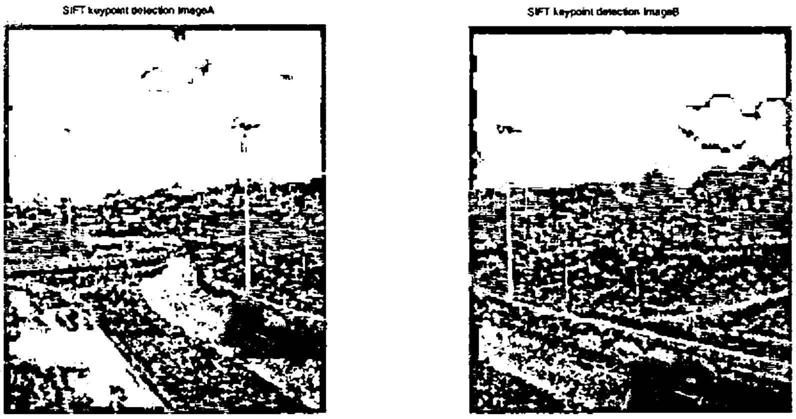
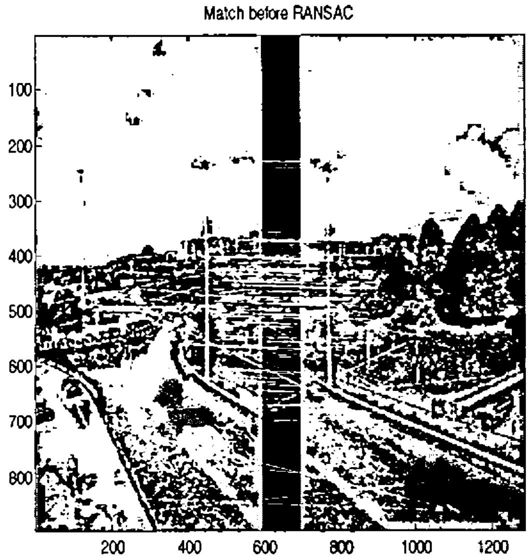


Fig 5.12 SIFT features extracted (from imageA & imageB)

254 matches found before RANSAC and after RANSAC algorithm 188 matches found from both images.



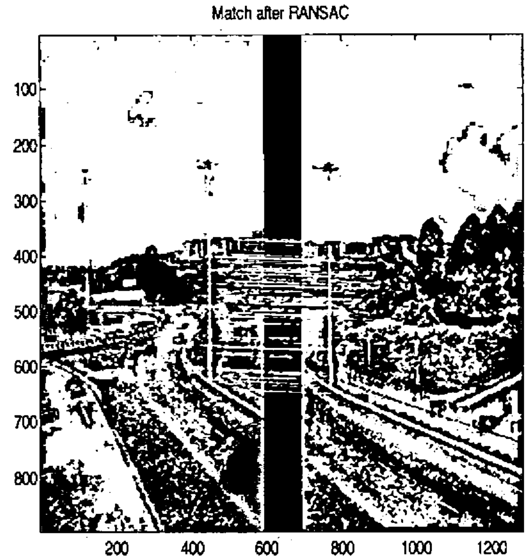


Fig 5.13 Feature matches before RANSAC **Fig 5.14 Feature matches after RANSAC**

Image transformation is done after feature matching.

