A Review paper on Image Registration Techniques

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Abstract - In Image registration process two or more images are aligned. Images used in this process are called (i) referenced image which is used as a reference and remains unchanged. (ii) Target or sensed image which is aligned to reference image. Geometric transformation functions are used so that mapping of location of target or sensed image into referenced image can be done by using control points of images. In image processing, registration can be done to match two or more images captured either at different times, from different sensors, or from different viewpoints. So based on these image registration applications can be categorised as multiview analysis, multitemporal analysis, multimodal analysis, Scene to model registration. We present a comprehensive review on various existing image registration techniques available in literature. Large number of applications based on image registration have been found like target recognition, matching stereo images to recover shape for navigation, satellite images are used for surveillance purposes, CT and MRI images are used in medical diagnosis.

Keywords: Image Registration, Geometric Transformation, Image smoothing, Feature extraction.

I. INTRODUCTION

Many image processing applications demands comparison or combining the information obtained from multiple images. This task can be done by using image registration where matching is performed for two or more images captured either at different times, from different sensors, or from different viewpoints. So based on these image registration applications can be categorised as

a. Different viewpoints (multiview analysis)
b. Different times (multitemporal analysis)
c. Different devices/sensors (multimodal analysis)
d. Scene to model registration.

In image registration mainly characters, objects, symbols and faces are registered in form of template matching where location of one image called template image is found, in a referenced image. Highest matching gives the accurate result. Images captured in various conditions may have real life problem like noise, occlusion, motion blur, shadow etc. which needs to be identified and then registration is done.
A number of applications based on image registration have been found like image mosaicing, target recognition, matching stereo images to recover shape for navigation, satellite images are used for weather forecasting and surveillance purposes, in medical imaging magnetic resonance imaging (MRI) and computer tomography (CT) images are combined in order to get accurate information about human body in medical diagnosis [1].
In 1992 Brown [2] discussed and summarized number of image registration techniques. The aim of the paper is to present the existing image registration techniques and hence tries to enlighten the recent development of image registration.

II. IMAGE REGISTRATION CLASSIFICATION

A number of classifications were proposed for image registration. Here we presented various categorization which depends on application, area based method and feature based method etc.
In 1992 Brown [2] suggested four classes of image registration as per image acquisition. Image registration applications [1] can be divided broadly into four groups.

a. Multiview analysis (Different viewpoints): Based on different viewpoints two-dimensional images are obtained. Image mosaicking in remote sensing is one of the example.

b. Multitemporal Analysis (Different times) : Based on different time(regular basis) and conditions images are captured so that continuous monitoring at different time can be put-up . Like in landscaping, surveillance of global land use, in medical imaging keeping eye on different diseases.
c. Multimodal Analysis (Different sensors) : Different devices and sensors are used to capture same image scene in order to perform number of task. Like in medical imaging magnetic resonance imaging (MRI) and computer tomography (CT) images are combined in order to get accurate information about human body in medical diagnosis and in computer vision biometric system are used for unique identification.
d. Scene of model registration: Image and its corresponding model of a scene needed to registered. It can be used as registration of satellite data into maps (remote sensing), template matching (computer vision) etc.

Maintz [3] surveyed in detail and classified image registration on the basis of nine criteria mainly used for medical imaging, describes as follows

a. Based on 2D or 3D Dimension: it describes the image dimension which may be two dimensional or three dimensional.
b. Registration method: means how registration takes place for two view either based on coordinate matching or matching based on image information.
c. Transformation type : it describes about various type of transformation like rigid, projective, affine, curved etc.
d. Domain of transformation: means measured transformation is local or global.
e. Interaction type: it depends on the freedom given to user for any registration algorithm.
f. Quality of optimization for registration:-it describes the measures for calculating quality of registration while using any registration algorithm.
g. Modalities involved: it describes how images are captured, which will be used for registration process.
h. Subject: it tells about type of sensed image.
i. Object: it describes various region image registration.

