

IMAGE BLENDING USING GRAPH CUT METHOD FOR IMAGE MOSAICING

*A thesis submitted in partial fulfilment
of the requirements for the award of the degree of*

Master of Technology

in

Electronics and Communication Engineering

(Specialization: Signal and Image Processing)

by

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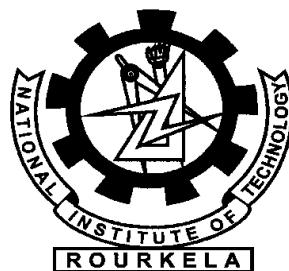
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CERTIFICATE

This is to certify that the thesis Report entitled **“IMAGE BLENDING USING GRAPH CUT METHOD FOR IMAGE MOSAICING”** submitted by **Mr SHISHIR MAHESHWARI** bearing roll no. **212EC6190** in partial fulfilment of the requirements for the award of **Master of Technology in Electronics and Communication Engineering** with specialization in **“Signal and Image Processing”** during session **2012-2014** at **National Institute of Technology, Rourkela** is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Prof. Umesh Chandra Pati

Place:

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*Dedicated
To
Almighty GOD and My Family*

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The success and final outcome of this project requires a lot of guidance and assistance from many people and I am extremely fortunate to have got this all along the completion of my project work. I whatever have achieved and done is only due to such guidance and assistance and I would not rather forget to thank them.

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At last, I would conclude with my deepest gratitude to my parents, my classmates and all my loved ones. My full dedication to the work would have not been possible without their blessings and moral support. This thesis is a dedication to them who did not forget to keep me in their hearts when I could not be beside them.

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ABSTRACT

In last few decades, real time applications in image mosaicing has been a challenging field for image processing experts. It has wide range of applications in the field of satellite imaging, 3D image reconstruction and several medical as well as computer vision fields. It can also be used for mosaic-based localization, motion detection & tracking, augmented reality, resolution enhancement, generating large FOV etc.

In this research work, feature based image mosaicing technique and image blending using graph cut method has been proposed. The image mosaicing algorithms can be divided into two broad categories. The direct method and the feature based method. The first is the direct method or the intensity based method and the second one is based on image features. The direct methods need an ambient initialization whereas, Feature based methods does not require initialization during registration. The feature based techniques are followed by the four primary steps: feature extraction, feature matching, transformation model estimation, image resampling and transformation, and image blending. Harris corner detection, SIFT and SURF are such algorithms which are based on the feature detection for the accomplishment of image mosaicing, but the algorithms has their own limitations as well as advantages according to the applications concerned.

The proposed method employs the Harris corner detection algorithm for corner detection. The features are detected and the feature descriptors are formed around the corners. The feature descriptors from one image are matched with other image for the best closeness and only those features are kept, rest are discarded. The transformation model is estimated from the features and the image is warped correspondingly. After the image is warped on a common mosaic plane, the last step is to remove the intensity seam. Graph cut method with minimum cut/ maximum flow algorithm is used for the purpose of image blending. A new method for the optimisation of the cut in the graph cut has been proposed in the research paper.

Keywords: Image mosaicing, Panorama, Image registration, Image blending, Graph cut.

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Chapter – 1

Introduction



- *INTRODUCTION*
- *OVERVIEW*
- *APPLICATIONS*
- *LITERATURE REVIEW*
- *OBJECTIVES*
- *ORGANISATION OF THE THESIS*

1.1. Introduction

Image mosaicing or mosaicing of images is the phenomenon of producing the high resolution disjoint mosaiced image so as to achieve large field of view. It is done by stitching multiple overlapping visual images with overlapping fields. The mosaiced or panorama image can be generated using the computer software. Many of the algorithms for mosaicing of images require nearly rigorous overlap between images. Also if the exposure is identical in all the images, it will help to produce seamless results.

1.2. Overview

The mosaiced image generated from a continuous sequence of images of the same scene is a synthetic composition. This is achieved by understanding the geometric relation between the input images, that how the other image is geometrically aligned with respect to the reference image. The geometric relations are the coordinate system that relates the different image coordinate systems. After the appropriate transformation has been applied, images are warped and the overlapping area of warped images are merged into a common surface which gives the single indistinguishable image which is tantamount to a single large image of the same scene. The resultant image is the motivation for image mosaicing. Various steps are involved in image mosaicing such as image registration, image warping and image blending. Example of image mosaicing is shown in Fig. 1.1.

Image registration is the most important step in image mosaicing. It is the process of superimposing two or more images of the same scene taken by different sensors, from different viewpoints, at different time instants. It is the process of aligning of two images geometrically - the reference and target images. Data can be multiple images of the same scene or from different sensors taken at different times or from different viewpoints.

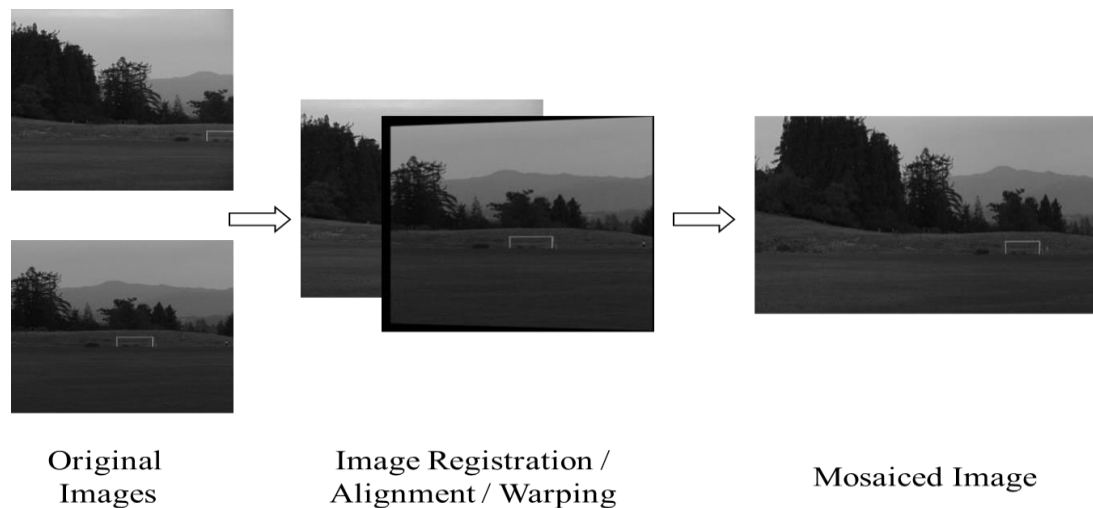


Figure 1.1. Example of Image Mosaicing.

Image registration plays a vital role among those image specific areas where the output information is received from the combined sources like in image mosaicing, image fusion, image restoration and change detection. Registration is necessary for comparison or integration of the received data from different measurements. Registration process can be classified into following types:

- algorithm that depends on image pixel value directly,
- algorithm that performs frequency domain analysis,
- algorithm using low level image features such as edges and corners, e.g., feature based methods,
- algorithm using level features such as identified objects, or relation between features, e.g., graphical methods.

Homography is the mapping between two spaces which is often used to represent the correspondence between two images of the same scene. It is bidirectional that is, can be performed in both the direction, reverse and forward.

Image warping is the process where the digital manipulation of an image can be done such that any shape illustrated have been somewhat sarcastic. It can be used for removing distortion in the image and also for creative purposes for e.g., morphing. At this step, the two images that are going to create mosaic are warped, by using the geometric transformation. It is the mapping function which maps or places the pixel intensity value from current location to new location.

Image blending is the technique of removal of intensity seam at the boundary of joint of two images in order to get the seamless mosaiced image. It is process of obtaining a mosaiced image with smooth transition. It modifies those pixels values which are present in the neighbourhood of the boundary that gives a smooth transition so as to obtain a blended image by removing the intensity seams.

1.3. Applications

Mosaicing of images is a process of joining two or more images in order to create a single wide area image. Some of the application areas are as follows:

- The mosaic of large air scape and satellite remote sensing image,
- Meteorological and environmental monitoring,
- Sea-bottom survey and geological survey,
- Combination of medicine and scientific micro-fragment image,
- The 3D rebuilding of objects,
- The building of virtual scene and virtual walkthrough,
- Video compression, video search browse, and video edit, etc,
- Military reconnaissance and taking evidence.