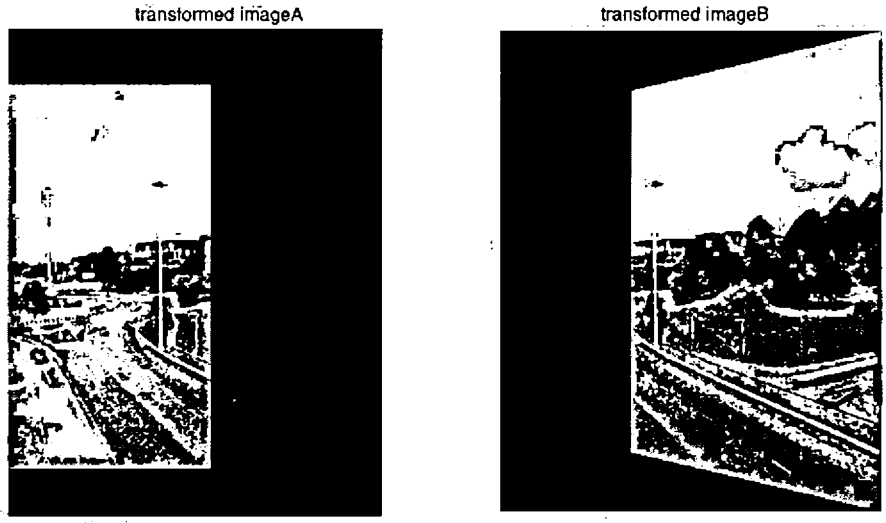


Fig 5.15 ImageB is transformed using Homography

Images are stitched after transformation.

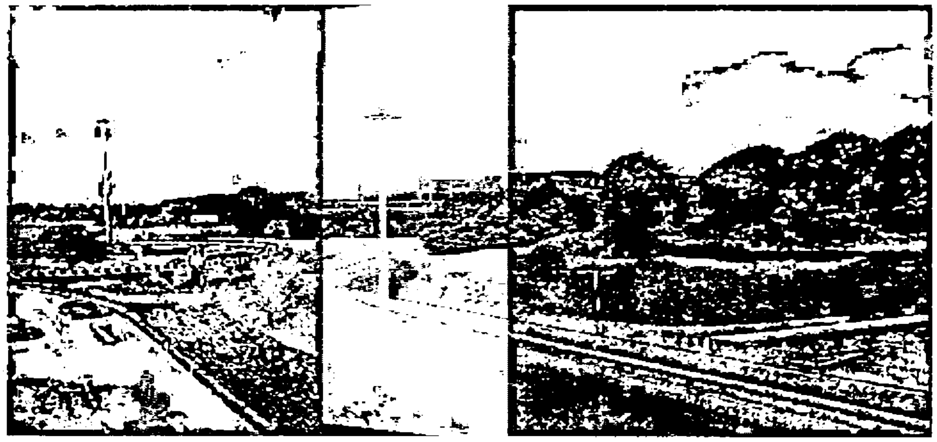
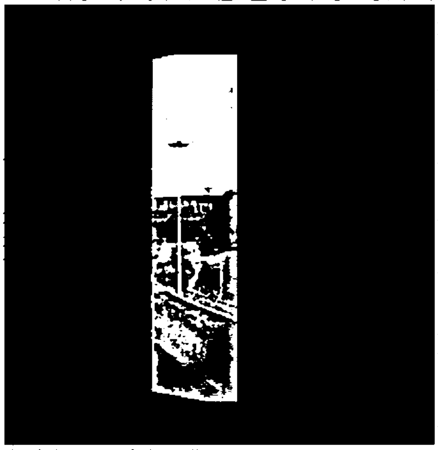


Fig 5.16 Mosaic before blending



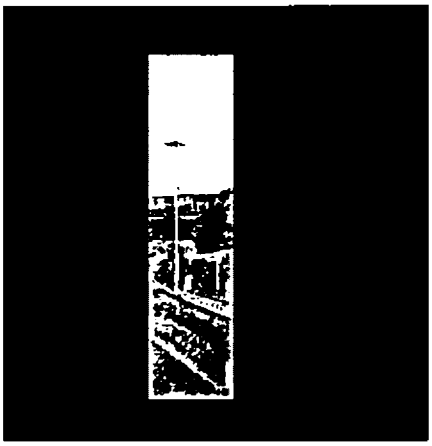


Fig 5.17 overlap region from stitched image **Fig 5.18 overlap region from imageA**

Result produced by proposed method and average weighted blending method are shown below. Size of mosaic image is 1139x1097.

