<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AT</td>
<td>Adaptive Thresholding</td>
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<tr>
<td>SWT</td>
<td>Stroke Width Transform</td>
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<tr>
<td>LPR</td>
<td>License Plate Recognition</td>
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<tr>
<td>RST</td>
<td>Rotation, Scaling and Translation</td>
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<td>LP</td>
<td>License Plate</td>
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<tr>
<td>RMSE</td>
<td>Root Mean Square Error</td>
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<tr>
<td>PSNR</td>
<td>Peak Signal to Noise Ratio</td>
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<tr>
<td>SSIM</td>
<td>Structural Similarity Index Matrix</td>
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<tr>
<td>CC</td>
<td>Cross Correlation</td>
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<tr>
<td>SIFT</td>
<td>Scale Invariant Feature Transform</td>
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<tr>
<td>DoG</td>
<td>Difference of Gaussian</td>
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<tr>
<td>DSP</td>
<td>Digital Signal Processing</td>
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<td>ISC</td>
<td>Increment Sign Correlation</td>
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<tr>
<td>MCC</td>
<td>M- estimator Correlation Coefficient</td>
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<tr>
<td>NCC</td>
<td>Normalized Cross Correlation</td>
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<td>MI</td>
<td>Mutual Information</td>
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<tr>
<td>PDF</td>
<td>Probability Distribution Function</td>
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<tr>
<td>RANSAC</td>
<td>RANdom SAmple Consensus</td>
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<td>PSO</td>
<td>Particle Swarm Optimization</td>
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<td>MRI</td>
<td>Magnetic Resonance Image</td>
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<td>CT</td>
<td>Computer Tomography</td>
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<td>PET</td>
<td>Positron Emission Tomography</td>
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<td>FOV</td>
<td>Field Of View</td>
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CHAPTER 1: INTRODUCTION

The field of image processing refers to processing digital images by means of a digital computer. It refers to processing of a 2D data / information by a computer. An image is a two dimensional function f(x, y), where x and y are spatial coordinates and the value of f is called pixel intensity. Vision is the most advanced of our senses, so it is not surprising that images play the single most important role in human perception. Today there is almost no area of technical endeavor that is not impacted in some way by digital image processing. Over the past 35 years, there has been much interest in the automatic processing and analysis of digital images, and many important techniques have been developed.

Modern digital technology has made it possible to manipulate multi dimensional signals with systems. The goal of this manipulation can be either image processing, image analysis or image understanding. In image processing, input image is processed, modified and resultant image is produced which is better than the original image. In image analysis, various parameters are calculated and measurements are done for the input image and in image understanding, high level description parameters are determined.

There are many techniques that require processing the digital images like image enhancement, image restoration, image segmentation, image compression, image matching, image registration and many more. The images need to be geometrically aligned for better observation. This procedure of mapping points from one image to corresponding points in another image is called Image Registration.
My contribution for the research work will focus on various algorithms for image matching and registration.

Image registration is the process of aligning two or more images of the same scene captured from different angles /view points, at different times and by different camera. It is a crucial step in all image analysis tasks in which final information is gained from the registered image. It consist transformation which modifies an image so that it matches another one. Many types of transformations may be considered like Fourier transformation, cosine transform, Hough transform, wavelet transform and affine transform and many more. Geometric affine transformations such as scaling, rotation, translation have been implemented. Image registration geometrically aligns two images – reference image and sensed image. One of the images is kept unchanged which is referred to reference image and other image, sensed image is deformed. A sensed image must be transformed to match the orientation and scale of reference image. Registering two or more images is useful in various fields such as computer vision – shape recovery, automatic change detection, automatic target recognition, medical imaging – monitoring healing therapy, monitoring of the tumor, diagnosis, remote sensing – motion tracking, mosaicing, fusion and metrology – science of measurement.

There are several algorithms available for this, like transformations using Fourier analysis, cross correlation, Eigen value decomposition, moment matching, warping, procedural approach, anatomic atlas, internal landmarks and many more. Correlation, feature and optimization based algorithms are investigated in this thesis.