1.4. Literature Review

There are algorithms that allow images to be aligned, mosaiced and seamlessly stitched together are the kind of the oldest most widely and precisely used in computer vision.

Image mosaicing is the procedure of seamless stitching or placing of two or more than two overlapping images together having some or more similarity of the same scene [1].

Image registration [2] is alignment of two images geometrically: the source and the target images. Registration methods can be classified into following types: algorithm that directly uses image pixels using correlation method; algorithm that use analysis in frequency domain [3]; feature based algorithm that use low level image features such as edges and corners [4]; algorithm that uses high level image features such as defined objects, or image patches or relation between image features.

Homography [5] is estimation of the transformation model used for the geometrical alignment of one image with respect to other. RANSAC is also used with the homography [6, 7] process to select the best set of inliers and estimate the transformation model. Martin A. Fischler and Robert C. Bolles [8] proposed an algorithm for model fitting.

Digital image warping [9] can be used for removing distortion in the image and also for creative purposes (e.g., morphing). At this step, the two images that are going to create mosaic are warped, by using the geometric transformation. It is the mapping function which maps or places the pixel intensity value from current location to new location.

In image stitching approach, there are two types of blending processes: optimal seam finding [10] and transition smoothing. Methods such as transition smoothing can be generally attributed as alpha blending or feathering methods that pursuit to minimize the discernibility of intensity seams by smoothing at the locations between the images. A classical approach is multi-resolution splining by Adelson and Burt [11]. Multi-resolution method has been broadly used in 2-D panoramas for image blending [12]. The gradient domain blending and the multi-

resolution blending using wavelets [13] is also an approach to transition smoothing. There are recent examples that include blending in gradient domain, which decreases the disagreement due to the discrepancy in the photometric response and illumination change of the cameras. The advantage blending methods such as gradient domain have is that the gradient difference are stable to the average image intensity. At a high computational cost, P. Pérez et al. [14] suggests that by determining discrete Poisson equation a least-squares solution can be found.

Optimal seam finding methods, on the other hand, change the intensity seam position, that is, it places the seam between two images where the intensity dissimilarity in the area of overlap are minimum by using graph cut and energy minimising function. The seam is then further optimised to get rid of the available seam.

Yuri Boykov et al. [15] has demonstrated energy minimisation via graph cuts. Vivek Kwatra et al. [16] has used image patches to create a new output image by repeatedly joining the patches using graph cut method. Nuno Gracias et al. [17] has used watershed method followed by graph cut for image blending. Andrew DeLong et al. [18] has introduced energy minimisation via label costs. Uyttendaele et al. [19] have searched among images using thresholds for regions of difference (ROD).

For moving objects over a non-dynamic background Davis [20] describes an image blending method. The relative visual difference is computed between two images, and Dijkstra's algorithm is used for searching the dividing low intensity minimum boundary of the difference image.

1.5. Objectives

Vision allows humans to observe and be aware of our surrounding world. The field of view of human eye is restricted to $170 \times 145^\circ$, in order to increase the field of view $360 \times 180^\circ$ panorama is used. Also, the normal camera has field of view of 45×50 . So for the application

purpose images has to be assembled together. Image mosaicing is a technique to create panorama, where images are assembled with some common FOV. It helps in increasing the FOV. It provide us a lot of useful data that are required to extract valuable information not only from a single image but from mosaicing image (i.e. multiple assembled image). Since image mosaicing has been an emerging field which focuses on feature extraction, matching, registration, homography, warping and blending. Moreover, the images not only contain the structure , shape and colour information about the picture, but also the possible camera motion, calibration and also on movements of objects in the scene.

There are a lot of existing image mosaicing algorithm and still research is going on. Each algorithm is considering a few variation in account while generating the output. So here improvement in the quality of image mosaicing by improving the robust mosaicing algorithms considering the combined effect of rotation, illumination, noise variation and other minor variation. It is precisely this information that is to be produced in this thesis.

1.6. Organisation of the thesis

The thesis is organised in six chapters including the present chapter. The organisation of chapters is as follows:

Chapter 2: Image Registration

This chapter gives a detail about image registration process and its types. It introduces the Harris corner detector, which is the most popular and widely used corner detection algorithm. It includes basic process of image mosaic, steps involved for the algorithm. And at last, there is analysis and simulation of the detector using two images having some common FOV.

Chapter 3: Homography and RANSAC

In this chapter, the homography process and types of homography has been discussed. Also the RANSAC algorithm and its functioning together with homography process has been discussed. The transformation model has also been estimated.

Chapter 4: Image Warping and Blending

This chapter is divided into two parts, image warping and image blending. The first part deals with the image warping explanation and its methods. The second part deals with the image blending procedure theory and its methods.

Chapter 6: Implementation and Results

In this chapter, the overall thesis is concluded with the help of results and implementation. The working algorithm is discussed and the steps involved in mosaicing of images and result of each step involved in the process is demonstrated.

Chapter 7: Conclusion

This chapter concludes the results of the research work carried out and provide the analysis and outlooks for future research.

Chapter – 2

Image Registration



→ *INTRODUCTION*

→ *IMAGE REGISTRATION METHODS*

→ *FEATURE EXTRACTION*

→ *HARRIS CORNER DETECTION ALGORITHM*

2.1. Introduction

Image registration is the procedure of geometrical alignment or superimposing two or more images of the same scene:

- from different viewpoints,
- taken at different times,
- by different camera sensors.

It is alignment of two or more images geometrically, taken two at a time - the reference and target images.

Image registration is the foundation and also the most important part of image mosaicing process. Registration of multiple source images with certain image requires an image transformation parameters generated by similarity measurement which collects two or more images of the same scene but produced from different perspectives, different sensors and different times. This procedure makes the transformation of multiple source images into a single homogenous coordinate system achieving the best match on pixel level. Two 2-D arrays representing source and target image $I_1(x,y)$ and $I_2(x,y)$ respectively, image registration can be stated as follows:

$$I_1(x, y) = g \left(I_2(f(x, y)) \right) \quad (2.1)$$

where f is a homography transform model estimated function for 2-D coordinates.

2.2. Image registration methods

The image registration process can be organised in following types:

2.2.1. Direct method or Intensity based method

In this method, the source image is matched with the target image with reference to individual intensity pixel values. The correspondence match is made individually between intensity pixel values of the source and the target image.

Cross-correlation of image pixel intensity values is the basic analytical approach of registration. In pattern recognition, it is often used for matching of image templates which utilise the orientation and location of a pattern or template in the picture. Cross correlation can be used for the measurement of closeness. For image I and template T , where T is small as compared to I , the measurement of similarity using cross-correlation function is

$$C(u, v) = \frac{\sum_x \sum_y T(x, y) I(x-u, y-v)}{\sqrt{\sum_x \sum_y I^2(x-u, y-v)}} \quad (2.2)$$

If the template matches the image at the particular position, then there is a peak at $C(i, j)$.

2.2.2. Frequency domain Phase correlation method

The multiplication property of Fourier transform is utilised in this case. It states that the correlation of two images in the spatial domain is the individual product of the Fourier transform of one image with the other. The Fourier transform of an image $f(x, y)$ is a complex function with real part $R(\omega x, \omega y)$ and an imaginary part $I(\omega x, \omega y)$ at each frequency $(\omega x, \omega y)$ of frequency spectrum.

$$F(\varphi_x, \varphi_y) = \frac{F_1(\varphi_x, \varphi_y)F_2^*(\varphi_x, \varphi_y)}{|F_1(\varphi_x, \varphi_y)F_2^*(\varphi_x, \varphi_y)|} \quad (2.3)$$

In spatial domain the phase of cross power frequency spectrum can be represented by taking the inverse Fourier transform of its frequency counterpart, then exits a function with an impulse which is approximately null everywhere except at the point of displacement which is needed for optimum registration of two images. Shift theorem agrees that the difference in phase between the images is tantamount to the phase of cross power spectrum. Above method is used to register images having only translation.