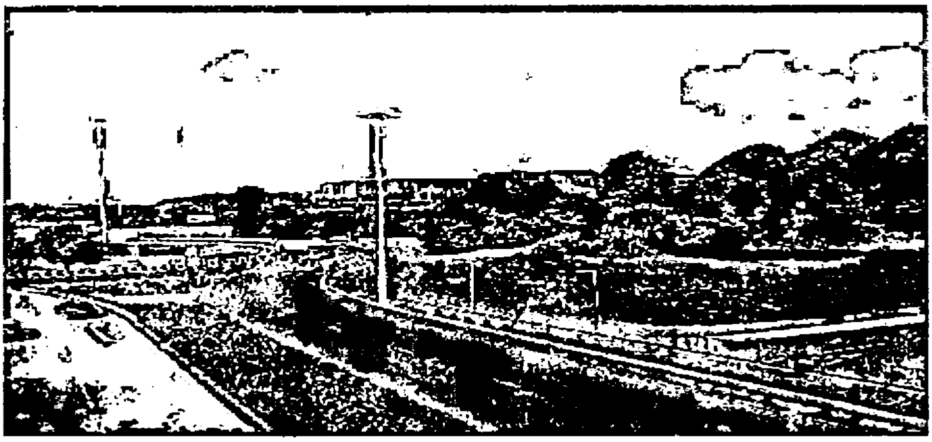


Fig 5.19 Mosaic by proposed technique

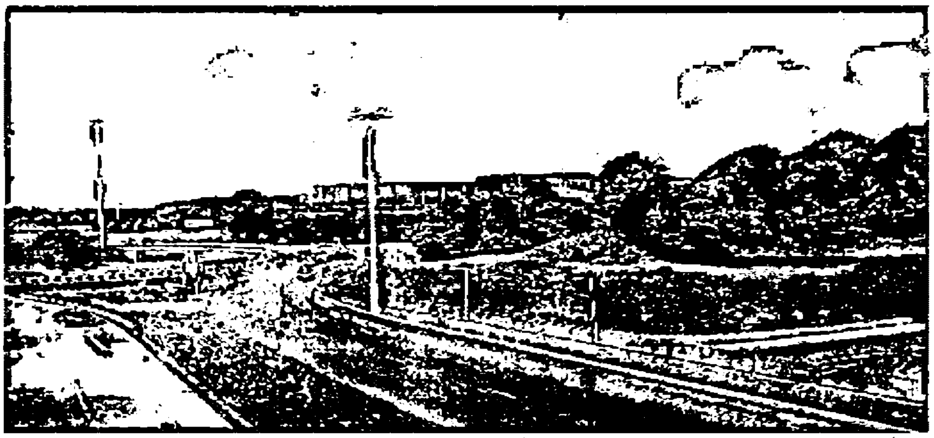


Fig 5.20 Mosaic by average blending method

Ghost appearance problem is not there in results of both techniques because moving vehicles are not in the overlap region of input images.

- **Example 3**

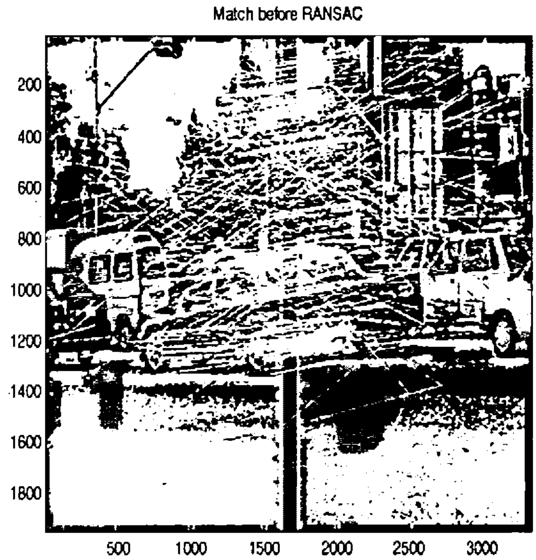
  The input images are of size 1950x1625.

Fig 5.21 Input images, imageA & imageB

9970 and 9433 keypoints found from imageA and imageB respectively.

Fig 5.22 SIFT features extracted (from imageA & imageB)

860 match points found before RANSAC and 437 match points found after RANSAC algorithm.