Barbara Zitova and Jan Flusser [4] gave classification based on area and feature based method.

a. Area Based Methods: Methods based on area are preferred when information is in form of gray level /colors. In sum of squared differences method, sum of squared difference value is minimized and only valid for same modality with properly normalized intensities. Mutual Information method is based on statistical calculation of two images and useful for image registration of images captured from different modalities. In correlation-like method intensities of the two images are defined linearly.
b. Feature Based Methods: when Image information in form of region-like features is given. Like projections of closed boundary regions of water ponds, lakes, buildings, forests, urban areas or shadows etc. A center of gravity is one of the parameter to represent regions, which are typically invariant to rotation, scaling etc. Line features represents the line segments while point features methods correspondence to line intersections.

III. IMAGE REGISTRATION PROCESS

Image registration has mainly following steps [2]:-

a. Pre-processing: Once images are captured in various different conditions, need to be processed as image smoothing, de-blurring, image segmentation.
b. Feature extraction: Feature like points, line intersections, regions, corners, templates, etc. are extracted from both the image.
c. Feature Correspondence: Determining the corresponding mapping between the features in both the images and transformation of sensed image is done by using estimated mapping functions parameters.

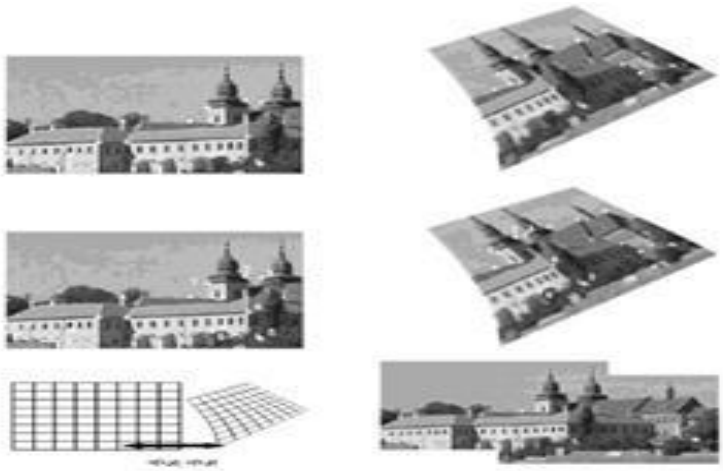

Figure1. First row: feature extraction, second row and last row: feature correspondence and transformation of sensed image is done by using estimated mapping functions parameters.

IV. IMAGE REGISTRATION TECHNIQUES [5, 6]

In this section various image registration techniques are discussed like Based on curve matching, correlation like method, Fourier methods, wavelet-based methods, distance calculation based and based on soft computing approach etc.

4.1 *Based on curve matching-*

Batler [7] gave curve matching algorithm for registration of 2-D projection images. Image registration is done by first generating sequence of respective points and second searching respective "open" curves manually, and finally registration process takes place. Local curvature in both the curve is used to generate best match of the respective curves.

Guifeng Shao and Fenghui Yao Mohan J. Malkani [8] developed a method for aerial image registration algorithm by using curve matching and template matching. Peng Wen [9], developed algorithm for medical image registration. In this algorithm points, contour and curves are used for registration. Since points were used for registration, results accuracy of registration, and got robust due to use of contour and curves. Although image features can be easily detected by applying any suitable detection method.

4.2 Based on correlation like method-

Correlation like methods allows linear relationship between the intensities of the two images. Various correlation based similarity measures are normalized cross-correlation, increment sign correlation and mask-based selective correlation coefficient etc. In image registration cross correlation technique is the oldest one, used for pattern matching. Cross correlation [2] is one of the classical approach in area based method.

Cross correlation gives the similarity measure value by using below-mentioned function where C(u,v) defines cross correlation.

$$c(u,v) = \frac{\sum x \sum y\, T(x,y) I(x-u, y-v)}{\sqrt{\sum x \sum y\, I(x-u, y-v)}}$$

For corresponding window coordinates of both referenced image and target images, similarity measure is calculated. The one which gives highest similarity measure value for window pair is set for further calculation.