2.2.3. *Feature based method*

In Feature based image registration techniques, grey levels values are not involved to describe matching entities. It makes use of low or high level image features such as corners, edges, image patches etc. to be derived by feature extraction algorithm. The purpose of feature based method is to extract the substantial information from original image data input and filter out the non-redundant information. These features are responsible for proper computation. Those features are acquired which are most unique and likely to be found in both images and more tolerant of local distortions. Therefore to perform exact calculation sufficient number of features must be detected.

After detecting features in each image, they must be matched. When the type of misalignment is unknown or if the class of transformations cannot be easily categorized, registering the images is the primary approach. In this we can use these extracted features and then match them using general transformation.

The method of point mapping consist of three stages-

- Extracting features in the image,
- Finding correspondence using feature points between data and the target image,
- Mapping in spatial domain.

Control points are referred as interest points. These play an important role for matching purpose in this method. Control points may be line of intersections, corners, edges, locally maximum curvature points on contour lines, closed-boundary centres of gravity regions and centres of windows having locally maximum curvature. Under this method we have computed edges of images in colour vector space by using colour gradients. For a scalar function $f(x, y)$, the gradient is a vector pointing in the direction of maximum rate of change of at coordinates (x, y) .

The comparison between the different registration methods are provided in table 2.1.

Table 2.1. Table comparing direct and feature based method of registration.

Direct method	Feature based method
<ul style="list-style-type: none"> ▪ Preferred for images without many prominent details. ▪ Windows of pre-defined size or even the entire images are used for the correspondence estimation. ▪ Can handle only translation and small rotation. ▪ Sensitive to intensity changes, due to noise, varying illumination, and/or by using different sensors. 	<ul style="list-style-type: none"> ▪ Generally faster than direct methods. ▪ More robust against scene movement. ▪ Robust estimation algorithms available. ▪ Suitable for fully automatic mosaicing. ▪ The respective features might be hard to detect and/or unstable in time.

2.3. Feature Extraction

Initially, the features were those objects which are manually selected by an expert. But due to the computerization of the registration process, approaches for feature understanding has been built. This approach rely on the extracting the salient features from the images. These feature points should be distinct and spreaded all over the image. Also these should be efficiently detectable in both the images. Significant points region corners, line intersections are understood as features here. During the whole experiment, these must be stable with variation in time and must stay at fixed positions in order to get proper result.

The accuracy and invariance of the feature detector method in the overlapping area determines the efficiency of extracted feature points in the two images. We can also say that the number of common feature points detected from the set of images should be sufficiently enough, disregarding to the variation in image geometry, presence of noise, radiometric conditions, and other minor variations etc. The effectiveness of the features is given by its definition. The feature based methods, on contrary to the area based methods, are not directly working on the image intensity. These features represent higher level information. Such properties of feature based methods make it satisfactory for situations that deals with changes in illumination or multi sensors.

2.4. Harris Corner Detection algorithm

This operator was developed in 1988 by Mike Stephens and Chris Harris as a low level based feature processing step. This was developed in order to help the researchers trying to frame perception based on image sequences for the robot's environment [3]. Specifically, Harris and Stephens were interested in using motion analysis techniques to interpret the environment based on images from a single mobile camera. They needed a method for

matching the point correspondence in subsequent image frames and also want to keep track of both corners and edges between frames, like Moravec. Harris and Stephens developed this combined corner and edge detector by eliminating the restrictions of the Moravec operator. The result is a far more desirable detector in terms of detection and repeatability rate at the cost of requiring significantly more computation time. Despite the high computational demand, this algorithm is widely used.

Fig. 2.1 shows the detection of corner using the directional change. In (a) part of the Fig. 2.1, there is a flat surface as there is no change in the all direction. In (b) part of the Fig. 2.1, there is no change in the edge direction whereas there is change in all the direction in part (c) of Fig. 2.1, so that point is referred as a corner.

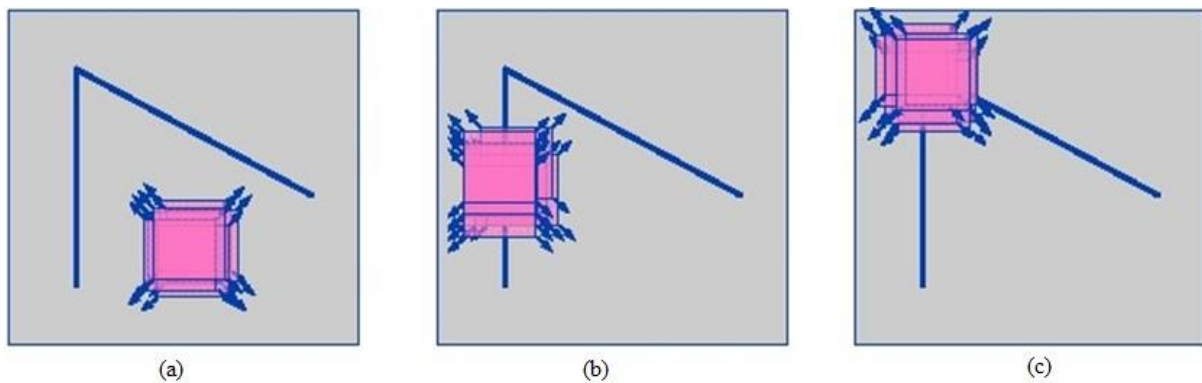


Figure 2.1. Detecting corners using directional change.

Let us consider the gray intensity of pixel (u, v) be $I(x, y)$ then the variation of gray pixel (x, y) with a shift of (u, v) can be denoted as:

$$E(u, v) = \sum_{x,y} w(x, y) [I(x + u, y + v) - I(x, y)]^2 \quad (2.4)$$

With the application of Taylor series expansion

$$E(u, v) = \sum_{x,y} w(x, y) [I_x u + I_y v + O(u^2, v^2)]^2 \quad (2.5)$$

For a small shift of (u, v) we have the following approximation,

$$E(u, v) \cong [u, v] M \begin{bmatrix} u \\ v \end{bmatrix} \quad (2.6)$$

where M is a matrix of 2×2 which has been calculated from the image derivatives:

$$M = \sum_{x,y} w(x, y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \quad (2.7)$$

If λ_1, λ_2 are the Eigen values of matrix M , then corner, edge and flat area of the image can be computed from the Eigen value as follows as shown in Fig. 2.2,

- Flat area: both λ_1, λ_2 are tiny
- Edge: one of λ_1, λ_2 is smaller and the other is bigger
- Corner: both λ_1, λ_2 are bigger and are nearly equal

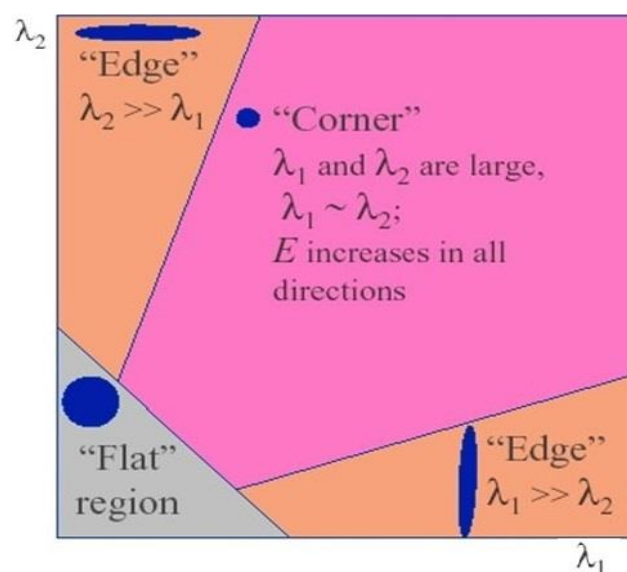


Figure 2.2. Image point classification based on Eigen values.

Algorithm steps for detecting Harris corners:

1. For each image pixel $I(x, y)$ of the image I , the autocorrelation matrix M is,

$$M = \sum_{x,y} \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \quad (2.8)$$

2. Gaussian filtering has been applied for each image pixel. Discrete 2-D zero-mean Gaussian function as follows:

$$Gauss = \exp\left(\frac{-(u^2+v^2)}{2\delta^2}\right) \quad (2.9)$$

3. The corners are calculated and R is measured for each pixel (x, y)

$$R = \det(M) - k * \text{trace}(M)^2 \quad (2.10)$$

4. Points which are local maximum are chosen. Harris method is considered that those pixel values which corresponds to the locally maximum interest point are the feature points.
5. Threshold T is set to detect corner points.