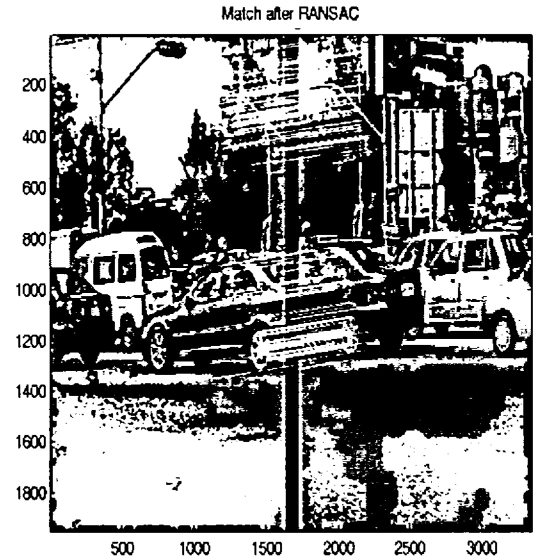


Fig 5.23 Feature matches before RANSAC **Fig 5.24 Feature matches after RANSAC**

Image transformation is done.

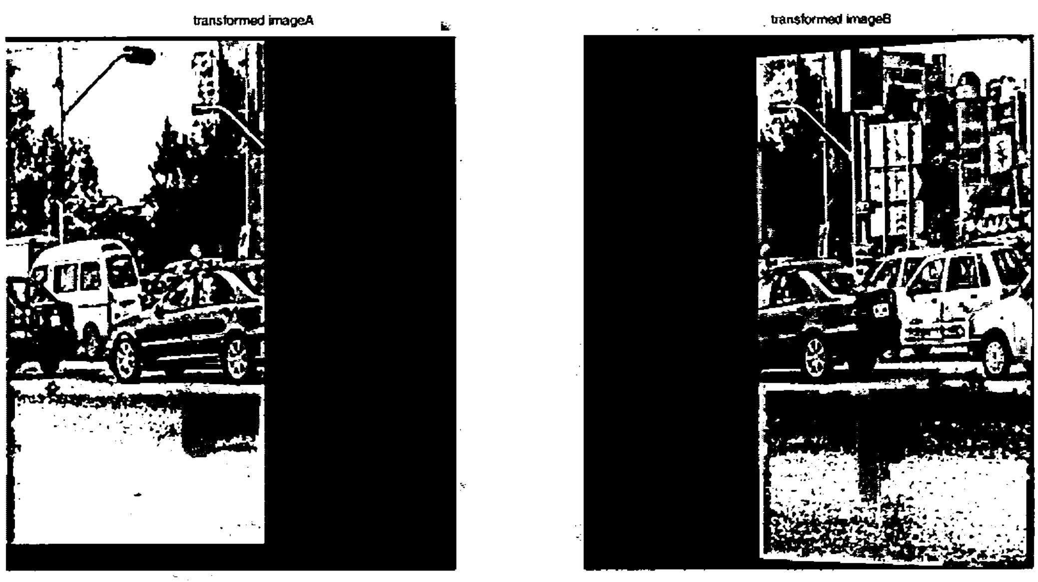


Fig 5.25 ImageB is transformed using Homography

Images are stitched after transformation.

