Chapter 2

Literature Review

2.1 Overview

A state-of-the-art review of image registration methods for various images processing application is presented in this chapter. During the last few decades, image acquisition devices have undergone rapid development with growing amount and diversity of obtained images invoked the research on automatic image registration. A comprehensive review of the existing literature available on image registration methods has been described. Registration methods can be categorized with respect to various criteria. The ones usually used are the application area, dimensionality of data, type and complexity of assumed image deformations, computational cost and the essential ideas of the registration algorithm. Mainly two types of registration methods described in literatures are area based methods and feature based methods. Majority algorithms consist of feature detection, feature matching, estimation of transform model and resampling to achieve image registration. The implementation of each registration step has its typical problems. First appropriate feature for given task should be decided such that feature must be distinctive detectable objects which are frequently spread over the images and these detected feature sets in the reference and sensed images must have enough common elements, even in situations when the images do not cover exactly the same scene or other unexpected changes so the algorithm should be able to detect the same features in all projections of the scene regardless of the particular image deformation. If the features are incorrect then it may cause problem for feature matching. In feature matching also it may possible that selected corresponding features are dissimilar due to the different imaging conditions so feature descriptors must be selected such that it should be invariant to assumed degradation and distinguish between different detected features. Mapping or homography function to find correspondence between images should be flexible and general enough to handle all possible degradations. Finally, the choice of the appropriate type of resampling technique depends on the trade-off between the demanded accuracy of the interpolation
and the computational complexity. The nearest-neighbor or bilinear interpolation are sufficient in most cases however, some applications require more precise methods [1][8].

2.2 Image Registration Methods

1. Area- based Methods

Area based methods deal with the images without attempting to detect salient objects. Windows of predefined size or even entire images are used for the correspondence estimation.

2. Feature-based Methods

Significant regions (forests, lacks, fields), lines (region boundaries, coastlines (road, rivers) or points (region corners, line intersections, points or curves with high curvature) are features here. They should be distinct, spread all over the image and efficiently detectable. They are expected to be stable in time to stay at fixed positions during the whole experiment. Feature based methods do not work directly with intensity values so it is most suitable technique when illumination changes are expected or multi sensor analysis is used. Following section presents the review on major steps for image registration which includes feature detection, feature matching, transform model estimation and image resampling and transformation.

2.3 Feature Detection

Region features are detected by means of segmentation methods. A.Ghshtasby and G.Stockman [1], proposed the refinement of the segmentation process to improve the registration quality. The segmentation of the image was done iteratively together with the registration in every iteration in which the rough estimation of the object correspondence was used to tune the segmentation parameters. They claimed the sub pixel accuracy of registration could be achieved. H.S.Alhichri and M. Kamel [2], proposed the idea of virtual circles, using distance transform for selection of region features. Here, the selections of features are invariant with respect to change of scale.

Line features can be the representation of general line segments, object contours, coastal lines, and roads. Standard edge detection methods have been proposed by Canny [3] and by D.Marr and E.Hildreth [4], based on the Laplacian of Gaussian are employed for the line feature detection. D.Ziou and S.Tabbone [5] has given overview of edge detection techniques and also its
evaluation in terms of merits and relationships between the wide variety of existing techniques and for assisting in the selection of the most suitable technique for a specific problem.

Point features group consists of methods working with the intersections, road crossings, centroid of water regions, oil and gas pads, high variance points, local curvature discontinuities, inflection point of curves, local extrema of wavelet transform and corners. Corners are widely used as control points mainly because of their invariance to imaging geometry and because they are well perceived by a human observer. K.Rohr [6] has given localization properties of direct corner detectors. Z.Zheng [7] has given analysis of gray level corner detection. Jie Chen and Li-Hui have given the comparisons and application of corner detection algorithms [58]. They describe two widely used corner detection algorithms, SUSAN and Harris corner detection algorithms which are both based on intensity, were compared in stability, noise immunity and complexity quantificationally via stability factor, anti-noise factor and the runtime of each algorithm. It concluded that Harris corner detection algorithm was superior to SUSAN corner detection algorithm on the whole. Moreover, SUSAN and Harris detection algorithms were improved by selecting an adaptive gray difference threshold and by changing directional differentials, respectively, and compared using these three criterions. In addition, SUSAN and Harris corner detectors were applied to an image matching experiment. It was verified that the quantitative evaluations of the corner detection algorithms were valid through calculating match efficiency, defined as correct matching corner pairs dividing by matching time, which can reflect the performances of a corner detection algorithm comprehensively. They provide a direction to the improvement and the utilization of these two corner detection. Kitchen and Rosenfeld [10] proposed to exploit the second-order partial derivatives of the image function for corner detection. But this method is sensitive to noise.