Mainly, image matching and registration is required in remote sensing, medical imaging and computer vision. Remote sensing includes multi spectral classification, environmental monitoring, image mosaicing, weather forecasting, change detection, integrating information from geographic information systems (GIS) and to create
super resolution images. Medical imaging includes monitoring tumor growth, verification of treatment, combining CT and MRI images to obtain total information about the patient and comparing patient’s data with anatomical atlas. Automation for the industrial quality control and target detection are some of computer vision applications.

**1.1 Image Registration Methodology**

As mentioned above, the image registration is widely used in computer vision, medical imaging, satellite imaging and many more. Based on the application, the methodology is classified into following categories:

1. **Multi view analysis:**

   Images of the same scene are taken from different angles, so the goal is to increase the Field Of View (FOV) by registering those images. It can be used in satellite image processing for image mosaicing.

2. **Multi temporal analysis:**

   Images of the same scene are acquired at different time and under different conditions. The goal is to find the changes in the scene between two consecutive image sequences. It can be used in landscape planning, change detection and monitoring of the healing therapy.

3. **Multi modal analysis:**

   Images of the same scene are acquired by different sensors. The goal is to integrate the information captured by different sources. It is used in remote sensing for image fusion and in medical imaging where different sensors are available like CT scan, MRI, PET, X-ray and Ultrasound modalities.
1.1.1 Challenges in Image Registration

Image registration is one of the challenging problems in image processing. Given two images taken, for example, at different times, from different devices or perspectives, the goal is to determine a reasonable transformation, such that a transformed version of the first image is similar to the second one.

Image registration can be quite challenging even when the images are identical or very similar. Robustness depends on the starting values of the transformation variables. Image registration is an Optimization problem. Optimization algorithm is applied to maximize the correlation between the images. In this work, the appropriate transformation is applied to one of the images usually it is on the sensed image and a comparison is made between the transformed image and the reference image. The optimization routine seeks to vary the transformation in some manner until the comparison is best possible.

The majority of the image registration methods consists of feature detection, feature matching, transform model estimation and finally image re-sampling and transformation. The features are distinctive elements of the images that are first extracted independently for two images to register and then correspondence between them is established. Transform model estimation will estimate matched features and parameters of mapping functions are computed and then interpolation of sensed image. This area is very challenging because of noisy environment, illumination changes, limitation of sensor capacity and many more. Robustness is very important property for success in above environments. The alignment process will find the correspondence between key points in the two images. Image features are unique image properties that can be used to establish correspondence between the images. The most required features are
points, because point’s coordinates can be directly used to determine the parameters of a transformation function that registers the images.

Correlation based methods registered images directly without finding their features. One image was shifted over another and at each shift position the similarity between the two was determined. The shift position producing the highest similarity was chosen to register the images. To reduce the computation time sub images can be used and to speed up further, multi stage and coarse - fine methods can be used. If the given image has non linear geometric differences, as the scale of the images is reduced, making the image more similar, registration accuracy increases. One can find feature points in low resolution image and map that point in next higher resolution and gradually finding more and more confident points.

The feature based methods, which are data dependent, we have to find the common features between the two images. If image gets changed, the data will change which will consequently change the features. Whereas, intensity based methods are free from this problem as it does not deal with the identification of geometrical landmarks.

1.1.2 Block Diagram of Image Registration

![Figure 1.1 Basic Image Registration block diagram](image-url)

Figure 1.1 Basic Image Registration block diagram
Image registration will require two images, image transformation, similarity measure and optimizer as shown in figure 1.1.

Image registration is an iterative process. It requires a pair of images called reference image and sensed image, a similarity measure, an optimizer, and a transformation type. A transformation model that defines geometric transformation is applied to sensed image. The similarity measures the degree of alignment and determines the accuracy of the registration. It can be correlation coefficients like normalized cross correlation, increment sign correlation, M – estimator coefficient or mutual information. This image similarity metric takes two images and calculate one parameter that returns a single value which describes how similar the two images are. The optimizer defines the methodology for minimizing or maximizing the similarity metric. The image transformation brings the misaligned image into alignment with the reference image.