Figure 2.3. Image with corner feature using Harris Corner detection algorithm.

Chapter – 3

Homography and RANSAC



→ *INTRODUCTION*

→ *HOMOGRAPHY TRANSFORMATION*

→ *SOLVING FOR HOMOGRAPHY*

→ *RANSAC*

→ *HOMOGRAPHY COMPUTATION*

3.1. Introduction

Any two images, in the field of computer vision, of the same plane surface in space are related by the homography. Camera rotation, motion and translation, image rectification are the applications of homography. Once the homography has been extracted from the estimated transformation model, it then can be used for the undersigned purpose.

The location of any 2-D point $I(x, y)$ image pixel can be represented as a 3-D vector X

$$X = (x_1, x_2, x_3) \quad (3.1)$$

where

$$X = [x \ y] \quad (3.2)$$

$$x = \frac{x_1}{x_3} \quad (3.3)$$

$$y = \frac{x_2}{x_3} \quad (3.4)$$

This is the representation of homogeneous transformation for a point which lies on the 2-D projective plane (P^2). These transformation includes projectivity, collineation, and planar projective transformation. A homography process can be referred as a reversible mapping of points and lines on the P^2 to itself as this is specific definition provided by Hartley and Zisserman [5] such that mapped points are collinear only when the points lie on the same. They also provided the algebraic definition which states that the projectivity exists if and only if the homography matrix is nonsingular such that the point x mapped to a new location plane x' equals to the Hx . It is acceptable to calculate the 3x3 homography matrix H such that x_i and x_i' maps each other where x_i' is synonymous of x_i .

There is 8 degrees of freedom (DOF) for homography transformation and there are some other simple transformations that uses the 3x3 matrix but they contain a specific restraint to downturn the number of DOF. There are hierarchy of transformations which leads to the homography. In this section, we will focus on how these simple transformations are used combinely to chain up homographies.

3.2. Homography Transformation

Some homography transformation are as follows:

3.2.1. Isometry Transformation

Euclidian distance is preserved in an isometry transformation. This means that there will always be the identical gap between any two corresponding points in the mapped image with respect to the points in original image. The angles between the lines and areas also follow the same rule of Euclidian distance. Isometry transformation have only 3 DOF as they are made up of only 2-D rotations. An isometry transformation matrix can be written as:

$$X = \begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix} x \quad (3.5)$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = K \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \quad (3.6)$$

where R is the rotation matrix of 2x2, t indicates the translation and 0^T is a row of 2 zeros.

3.2.2. *Similarity Transformation*

This transformation is similar to the transformation described above. In addition it is also incorporated with isotropic scaling. Isotropic scaling is as referred to scale which is direction independent or invariant. This isotropic scale adds an additional DOF and as a result, now the similarity transform contains 4 DOF. Also this do not affect the angles likewise in isometry. The ratio of distances is preserved as any scale change cancel out but the distance between points are no longer invariant. A similarity transform can be written as:

$$X = \begin{bmatrix} sR & t \\ 0^T & 1 \end{bmatrix} x \quad (3.7)$$

where s is referred to as isotropic scaling and is a scalar quantity.

3.2.3. *Affine Transformation*

An affine transformation is composed of two rotations and two non-isotropic scaling whereas similarity transform is a composition of a single rotation and isotropic scaling. It contains two more DOF's as compared to the similarity transformation. The scaling parameter ratio and other is angle specifying the scaling direction. In this transformation, the distance ratios or the angles between lines remains same in the mapped image as that of original image. The parallel lines in original image as well as in the mapped transformed image remain as it is and length ratios are preserved for areas and parallel line segments. It can be written as:

$$X = \begin{bmatrix} A & t \\ 0^T & 1 \end{bmatrix} x \quad (3.8)$$

where A is a non-singular matrix of 2x2.

Decomposition of A can be done as:

$$A = R(\theta)R(-\phi)DR(\phi) \quad (3.9)$$

where θ and ϕ in $R(\theta)$ and $R(\phi)$ respectively, indicates the amount of rotation and diagonal matrix D can be written as:

$$D = \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix} \quad (3.10)$$

where λ_1 and λ_2 are two scaling values.

So according to Eq. 3.9, the matrix A is thus defined as a multiplication chain of rotation and scaling in x and y direction by ϕ , λ_1 and λ_2 respectively, again rotation back by $-\phi$ and θ .

3.2.4. Projective Transformation

Projective transformations contain two more DOF as compared to that of affine transformations. The matrix now contains ratio significant nine elements.

A projective transformation can be written as:

$$X = \begin{bmatrix} A & t \\ V^T & v \end{bmatrix} \quad (3.11)$$

where $v = (v_1, v_2)^T$.

Vector v , which is null in the affine case is the point difference between affine and projective transformation. The scaling are same everywhere in the plane and changes with respect to the position in the image for affinities and projectivities respectively. This nonlinear effects of the projectivity is due to the vector v which is non-singular. The transformed line orientation depends on the of the original line orientation in case of affinities while the

orientation of transformed line's position gets effected by the original line on the plane in case of projectivities.

The decomposition of the projective transformation into a multiplication chain can be represented using previously defined transformations:

$$H = H_S H_A H_P = \begin{bmatrix} sR & t \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} U & 0 \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} I & 0 \\ V^T & 1 \end{bmatrix} = \begin{bmatrix} A & t \\ V^T & v \end{bmatrix} \quad (3.12)$$

where H_A represents an affinity, H_S represents a similarity transformation and H_P represents a projectivity.

$$A = sRU + tv^T \quad (3.13)$$

and U is a normalised upper triangular matrix with determinant $|U| = 1$. For a valid decomposition, v should be non-singular that is it cannot equal to 0. This is unique decomposition if s is positive.

The graphical representation of various homography is as shown in Fig. 3.1.

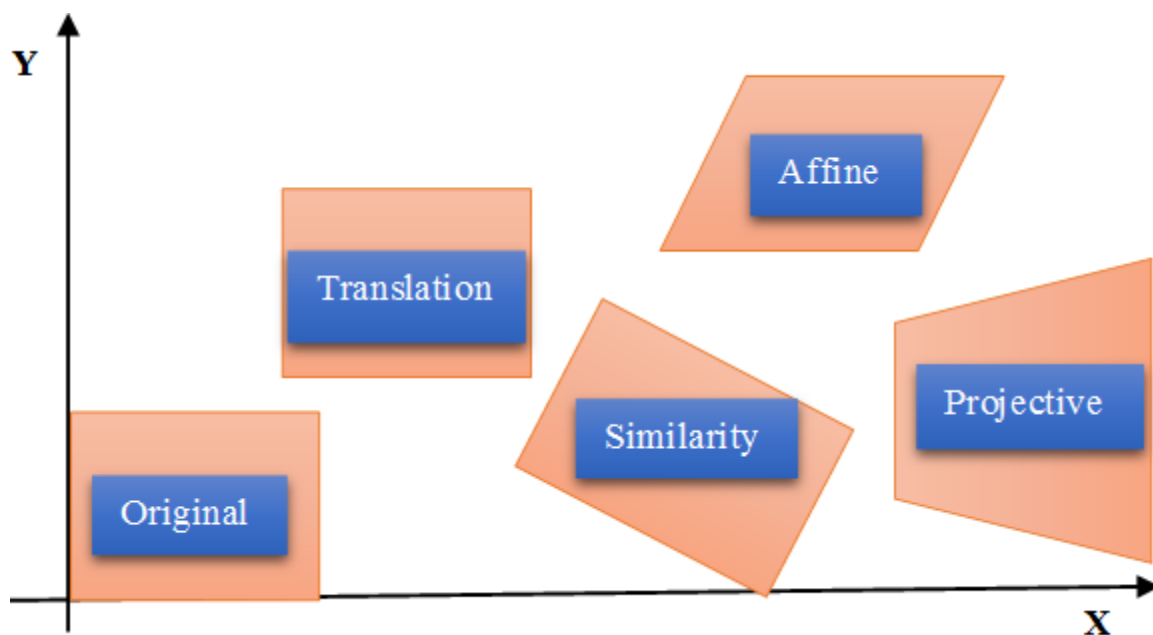


Figure 3.1. Types of homography transformation.