From a survey of image registration methods [8] it has been concluded that the use of feature based method is recommended if the image contain enough distinctive and easily detectable objects. This is usually the case of applications in remote sensing and computer vision. On the other hand, medical images are not so rich in such details and thus area based methods are used here. Nowadays, research work is going on combining both area based and feature based approaches.
2.4 Feature Matching

The detected features in reference and sensed images can be matched by means of image intensity values in their close neighborhoods, the feature spatial distribution or the feature symbolic description.

2.4.1 Matching for Area Based Methods

These methods deal with the images without attempting to detect salient objects. W.K. Pratt [9], has given correlation techniques of image registration. Windows of predefined size or even entire images are used for the correspondence estimation. In our research we have combined this correlation technique with optimization to find the proper transformation parameters which can match original image. Huttenlocher [10] proposed a method in which they registered binary images (the output of an edge detector) transformed by translation or translation plus rotation, by means of Hausdorff distance. In case the images/objects to be registered are partially occluded the extended CC methods based on increment sign correlation can be applied [11]. Fourier methods for area based methods are preferred when acceleration of the computational speed is needed if the images were acquired under varying conditions or they are corrupted by frequency-dependent noise [8]. They exploit the Fourier representation of the images in the frequency domain. R.N. Bracewell [12] has proposed the phase correlation method based on the Fourier shift theorem and was originally proposed for the registration of translated images. The method shows strong robustness against the correlated and frequency dependent noise and non-uniform, time varying illumination disturbances. The computational savings are more significant if the images, which are to be registered, are large. E.D. Castro and C. Morandi [13] introduced an extension of the phase correlation for additional rotation information. The mutual information (MI) has appeared recently and represents the leading technique in multimodal registration. Registration of multimodal images is the difficult task but often necessary to solve, especially in medical imaging. The MI, originating from the information theory, is a measure of statistical dependency between two data sets and it is particularly suitable for registration of images from different modalities. P. Viola and W.M. Wells [14] describes the application of MI for the registration by magnetic resonance images. Thevenaz and Unser [15] tried to combine various approaches, solving individ-
ual steps of MI registration. In our research, we have combined mutual information technique with NM optimization and to find mutual information, we use joint histogram (conventionally it is used for color image processing) to find joint entropy. For optimization in area based methods, R.Sharma, M.Pavel[17] has given the application of Gauss-Newton numerical minimization algorithm for minimizing the sum of squared differences, where the projective geometric deformation was used. Seok Lee and Minseok choi[37] has given the direct search algorithms for image registration. They have demonstrated the algorithm which is numerically more stable and the better convergence properties than existing local coordinate based algorithms. Gradient based methods exploit derivative information of the function and are usually faster search methods [53]. In Levenberg- Marquardt method, Cauchy’s method is initially followed, there after Newton’s method is adopted. The transition from Cauchy’s method to Newton’s method is adaptive and depends on the history of the obtained intermediate solutions [53, 54]. The problem for which the LM algorithm provides a solution is called Nonlinear Least Squares Minimization.

2.4.2 Matching for Feature Based Methods

Two sets of features in the reference and sensed images represented by the control points (points themselves, end points or centers of line features, centers of gravity of regions, etc) have been detected. The aim is to find the pair wise correspondence between them using their spatial relations or various descriptors of features. Methods based primarily on the spatial relations among the features are usually applied if detected features are ambiguous or if their neighborhoods are locally distorted. A.Goshtasby and G.C.Stockman [18] described the registration method based on the graph matching algorithm. He was evaluating the number of features in the sensed image that after the particular transformation, fall within a given range next to the features in the reference image. The transformation parameters with the highest score were then set as a valid estimate.

In methods using invariant descriptors the correspondence of features can be estimated using their description, preferably invariant to the expected image deformation. The most important ones are invariance (the descriptions of the corresponding features from the reference and sensed image have to be the same), uniqueness (two different features should have different descriptions), stability (the description of a feature which is slightly deformed in an unknown manner
should be close to the description of the original feature) and independence (if the feature description is a vector, its elements should be functionally independent). However, usually not all these conditions have to (or can) be satisfied simultaneously and it is necessary to find an appropriate trade-off [18]. Zana and J.C. Klein [19] describe each feature point by means of angles between relevant intersecting lines. A large group of the registration methods is based on the relaxation approach, as one of the solutions to the consistent labeling problem (CLP), to label each feature from the sensed image with the label of a feature from the reference image, so it is consistent with the labeling given to the other feature pairs. The process of recalculating the pair figures of merit, considering the match quality of the feature pairs and of matching their neighbors, is iteratively repeated until a stable situation is reached. S. Ranade and A. Rosenfie[20] have done point pattern matching by relaxation pattern recognition. Hall and Llinas gave a general introduction to multi-sensor data fusion [21]. Nitin Bhatia and Megha Chhabra [60] have given the method for accurate corner detection using two step approach. They describe different approaches to detect corner in efficient way. Based on the works carried out by Harris method, the authors have worked upon increasing efficiency using edge detection methods on image, along with applying the Harris on this pre-processed image. This paper contains a quantitative comparison of three such modified techniques using Sobel–Harris, Canny-Harris and Laplace-Harris with Harris operator on the basis of distances computed by these methods from user detected corners.