Brown [2] presented more detailed review on the same. A. Collignon [10] used Entropy Correlation Coefficient (ECC) and normalized mutual information for image registration.

S. Gopal [11] suggested a method for registration of intra subject mammograms by comparing normalized mutual information and the similarity measure of correlation coefficient.

This method has certain drawback, as the correlation like methods has the high computational complexity and useful only for registration of mono modal images.

4.3 Based on Fourier Methods-

As per correlation theorem [12] Fourier transform of the correlation of two images is the product of Fourier transform of one image and complex conjugate of Fourier transform of other. The Fourier transform of an image f(x,y) is a complex function, each has real valued part R$(w_x, w_y)$and an imaginary valued part I (w_x, w_y)at each frequency $(w_x, w_y)$of frequency spectrum.

$$F(w_x, w_y) = F(w_x, w_y)e^{-\varphi(w_x, w_y)}$$

Where $F(w_x, w_y)$ is a magnitude and $\varphi(w_x, w_y)$ is a phase angle.

In Fourier method, image registration process is done by using Fourier shift as a part of phase shift correlation method. Yang developed an algorithm (scaling and translation operation followed by correspondence of unregistered image) rely on phase correlation and Harris operator for image mosaicing. Once transformation is done, feature extracted and matching occurs. It is concluded that Fourier methods are more useful in case noisy images or if we want high computational speed over correlation method.

4.4 Based on wavelet-based methods [13,14]-

In wavelet based method features are obtained by using feature detection algorithm rather than intensity values. Wavelet transform can be represented as an intermediate between Fourier and spatial representation. The wavelet-based approaches are preferred if working with multi spectral images because spectral characteristics of image are preserved in this case as compared to standard PCA and HIS methods.

As wavelet decomposition of the images has multiresolution character inherently, so it was more suitable for the pyramidal approach. For image registration many methods are proposed based on wavelet coefficients. In wavelet decomposition an image is divided into four coefficient matrices i.e LL, HL, LH and HH by applying a low pass filter L and a high pass filter H. Both the low pass filter L and high pas filter H are applied on image matrix in form of rows and columns.

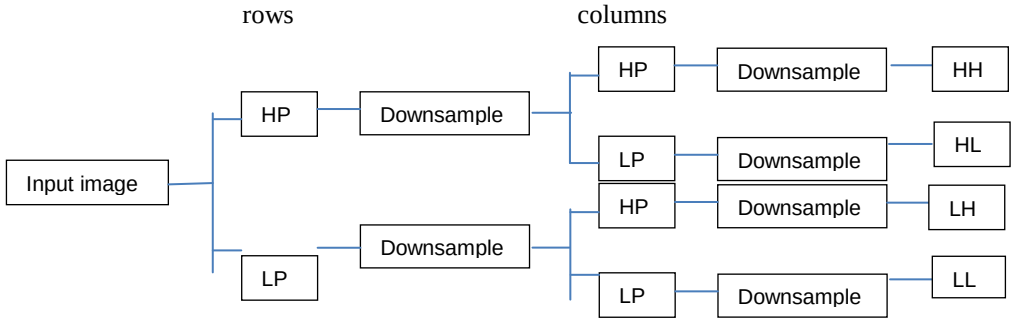

Figure 2. Wavelet Decomposition

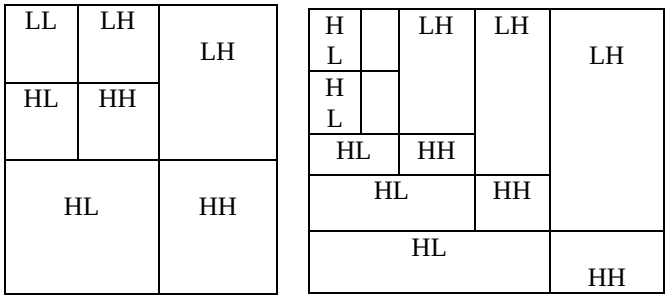

Figure 3.2-level and 4-level Decomposition

Gang Hong and Yun Zhang [15] developed new wavelet based approach. This approach used combination of normalized cross correlation matching and feature detection approach based on wavelet. By using approach, more control points can be obtained results less local distortions.