Fig 5.26 Mosaic before blending

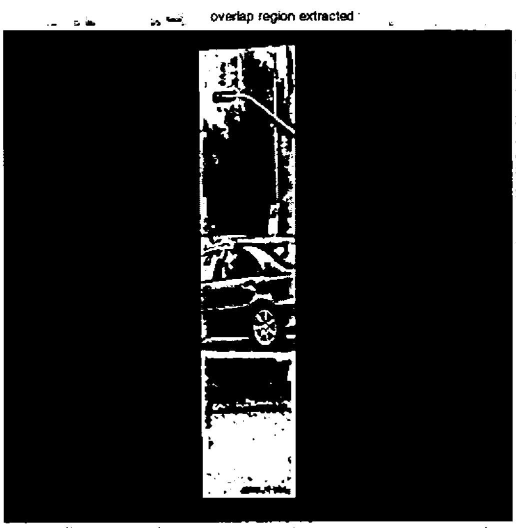


Fig 5.27 overlap region from stitched image

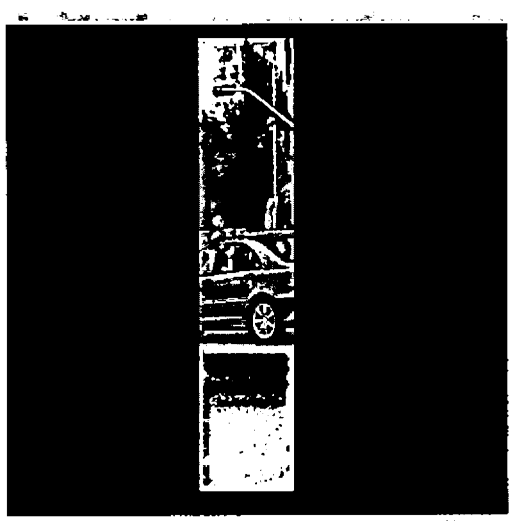


Fig 5.28 overlap region from imageA

Final mosaic is of size 2070x2085.

Fig 5.29 Mosaic by proposed technique

Fig 5.30 Mosaic by average weighted blending method

No ghost is there in both techniques' resultant images as traffic is immobile but there is an obvious seam in Fig 5.30 i-e by average weighted blending method, while Fig 5.29 shows smooth blending.

- **Example 4**

The input images are of size 972x1448.

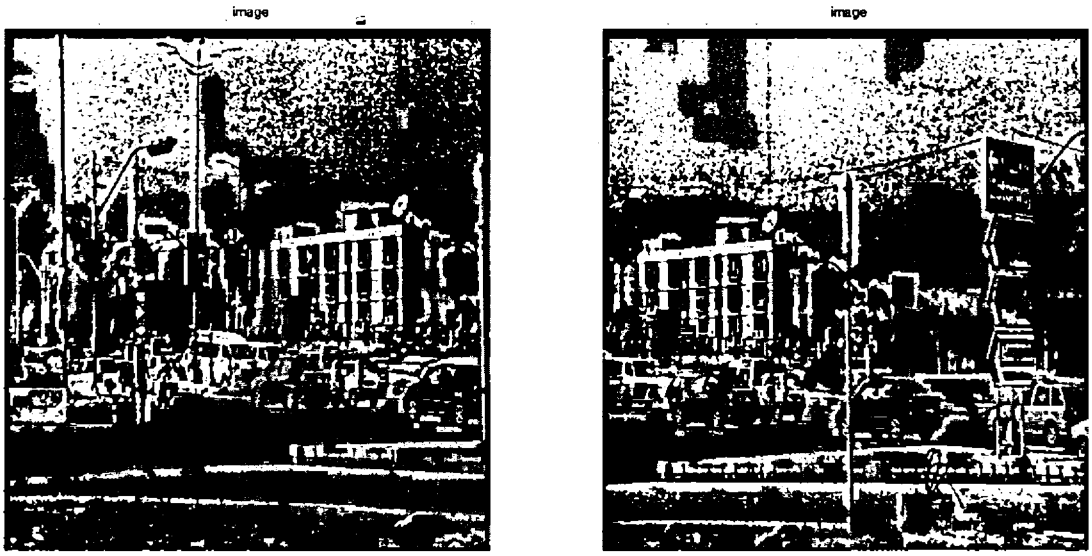


Fig 5.31 Input images, imageA & imageB

3786 keypoints found from imageA and 4231 keypoints from imageB.