Recent developments of multi sensor and multi focus image registration have not been discussed in detail yet. Many image processing algorithms use principal component as a feature. A set of variables that define a projection that encapsulates the maximum amount of variation in a dataset is known as principal component [45]. Principal Component Analysis (Karhunen-Loeve or Hotelling transform) belongs to linear transforms based on the statistical techniques. This method provides a powerful tool for data analysis and pattern recognition which is often used in signal and image processing. PCA is commonly used in microarray research as a cluster analysis tool [43,44,51]. In our proposed algorithm, we have developed window based Principal Component Analysis approach which gives best result compared to conventional averaging method for multi focus images. Chiou-Ting Hsu and Rob Beuker [22] have given the method for multi resolution feature based image registration in which they have used projective transformation and images are taken form hand held digital still camera while the rotation about its optical axis and scaling
changes are due to manual operation. Roger D. Eastman [23] has given the research issues in image registration for remote sensing. C.A. Glasbey and K.V. Mardia [46] have given the review of different warping methods for feature correspondence. Image warping is a transformation which maps all positions in one image plane to positions in a second plane. Image warping is in essence a transformation that changes the spatial configuration of an image [52]. Euclidean, affine and perspective transformation are described to establish correspondence in terms of rotation, translation, scaling, shearing in x and y direction using selected control points [46, 52].

In our research we have developed multimodal, multi focus and multi view image algorithms which can be used for remote sensing applications and medical image applications.

2.5 Transform Model Estimation

After the feature correspondence has been established the mapping function is constructed. It should transform the sensed image to overlay it over reference one. The correspondence of the CPs from the sensed and reference images together with the fact that corresponding CP pairs should be as close as possible after the sensed image transformation are employed in the mapping function region. The task to be solved consists of choosing the type of the mapping function and its parameter estimation. The type of the mapping function should correspond to the assumed geometric deformation of the sensed image, to the method of image acquisition (e.g. scanner dependent distortions and errors) and to the required accuracy of the registration. For transform model estimation available models are global mapping models, local mapping models, mapping by radial basis functions. D.N. Fogel [24] has given the Image rectification with the use of radial basis functions. A. Fischler and R. Bolles [48] have presented a technique to homography estimation using a new paradigm, Random Sample Consensus (RANSAC), for fitting a model to experimental data introduced. RANSAC is capable of interpreting/smoothing data containing a significant percentage gross errors, and is thus ideally suited for applications automated image analysis where interpretation based on the data provided by error-prone feature detectors [47, 48, 67]. They describe application of RANSAC to the Location Determination Problem (LDP) for given an image depicting a set landmark with known locations; determine that space from which the image was obtained. In response to a RANSAC requirement, new results derived on the minimum number of landmarks needed obtain a solution, and algorithms are presented.
computing these minimum-landmark solutions in form. These results provide the basis for an automatic system that can solve the LDP under difficult viewing.

A. Agrawal, C. Jawahar and P. Narayana [68] have given the survey of planar homography estimation techniques. They survey several homography estimation techniques from the literature, presented the essential theory behind each method briefly and compared with the others. P. Rangarajan and P. Papamichalis [69] have presented method for estimation of homographies without normalization. Unlike existing linear methods, they proposed Taubin estimator, which is theoretically unbiased, and unaffected by similarity transformations of correspondence in the two views. In addition, it can be adapted to estimate other quantities such as trifocal tensors. Eduard Seradell and M. Ozuysal [70] have combined geometric and appearance priors of ambiguous descriptors for robust homography estimation. For each point they retain its best candidates according to appearance and then prune the set of potential matches by iteratively shrinking the regions of the image that are consistent with the geometric prior. They have successfully computed homographies between pairs of images containing highly repetitive patterns and even under oblique viewing conditions.