The process begins with the transform we choose. Then comparison between two images is done based on similarity matrix. Finally, the optimizer checks for a stop condition. For most of the cases, either process has reached termination point or it has reached to the maximum number of iteration.

1.2 Motivation for the work

Registration problem is to find reasonable transformation such that the transformed sensed image will look similar to reference image. Medical image registration plays very important role in clinical applications including detection and diagnosis of disease, planning of therapy, guidance, follow up and monitoring of patients. The goal of this registration is to establish geometric correspondence between the two images such that the images can be compared and analyzed in a common frame. When the person is ill, he/she may not be in the position to stay steady while scanning is going on. It is very difficult
for patient to be steady for several minutes, may be because of chronic pain. So as a result we may get rotated or translated image. To align the acquired image, image registration is required. For multimodal image registration, mutual information based algorithm will provide best results. When FOV is large, Image matching and registration will generate large panoramic images (mosaicing) from several overlapping images, producing super resolution images from multiple images of the same scene, change detection and multi sensor image fusion are the common tasks. Scale Invariant Feature Transform (SIFT) algorithm will detect potential matched key points between the images.

1.3 Major Contributions and Objective of the Thesis

1.3.1 Segmentation and Registration of Recent License Plate with Security Features

License Plate Recognition (LPR) plays a very important role in day to day life as traffic rule violation, parking lot safety, theft of vehicles and number of vehicles especially cars are increasing which causes difficulty in tracking vehicles. The LPR system basically divided into three main steps: detection of license plate, character segmentation and recognition. Character segmentation is a most challenging step among these three steps. Recognition accuracy will be highly depended on segmentation result. Furthermore, lighting condition and rotation angle will degrade the accuracy of LPR system. So in order to overcome these problems, robust method is required. When the angle between camera and vehicle is not proper then registration algorithm is required prior to character recognition. For license plate detection, stroke width transform method is used where stroke width of each license plate characters are computed. Then RST transformation
should be applied on the detected license plate image, then transformed image is compared with the reference image and quality assessment parameters have been computed and finally segmented using connected component labeling.

1.3.2 Scale Invariant Feature Transform based Image Registration

This work presents image matching and registration method that is invariant to scale, rotation, translation and illumination changes. The method is named as Scale Invariant Feature Transform (SIFT). This algorithm will detect and describe image features such as contours, points, corners etc. SIFT descriptors are the characteristic signature of the feature. The features calculated from the image to be registered should be distinctive and then it can be matched. It can be useful in object recognition, image mosaicing, 3D reconstruction and video tracking. The simulation results shows that this algorithm works well in all types of cases having scale and rotation difference, it also register the object having occlusion and clutter background.

1.3.3 Image Matching and Registration Using Increment Sign Correlation and M – Estimators

Increment Sign Correlation is based on average estimation of incremental tendency of brightness in neighboring pixels. A novel and robust statistics as a similarity measure for image registration is proposed. The statistics is named as M-estimator because it is based on the probabilistic models that describe the likelihood of outcomes and used to predict future events. Probability distribution allocates likelihood to outcomes and often represented by parameterized functions. A basic algorithm that scans, searches and registered over a large scene is represented with a technique of M-estimator is suggested. The suggested algorithm is robust to light variations,
shadows, occlusions, noise, scaling and rotation. Many experimental results with real images are simulated and discussed.

1.3.4 Implementation of Satellite Image Registration using Particle Swarm Optimization

The aim of this research is to register satellite images on the DSP processor using probabilistic optimization method named as particle swarm optimization. Satellite image registration is necessary in order to find change detection, to eliminate influence of camera distortion (roll, pitch and yaw), merge satellite imagery and in urban planning. Particle Swarm Optimization is a stochastic search technique with less computation and still very effective as compared to other optimization techniques. It is based on bird flocking, fish schooling and swarm theory. It can be used in object recognition, image segmentation, matching and registration. The performance of this algorithm is measured and results are shown using DSK 6713 hardware along with VM32242.