3.3. Solving for Homography

To work in homogeneous coordinates, there should be a relationship between the coordinate points which we are dealing with. Hence, between the two corresponding points x and x' , the relationship can be re-written as:

$$X' = Hx \quad (3.14)$$

where

$$H = \begin{bmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{bmatrix} \quad (3.15)$$

and

$$X' = [x' \ y' \ 1] \quad x = [x \ y \ 1] \quad (3.16)$$

Now divide the 1st and 2nd row of equation (3.14) and similarly the 2nd and 3rd row, the following set of equations can be written as:

$$-h_1x - h_2y - h_3 + (h_7x + h_8y + h_9)u = 0 \quad (3.17)$$

$$-h_4x - h_5y - h_6 + (h_7x + h_8y + h_9)v = 0 \quad (3.18)$$

Equations (3.16) and (3.17) can be expressed in matrix form as:

$$A_i h = 0 \quad (3.19)$$

where

$$A_i = \begin{bmatrix} -x & -y & -1 & 0 & 0 & 0 & ux & uy & u \\ 0 & 0 & 0 & -x & -x & -1 & vx & vy & v \end{bmatrix} \quad (3.20)$$

And

$$h = [h_1 \ h_2 \ h_3 \ h_4 \ h_5 \ h_6 \ h_7 \ h_8 \ h_9] \quad (3.21)$$

Now if 2 equations are provided by each correspondence point, 4 correspondence points are enough and can solve the 8 DOF of H. The limitation is no any three points can be collinear. One per correspondence point, there is now four 2×9 A_i matrices, making a single 8×9 matrix A.

In many cases, for more robust solution, we can use more than 4 correspondence points. However many correspondence points are used, then A will still have rank 8 if all the points are exact and there is a single homogeneous solution. However, due to some uncertainty there may not be an exact solution if the points are not exact there. If everything goes right, vector h has to be solved for minimising the cost function.

3.4. RANSAC

RANSAC (RANdom SAMple Consensus) is a repetitive method for calculating the mathematical model from a bunch of observed data set which contains many outliers as well as inliers. The algorithm is non deterministic which produces a reasonable result with a certain probability. Hence, probability increases as repetition increases. Assuming that the observed data contains inliers, that is, data which can have a parameter model and outliers that do not have or do not fit the model.

RANSAC algorithm input consists a set of observed data and a parameterized mathematical model which can fit to the observations or observed data, along with some confidence parameters. RANSAC goal can be achieved by iterative selection of a random subset data points from the original data, supposed to be inliers. This can be tested as follows:

1. A model is estimated in accordance with the supposed inliers.
2. All other data points are tested iteratively to fit the model.
3. If a point fits to the estimated model, that is considered to be as hypothetical inlier.
4. The efficiency of the estimated model depends on the number of points sufficiently have been selected as hypothetical inliers.
5. Using all the hypothetical inliers the model is re-estimated again.
6. the model is finally assessed by calculating the error of the inliers with respect to the model.

A fitting problem is given with parameter x , it estimates the parameters considering the following assumption:

- Available data items are totally M
- From N data items the parameter is be estimated.
- Let P_g be the probability of a randomly selected data item being part of a good model.
- Let P_f be the probability that the algorithm exit without finding a good fit if one exists.

3.4.1. RANSAC Algorithm

The algorithm is as follows by considering the above fitting problem:

1. N data points are randomly selected.
2. Parameter X is estimated.
3. Number of data points which fit the model with parameter vector X are found out within a user defined tolerance. Let it be K .
4. If K is large enough, it is accepted and exit with success.
5. The process is repeated $1.4 L$ times.

6. The process is failure if it again enters the loop.

Value of L is found by the following formulae:

Pf = Probability of L consecutive failures

Pf = (Probability that a given trial is a failure) L

Pf = (1 – (Probability that a random data item fits the model) N) L

$$P_{fail} = (1 - (P_g)^N)^2 \quad (3.22)$$

$$L = \frac{\log(P_{fail})}{\log(1 - (P_g)^N)} \quad (3.23)$$

3.5. Homography Computation

It is mapping between two spaces which is often used to represent the correspondence between two images of the same scene. It is widely used for the project where multiple images are taken from a rotating camera center ultimately warped together to produce a panoramic view.

The Homography Detection Algorithm using RANSAC scheme is:

1. Detection of corner points in both the images.
2. Corner points is processed with the Variance normalized based correlation.
3. Those pairs are collected from a set of candidate match which has sufficiently high correlation score.
4. For homography computation, four points are selected at random from the matched set of candidate points.

5. Those pairs are selected which agree with the mathematical homography model. For some threshold ϵ , a pair (p, q) is considered to agree with a homography H ,

$$Dist(Hp, q) < \epsilon \quad (3.24)$$

6. Repeat steps 4 and 5 till we get sufficient number of pairs which agree above Eq. (3.23).
7. Now to find the best homography model, for all the pair correspondences, the homography is recomputed by solving step 5.

Chapter – 4

Image Warping and Blending



→ *INTRODUCTION*

→ *IMAGE WARPING METHODS*

→ *INTRODUCTION*

→ *IMAGE BLENDING METHODS*

→ *FEATHERING*

→ *ALPHA BLENDING*

→ *PYRAMID BLENDING*

→ *GRAPH CUT BLENDING*

4.1. Image warping

Image warping places the images on the single mosaic plane after the homography process. Warping of images is the process of shaping an image digitally such as any shape embedded in the image has been significantly distorted. Basically we can simply warp all the input images to a plane defined by one of them known as reference image. Warping can correct image distortion and can be used for creative purposes. The same procedure is equally applicable to video. The two images that will form the mosaic are warped, by using the geometric transformation. Images can be transformed in various ways using the warping procedure, like, in pure warping the points are mapped to new points without altering the colors. It can be done mathematically based on any function from plane to the plane. If the function is put in the original then it can be reconstructed.

The following list give idea where image warping can be applied.

- Images can be distorted due to simulation of optical deviation.
- Images may be viewed as if they had been projected on to a curved or mirrored surface.
- Images may be divided into polygons and every polygon is distorted.
- Images may be aberrated using morphing.

4.2. Image Warping methods

There are two methods for generation of an image for any type of distortion.

4.2.1. Forward mapping

This is type of warping where points from the source image are transferred to the target image. The given mapping model function from sources to images is directly applied. Fig. 4.1

shows the forward warped image. The warped image is defined by mapping from the coordinate space of a source image (u,v) to the destination image (x,y) .

$$x' = x(u, v) \quad \text{and} \quad y' = y(u, v) \quad (4.1)$$

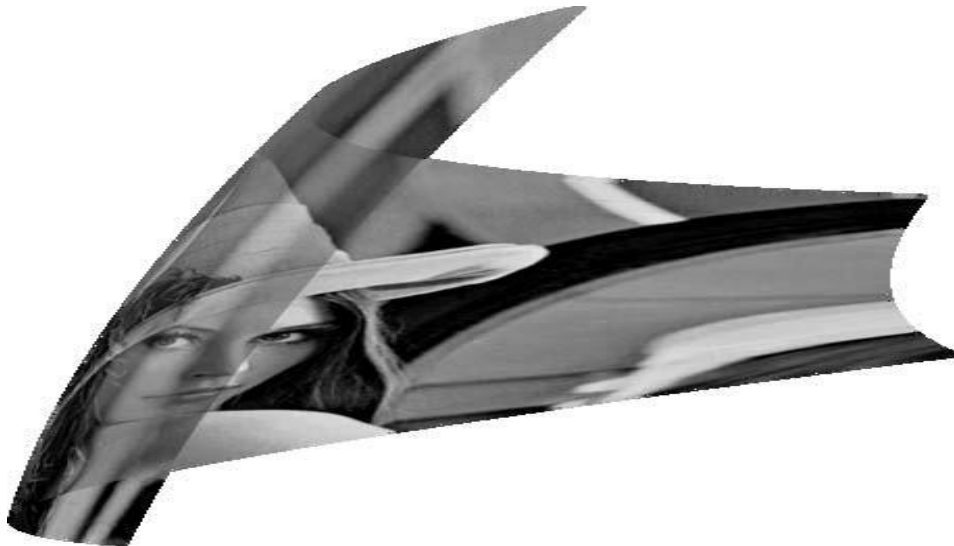


Figure 4.1. Forward warped image.