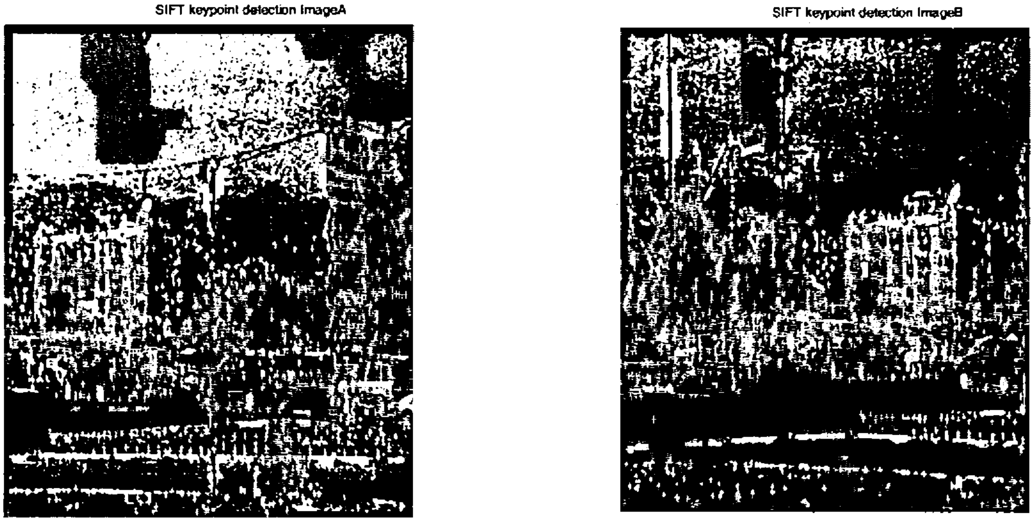


Fig 5.32 SIFT features extracted (from imageA & imageB)

1112 matches found from both images and after RANSAC 837 matches found.

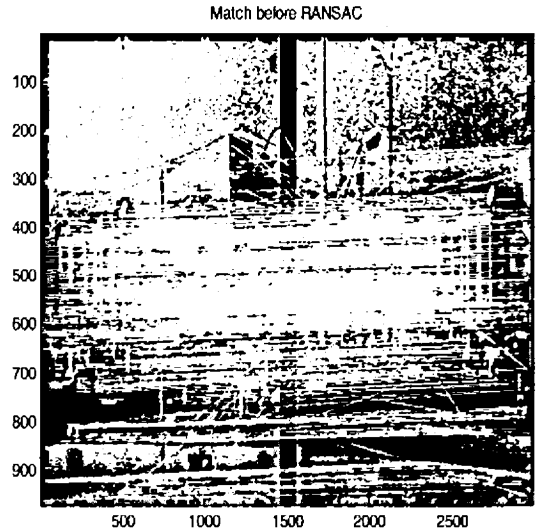


Fig 5.33 Feature matches before RANSAC

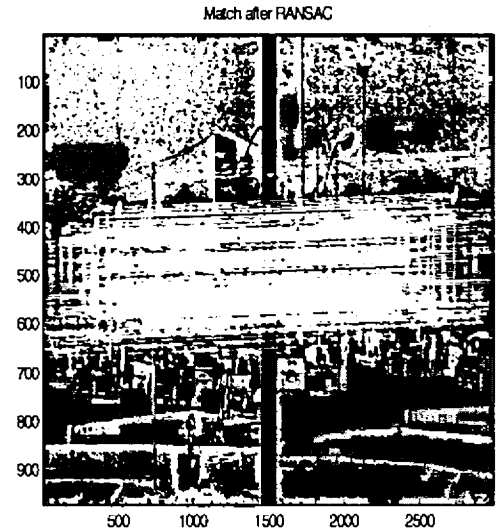


Fig 5.34 Feature matches after RANSAC

ImageB is transformed using Homography matrix.

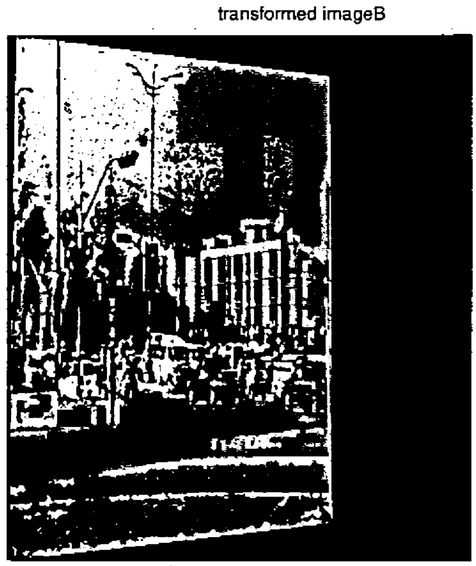


Fig 5.35 ImageB is transformed using Homography

Fig 5.36 Mosaic before blending

After transformation images are stitched.