1.4 Organization of the Thesis

The organization of the thesis is as follows.

Chapter 1 gives introduction about Image matching and registration methods and algorithms with applications of it. The chapter also outlines image registration methodology, the challenges, and the motivation for the work, major contributions and objectives of the research work carried out in this thesis.

Chapter 2 discusses review of literature carried out for this research work. The methods and algorithms that describe these concepts have been presented in this chapter. The segmentation and registration techniques on the latest license plates (with security features) in India
have been implemented using stroke width transform is described in chapter 3.

Chapter 4 explained Scale Invariant Feature Transform based image matching and registration algorithm along with results obtained by that method.

Chapter 5 describes Increment Sign Correlation, M estimator based algorithm, mutual information based image registration for medical images and Particle Swarm Optimization based method with an application to satellite image registration which was implemented in DSP hardware. And finally conclusion and future work is mentioned in chapter 6.
CHAPTER 2: LITERATURE REVIEW

Image matching and registration is a very challenging area in the field of image processing. This work aims to study various algorithm related with image matching and registration. In this section, a comprehensive survey on various image matching and registration methods have been presented. Many feature based registration methods are available in literature. Authors of different papers try to find and match image features such as points, lines, corners and objects between reference and sensed images.

Many types of transformation is to be applied over the sensed image and transformed sensed image is matched with the reference image and some parameters needs to be calculated and then depending on the minimum and maximum value, optimizer method will decide the iteration and stopping criterion. Transformation can be rotation, scaling, translation, projective, shear and affine. Parameters which can be calculated may be normalized cross correlation, increment sign correlation, M estimator correlation and mutual information. Optimization techniques can be based on neural network, fuzzy, Nelder Mead or particle swarm. Optimization is the selection of a best alternate from the available alternatives. In other words, it consists of maximizing and minimizing a real function by choosing appropriate input values.

2.1 License Plate Detection, Segmentation and Registration

In previous years, many researchers have implemented several algorithms for License Plate (LP) Detection, Segmentation and Recognition in different conditions, but still search for robust algorithm is not over. There are many challenges in this area like images having complex background, noise, poor illumination, wrong capturing angle, low resolution camera, motion blur and LP of varying styles, where many algorithms fails to recognize the license plate.

Feature extraction for an offline license plate recognition system based on global features is suggested by Mohindra and Shukla [1]. They have tested their algorithm on 100 real time images captured at different times in a day. They have used edge detection method, connected component analysis and discrete radon transform method
Chapter 2: Literature Review

for image segmentation. The efficiency of recognizing each character is 95% and total time taken for one image recognition is 15 seconds.

Edge finding method and window filtering is suggested by Kranthi et al. [2]. Edge finding method is not giving significant output when image is having complex background because it is very sensitive to unwanted edges. So windowing method where intensity summation in horizontal and vertical direction is calculated that will provide proper detection of license plate. For object enhancement they have used scale down, sorting of intensity pixel and then multiplication of top 20% pixel by 2.55, which provide better result compared to histogram equalization technique.

Abbas et al. [5] suggested vertical edge based car license plate detection method. For low resolution image of size 352 * 288, in which they have used adaptive thresholding technique followed by vertical edge detection using 2 * 4 mask and proved that its performance is faster (47.7 ms) than the sobel and getting 91.4% correct detection. Advantages are like able to process low resolution image and with complex background, tolerance to lighting, tilt, varied sizes and designs of LPs. But their algorithm is highly complex.

Adaptive thresholding using the integral image described by Bradley and Roth [11], this type of thresholding is suitable in spatial variations in illumination. Integral image is summation of corresponding row and column and then different local threshold is calculated based on neighboring pixel values. It is highly robust when illumination changes occur in the image.

Multi features approach has been used by Zhang [17] for robust license plate detection. Features like mathematical morphology, rectangle features (Aspect ratio, Area, Density), edge statistics and character features. They have also used character feature verification algorithm to determine final detection.