4.2.2. Inverse mapping

This is just opposite to that of the warping procedure discussed above. In this warping procedure, points from the target image are copied to the source image. Fig. 4.2 shows the inverse warped image. The mapping is such that the source is formed from the target image. If the source coordinates are the functions of the destination coordinates, the mapping is called an inverse mapping.

$$u' = u(x, y) \quad \text{and} \quad v' = v(x, y) \quad (4.2)$$



Figure 4.2. Inverse warped image.

Forward and inverse mappings actually describe different kinds of classes of image warping. A forward mapping can be described as many-to-one mapping and hence it can happen in model warps where several points map to the same point in the destination image from the source image. An inverse mapping, on the other hand, can be described as one-to-many mapping and can model warps where several points map to the same point in the source image from the destination image.

In addition to this conceptual difference, different implementation techniques are used for the forward and inverse mappings. An image warped by a forward mapping function is most of the time a simple natural process. It is performed by pixel by pixel scanning of the source image and evaluating the mapping function for calculating the corresponding location in the target image. Then after filling that location with the grey level colour intensity value of the source pixel in the destination image.

On the other hand, an image warping method described by an inverse mapping is performed by pixel by pixel scanning of the target image and evaluating the mapping function

for calculating the corresponding location in the source image. Then after filling that location with the grey level colour intensity value of the target pixel in the source image.

4.3. Image blending

This is the final step in the image mosaicing process. This is to blend the pixel colours in the overlapped region to avoid the seams. Image blending is the procedure to obtain a smooth transition between images by removing the intensity seam in the neighbourhood of the boundary as and modifying the image grey levels at the junction joint. It also determines the representation in the overlapping area.

Whenever the images are taken by rotating the camera position, or taking the images at different time intervals, or at difference exposures, then due to all these phenomenon the images differs in photometric. This photometric effect can be seen at the junction of the mosaiced image when two or more images are used for mosaicing. This creates an intensity seam which is sudden change in the intensity value for the same scene. The highlighted part in Fig. 4.3 shows the intensity seam.



Figure 4.3. Highlighted part of image showing intensity seam.

4.4. Image blending types

There are different image blending procedure as follows:

4.4.1. Feathering

This is the simplest of all the image blending procedure. This is a known as transition smoothing algorithm. In this method, the boundary of the two images are smoothed and then are placed side by side. This removes the step change in intensity values of the same scene but did not remove the seam completely. Fig. 4.4 shows the feather blending.



Figure 4.4. Feather blending.

4.4.2. Alpha blending

This is also transition smoothing algorithm. In this method, instead of smoothing the image boundaries, the image boundaries are gradually degraded in decreasing order as well as increasing order according to the equation,

$$I = I_1 * alpha + I_2 * (1 - alpha) \quad (4.3)$$

The result of feathering blending are same or different depending upon the size of the window. The alpha value depend upon the window size. It varies from 0 to 1 and vice versa and the increment or decrement respectively depends on the window size. Fig. 4.5 shows the feather blending with different window sizes.

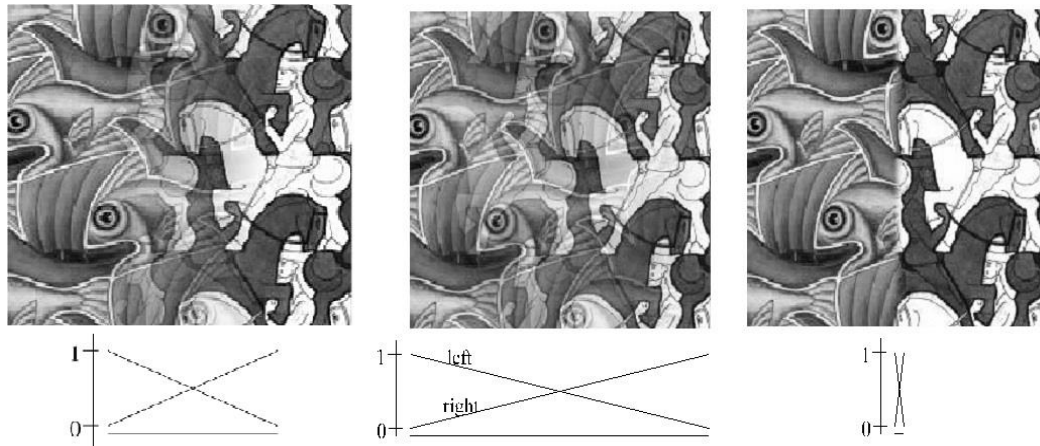


Figure 4.5. Alpha blending with varying window size.

4.4.3. Pyramid blending

This is also a kind of transition blending. The images are decomposed into the Laplacian pyramid and are then blended in each stage. As shown in Fig. 4.6,

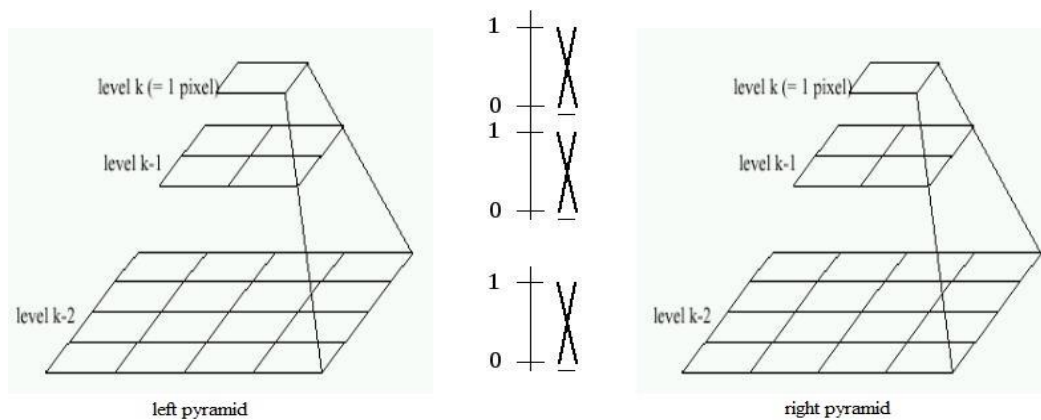


Figure 4.6. Pyramid creation in pyramid image blending.

The blending equation for the Laplacian pyramid at each level can be written as:

$$L_{12}^i = L_1^i * R^i + L_2^i * (1 - R^i) \quad (4.4)$$

where L_1^i and L_2^i represent the image 1 and image 2 at i th level of the Laplacian pyramid and R^i is the region mask at i th level of the Laplacian pyramid. This can be also considered as feathering blending (in case of feather mask) done at different image down-sampled version. The example for pyramid blending is shown in Fig. 4.7



Figure 4.7. Pyramid blending.

4.4.4. Graph cut Blending

This is a kind of optimal seam removal image blending algorithm. As the name indicates, in this algorithm the cut in the image is made in the common overlapping area part of the two images using the minimum cut / maximum flow algorithm.

In image processing, an image can be referred as a graph. If the image is gray scale image then it is a 2-D graph or if the image is colour image then it is a 3-D graph. A directed weighted graph is denoted as,

$$G = \langle \vartheta, \varepsilon \rangle \quad (4.5)$$

where G is a graph, v is a set of nodes and E is a set of directed edges. Terminals are the additional special node that the graph contains. Terminals in computer vision, can be referred as a set of labels that is assigned to pixels, with two terminals that are usually referred as the source, s and the target, t as shown in Fig. 5-7.

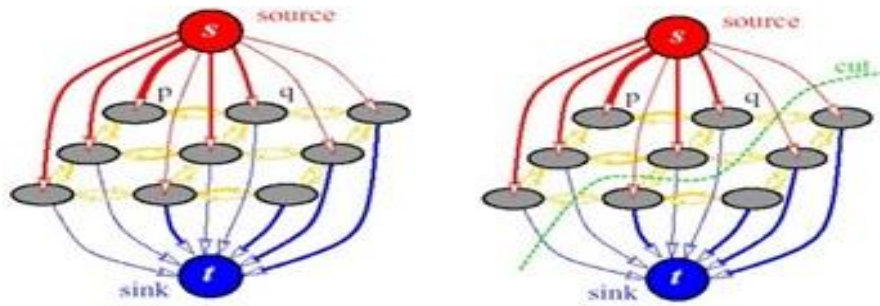


Figure 4.8. Graph and graph cut with source and target images.