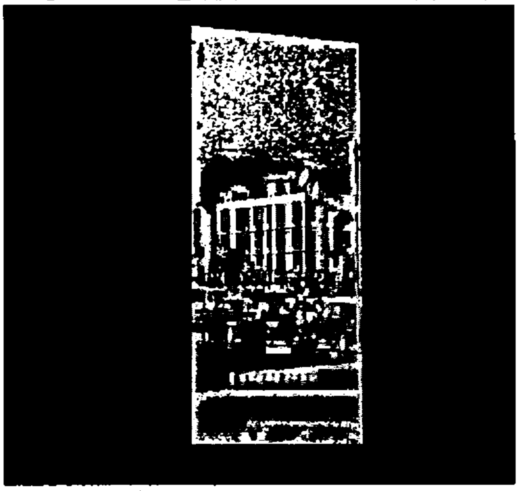


Fig 5.37 overlap region from stitched image

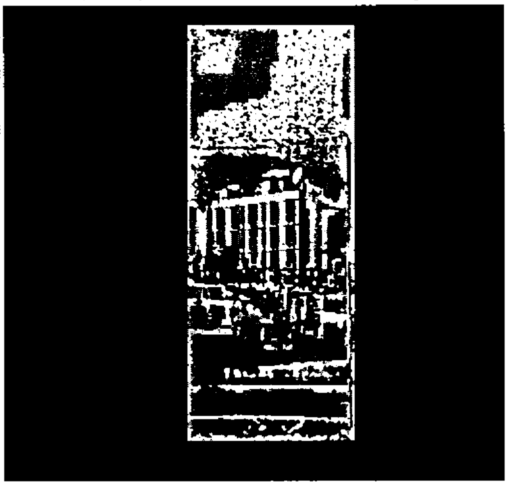


Fig 5.38 overlap region from imageA

The input images have moving traffic in overlap region.

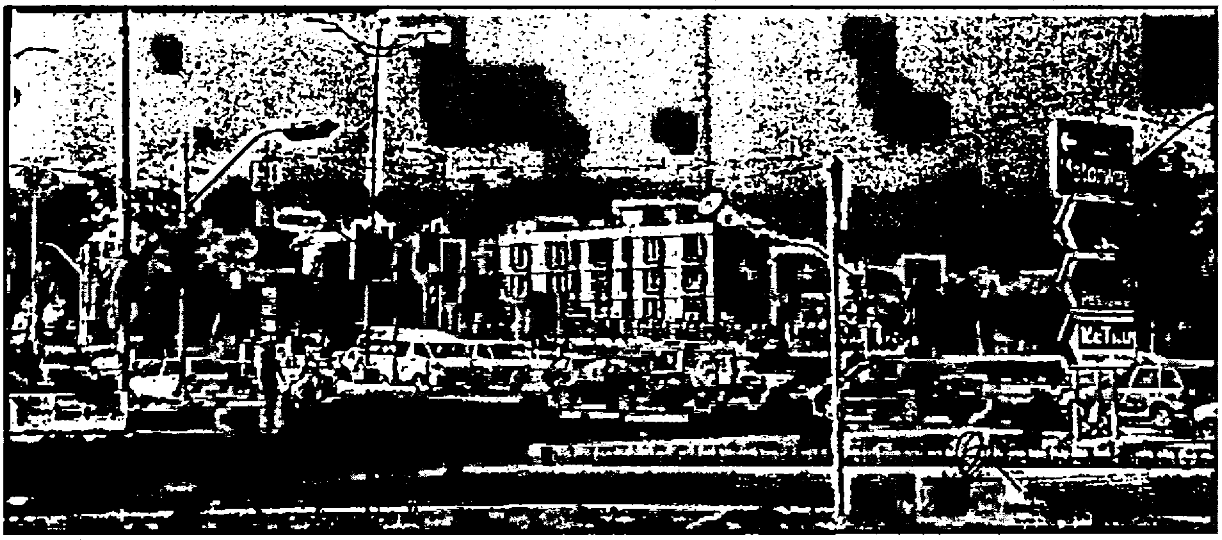


Fig 5.39 Mosaic by proposed technique

The stitched image through proposed technique is given in Fig 5.38.The mosaic image is well blended with no ghost appearance problem.