Yao Jianchao [71] has presented technique for estimation by feature and intensity matching. The algorithm utilizes a parametric projective model accounting for geometrical variation and a polynomial model with a small number of polynomial coefficients explicating the smooth spatially varying illumination variation. The initial projective model parameters are first estimated by using feature-based approach. Subsequently, the coefficients of the illumination model are determined simultaneously with the projective transformation parameters through the process of intensity matching. S. Konishi, A. Yuille and S. Chun Zhu [72] have used edge cues for model estimation. They formulate edge detection as statistical inference. This statistical edge detection is data driven, unlike standard methods for edge detection which are model based. They evaluate the effectiveness of different visual cues using the Chernoff information and Receiver Operator Characteristic (ROC) curves. They show that their approach gives quantitatively better results than the Canny edge detector when the image background contains significant clutter and prove the effectiveness of different edge cues and gives quantitative measures for the advantages of multilevel processing, for the use of chrominance, and for the relative effectiveness of different detectors.
2.6 Image Resampling and Transformation

The mapping functions constructed during the previous step are used to transform the sensed image and thus to register the images. The transformation can be realized in a forward or backward manner. Each pixel from the sensed image can be directly transformed using the estimated mapping functions. This approach, called a forward method, is complicated to implement, as it can produce holes and/or overlaps in the output image (due to the discretization and rounding). Hence, the backward approach is usually chosen. The registered image data from the sensed image are determined using the coordinates of the target pixel (the same coordinate system as of the reference image) and the inverse of the estimated mapping function. The image interpolation takes place in the sensed image on the regular grid. In this way neither holes nor overlaps can occur in the output image. A detailed investigation and comparison of resampling techniques was carried out by J.A.Parker [25]. He has given comparisons of interpolating methods for image resampling. In our proposed algorithms, image blending using bilinear interpolation technique have been used to create a final registered image after estimation of transform parameters.

2.7 Evaluation of Image Registration Methods

Regardless of the particular images, the used registration method, and the application area, it is highly desirable to provide the user with an estimate how the accurate the registration actually is. T.Makela and N.Pauna [73], have given the review of cardiac image registration methods. In this paper, the current status of cardiac image registration methods is reviewed. The combination of information from multiple cardiac image modalities, such as magnetic resonance imaging, computed tomography, positron emission tomography, single-photon emission computed tomography and ultrasound are of increasing interest in the medical community for physiologic understanding and diagnostic purposes. Medical images edge detection based on mathematical morphology is described in [88]. M.Xia and B.Liu [74] have registered the images using “Super-Curves”. They solve the 2-D affine image registration problem by curve matching and alignment. Their approach starts with a super-curve, which is formed by superimposing two affine related curves in one coordinate system. They use B-spline fusion technique to find a single B-spline approximation of the super-curve and a registration between the two curves simultaneously. This approach achieves superior accuracy and efficiency in curve matching and alignment.
Q. Zheng and R. Chellappa [75] have described a computational vision approach to image registration. In this paper, a computational vision approach is presented for the estimation of 2-D translation, rotation, and scale from two partially overlapping images. They used an illuminant direction estimator for obtaining an initial estimate of camera rotation and feature points are located based on a Gabor wavelet model. This results in a fast and novel algorithm that produces good results even when large rotations and scale changes have occurred between the two frames. Different matching algorithms for image registration are discussed in [76, 77, 78]. They have given the fast multi-resolution feature matching algorithms for exhaustive search in large databases, feature similarity, and for airport lighting.

Y. Bentoutou, N. Taleb, and J. Ronsin [83] describe the method for an automatic image registration in remote sensing. This technique exploits the invariant relations between regions of a reference and a sensed image, respectively. It involves an edge-based selection of the most distinctive control points (CPs) in the reference image. The search for the corresponding CPs in the sensed image is based on local similarity detection by means of template matching according to a combined invariants-based similarity measure. The final warping of the images according to the selected CPs is performed by using the thin-plate spline interpolation. An efficient technique for automatic iris image acquisition and preprocessing system is given by K. Quingqi and Q. Sun [86]. Imam S, A. Yetik, and A. Nehorai [87] have described the performance bound of image registration by numerical examples. In this paper bounds on a wide variety of geometric deformation models, including translation, rotation, shearing, rigid, more general affine and nonlinear transformations, are derived and extended to unknown original objects.

### 2.8 Summary

Image registration is one of the most important tasks when integrating and analyzing information from various sources. From the above literature survey, it is concluded that due to diversity of the images to be registered and due to various types of degradations it is impossible to design a universal method applicable to all registration tasks. So the registration method should be designed according to application-dependent data characteristics. Automatic image registration still remains an open problem. Multimodal registration and registration of N images (where N>2) belong to the most challenging task at this moment so multi modal registration and registration of more than two multi view images having different information is motivation behind this thesis.