The goal is to minimize the energy function by finding a minimum cost labelling function in the standard form,

$$E(f) = \sum_{p \in P} D_p(f_p) + \sum_{p,q \in N} V_{p,q}(f_p, f_q) \quad (4.6)$$

where N is a system of $P \times P$ neighbourhood pixels. f_p assigns the label to the pixel p is defined by $D_p(f_p)$, while f_p and f_q assigns the labels to the adjacent pixels p and q is represented by $V_{p,q}(f_p; f_q)$ which is used to impose spatial smoothness.

Optimal seam finding methods, in contrast, changes the position of the intensity seam in the overlapping area between two images where minimum intensity differences exist by using graph cut and energy minimising function. The seam is then further optimised to get rid of the available seam.

The image (a) and (b) from Fig. 4.7 are blended using the graph cut as shown in Fig. 4.9. The images are blended from the middle as the overlapping part is the small window throughout the image.

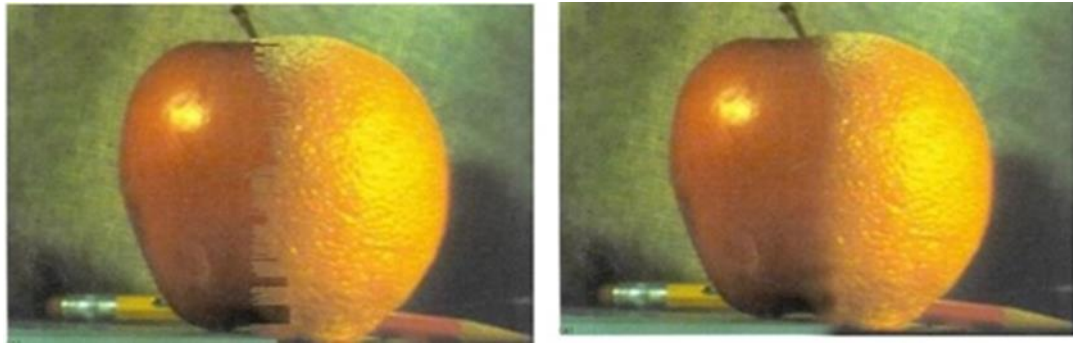


Figure 4.9. Image blending using Graph cut and optimised graph cut method.

The minimum s/t cut problem can be solved by maximum flow from the source s to the target t . The maximum flow is the maximum amount of water that flows from the source to the sink. Ford and Fulkerson [21] theorem states that a maximum flow from source s to target t saturates at the point where there is a minimal flow. Interpreting that the graph edges are directed pipes with capacities equal to edge weights. A minimum cut in the graph divides the nodes through a set of edges into two disjoint parts. Thus, minimum cut and maximum flow problems are the same.

Chapter – 5

Implementation and Results



→ *IMPLEMENTATION*

→ *RESULT FOR 1ST SET OF IMAGES*

→ *RESULT FOR 2ND SET OF IMAGES*

→ *RESULT FOR 3RD SET OF IMAGES*

5.1. Implementation

Image mosaicing is the procedure of joining two or more than two overlapping images so as to get the large field of view. The steps in image mosaicing are image registration, image warping and image blending. Image registration involves feature detection, feature descriptor, feature matching and transformation model estimation. All of these are already discussed in the preceding chapters.

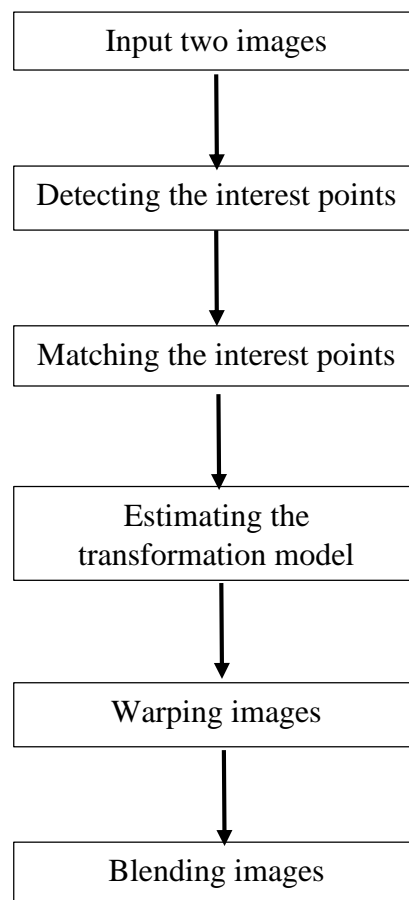


Figure 5.1. Work flow of the image mosaicing algorithm.

The algorithm for mosaicing of images implemented in MATLAB R2012b and has been executed in system with configuration i5 processor, 4 GB RAM, 2 GB cache memory and 2.8GHz processor. The implementation and result will be described side by side.

5.2. Results

The result is divided in three parts of input images where 1st part consists of two images, 2nd part consists of three images and 3rd part consists of five images.

5.2.1. Mosaicing of two input images

There are two images in 1st part for mosaicing of images. The images are shown in Fig. 5.2. The step by step procedure and results for 1st set of two input images are as follows:



Figure 5.2. Two input images for image mosaicing.

1. Detect the interest points using the Harris corner detection method in both the images. Corresponding resultant is shown in Fig. 5.3.
2. Create the feature descriptor around the interest points that is corner, in both the images. The feature descriptor is a window of $N \times N$ pixels around the interest point.



Figure 5.3. Images with Harris corners.

3. Match the feature descriptor of one image with that of reference image. Only those interest points are kept which are matched close and rest are discarded. The correspondence match of the points are shown in Fig. 5.4.

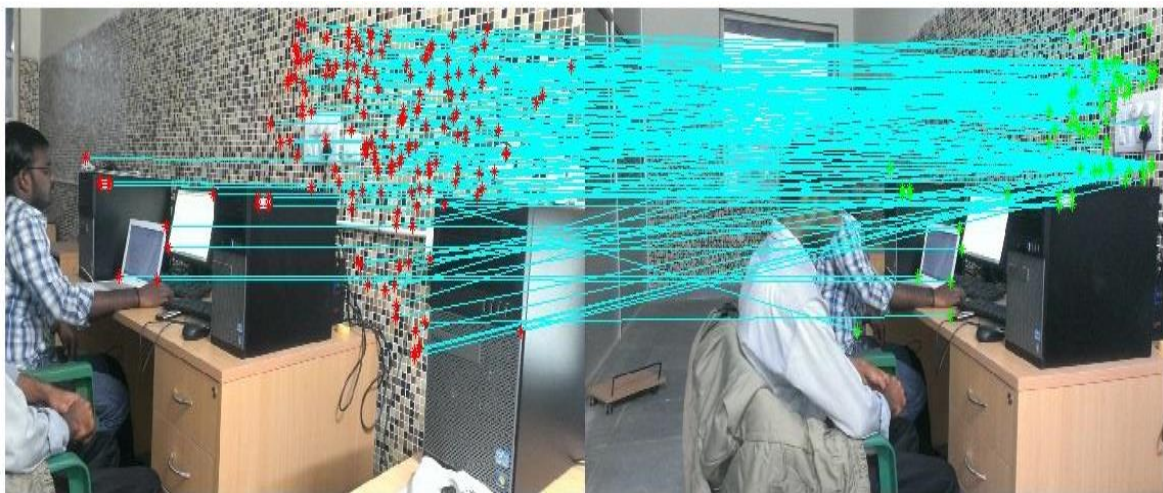


Figure 5.4. Interest point descriptor correspondence match in both the images.

4. Estimate the transformation model using the interest points. Homography and RANSAC are together used for estimating the homograph matrix, H .

5. Apply the transformation matrix H to the source image. The corresponding homographed images in shown in Fig. 5.5.



Figure 5.5. Homographed image with respect to other image.