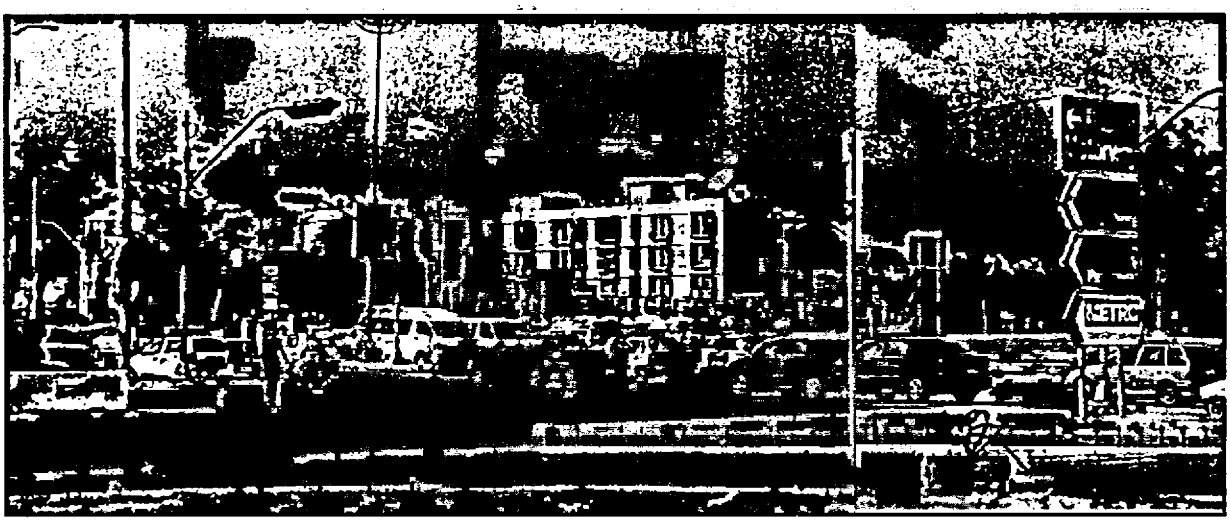


Fig 5.40 Mosaic by average weighted blending method

The image stitched through average weighted blending method is shown in Fig 5.40.The ghost appearance is obvious in the overlap region.

All above results shows that proposed technique blends well with no ghost appearance as compare to average weighted blending method.

5.7 Performance Evaluation

The performance of proposed technique is evaluated visually in terms of ghost appearance problem and seamless stitching. It is obvious that ghost appearance problem is eliminated which was present in Fig 5.10 & 5.40. The results have been compared with average weighted blending method because this method is simple and fast [11]. Fig 5.9, 5.29 & 5.39 show that the proposed technique works well when there are moving objects in overlap region of input images as it prevents ghost problem to appear in resultant image.

In proposed technique the overlap region contains the information from only one image while average weighted blending method, average of features in overlap region are taken and multiply with a weight. It can make the mosaic seamless but it doesn't eliminate ghost appearance problem. That's why the proposed technique gives better results for traffic images as traffic images has more possibility of having moving objects (vehicles) in the overlap region. However this technique can be applied to other images also where object movement is present.

Chapter 6

Conclusion and Future work

6 Conclusions and future work

Experimental results leads to some conclusion.

6.1 Conclusions

Many techniques have been developed for stitching of multiple images. Most of these techniques are focusing on images that don't have moving objects as moving object is a source of ghost appearance. Some methods for de-ghosting are there but they are complicated in a sense that they include searching of moving objects in the overlap region.

The proposed blending method not only diminishes the seam but it also eliminates the ghost from the image and is less complicated.

Proposed method has been applied on traffic images (with moving vehicles as well as still vehicles) and the results shows that the proposed method for blending produced better blended images than that of average weighted method and ghost is completely eliminated.

Experiment shows that our method for blending is also effected for images other than traffic images. It can be concluded that proposed method produces better results for any type of images.

6.2 Future work

Further improvement can be done while stitching of more than two images. And the proposed method can be enhanced to get good results for RGB images.

Appendices

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