4.5 Based on distance calculation [16]-

4.5.1 Euclidian distance:- Let (x_1, y_1) and (x_2, y_2) be coordinates of two points. So Euclidian distance can be calculated as follows

Euclidian distance = $\sqrt{(x_2 - x_1)^2} + \sqrt{(y_2 - y_1)^2}$

By using Euclidian distance respective feature point pairs can be obtained. Respective feature points are correspondence to respective feature points of both the reference image and target image.

4.5.2 Root mean square error (RMSE):- Based on transformed image in the image space and working with set of control points (CPs), the matches can be detected by

$= \sqrt{(x'_i - x_i)^2} + \sqrt{(y'_i - y_i)^2} < E_r$ where i Є set of control points (CPs)

and

$x'_i = \propto_0 + \propto_1 x_i + \propto_2 y_i$ and $y'_i = \beta_0 + \beta_1 x_i + \beta_2 y_i$

E_r =maximum root mean square error (RMSE) allowed at each control point CPs

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} [(\propto'_0 + \propto'_1 X_i + \propto'_2 Y_i - X'_i)^2 + (\beta'_0 + \beta'_1 X_i + \beta'_2 Y_i - Y'_i)^2]}{N}}$$

4.6 Based on Soft Computing approach [17]-

Neural network, Genetic algorithm and Fuzzy logic approaches are the example of soft computing based techniques.

4.7.1 Artificial Neural Networks (ANN): It can be defined as a mathematical model or computational model. In artificial neural network (ANN) there are number of artificial neurons in the form of interconnected group and computation is performed by passing information through it. Artificial neural network is consisting of single processors having some weight with number of connected links. It has feed forward network architecture and recurrent network architecture. In feed-forward networks connected links have no loops. Example radial basis function neural networks (RBF) and multilayer perceptron (MLP) and while in recurrent networks, connected links have loop. Example self-organizing maps (SOM) and Hopfield networks.

Lifeng Shang [19] proposed an algorithm for CT-MR and MR-MR registration based on principal component analysis (PCA) neural network.

4.7.2 Genetic Algorithm: in genetic algorithm technique solutions are defined in terms of binary values as 0s and 1s, where solution is either approximated or computed exactly. Genetic algorithm iterated as long as maximum number of generations were produced. Every iteration uses randomly generated individual population in-order to generate a new population by recombining and mutating arbitrarily approaches to form a new population. L. Ramirez [18] proposed a method to calculate parameters of number of transformations like projective, rigid, affine etc. in Image registration.

4.7.3 Fuzzy sets: The set in which every element has degree of membership, is called fuzzy sets. In fuzzy set membership of every element is described by a membership function, based on membership function (in unit interval [0, 1]) continuous assessment of membership happens. Results obtained from fuzzy sets are quite interpreted because it uses linguistic terms like small, short, tall, large etc. in order to define the domain. L. Ramirez [18] proposed method which uses fuzzy sets in image registration.

V. CONCLUSION

In image registration process an image is set to map with available dataset. Image registration process becomes very useful when we need to analyse combined information collected through various sources. There are number of image registration approaches are discussed in this paper like Based on curve matching, correlation like method, Fourier methods, wavelet-based methods, distance calculation based and based on soft computing approach etc. So far available techniques are based on mapping of sensed image into available dataset of referenced image. This paper surveyed available image registration techniques based on various parameters. Further challenge during image registration process is, mapping of occluded image to available image dataset.

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