6. Warp the homographed image and reference image onto a common mosaic frame. After warping the mosaiced image looks like as shown in Fig. 5.6

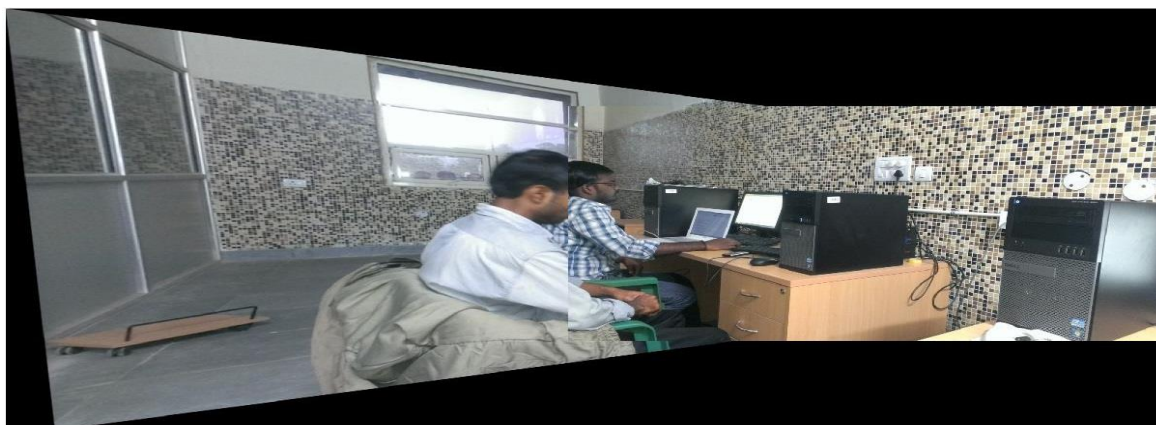


Figure 5.6. Mosaiced image.

7. The last step in the process is image blending. Graph cut image blending procedure has been used for the removal of intensity seam from the junction joint of images. Final blended mosaiced image is shown in Fig.5.7.

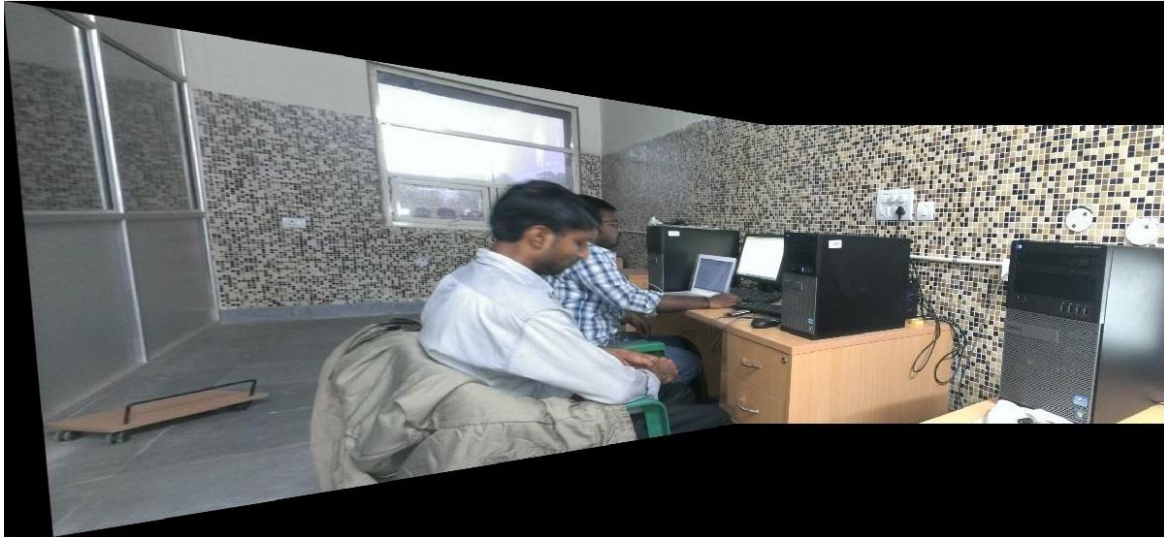


Figure 5.7. Mosaiced image with graph cut blended.

5.2.2. Mosaicing of three input images

There are three images in 2nd set of input images. This section contain the mosaiced images of three input images. The procedure is same as discussed step by step for 1st set of input images. Take two images at a time. After the mosaicing of 1st and 2nd image, mosaic 3rd image with resultant mosaic of 1st and 2nd image. The three input images for mosaicing are shown in Fig. 5.8 and the corresponding mosaiced image is shown in Fig. 5.9.



Figure 5.8. Three input images for image mosaicing.



Figure 5.9. Mosaiced image with graph cut blending.

5.2.3. Mosaicing of five input images

There are five input images in 3rd set of images. This part contains the mosaiced result of five input images. The same procedure is followed for the mosaicing as discussed above. The two images are taken at a time and the procedure is repeated till all the images are incorporated. The Fig. 5.10 shows the five input images for mosaicing and the corresponding mosaiced image is shown in Fig. 5.11.



Figure 5.10. Five input images for image mosaicing.



Figure 5.11. Mosaiced image.

5.3. Discussions

The mosaicing of images has been done on two, three and five input images. Graph cut method has been employed for the purpose of image blending. The expansion of alpha procedure is used for the optimisation of the minimal cut obtained using the minimum cut / maximum flow

algorithm. Blending using graph cut method removes the ghosting effect caused by the moving object present in the image. Other blending methods suffers ghosting effect whereas graph cut method does not as it makes use of a minimal cut in the overlapping area.

Harris corner algorithm is used for detection of interest points. Interest points are matched and homography transformation model is obtained from the matched points. There are images where the interest points obtained from the Harris algorithm does not provide with the useful solution such as the transformation model cannot be calculated with the given number of matched points. This is because, in some images as shown in Fig. 5.2, many corners are aggregated in some confined area and rest of the part is left uncovered.

So for these types of images interest points are detected from the mask obtained from the unsharp masking algorithm. Unsharp masking is used for the sharpening the image.

Chapter – 6

Conclusion



→ *CONCLUSION*

→ *SUGGESTIONS FOR FUTURE WORK*

6.1. Conclusion

Image mosaicing is the method of assembling the images with overlapping area into a single image. Harris corner detector is the most popular and widely used corner detector. It can be combinely used for corner and edge detection but in this chapter it is used for detection of corner points, which are nothing but the interest points. Interest points are used for finding the match between two images having some common overlapping area. This corner detector is efficient, cheap and rotation invariant but it can' t handle the images which suffer scale variation.

Homography and RANSAC are together used for the transformation model estimation. The RANSAC algorithm randomly chose the four points for estimating the homograph matrix. The iterations are made for getting number of homograph matrix. The matrix that gives the maximum number of inliers is used for the homography purpose. Generally, one point gives two set of equations, so four points are enough for determining the best solution. More points can be used for more accurate estimation

Estimated the transformation model, the image is then homographed with respect to the reference image and warped on a common mosaic frame.

Image blending using graph cut method has been implemented. The minimum cut / maximum flow algorithm has been used for the graph cut method. The graph cut optimisation has been applied for the removal of the optimal seam placed by the minimum cut / maximum flow algorithm. It also corrects the geometrical distortion occurred due to the movement of object in the images for mosaicing. It takes care of the moving objects whereas other image blending algorithm cannot. For the optimisation purpose, the expansion of alpha technique is used and Gaussian filtering is applied after then.

6.2. *Suggestions for Future Work*

The test input images used for the present work were the planar 3-D images, it can be extended for the cylindrical and spherical images as well. Individual algorithms can be further improved at the algorithmic level rather than at the level of implementation to incorporate the added and complimentary features of the other algorithms, and hence the execution time as well the procedural length can be greatly reduced.

The algorithm can also be extended for automatic stitching of images. The algorithm can automatically detect the first or second image based on the correlation match between the images.

Dissemination

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- [2] Shishir Maheshwari, Umesh C. Pati, “Graph cut optimisation using expansion of alpha and Gaussian filtering for image blending”, Communicated to International Journal of Image and Graphics (World Scientific Publishing Company).

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