Image Registration Techniques for Satellite and Medical Images: A Survey

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Abstract
Image registration is one of the basic image processing operations in remote sensing. With the increase in the number of images collected every day from different sensors, automated registration of multi-sensor/multi-spectral images has become an important issue. A wide range of registration techniques has been developed for many different types of applications and data. Given the diversity of the data, it is unlikely that a single registration scheme will work satisfactorily for all different applications. A possible solution is to integrate multiple registration algorithms into a rule-based artificial intelligence system, so that appropriate methods for any given set of multisensor data can be automatically selected. On the other hand for time critical applications where tracking is very important based on the information from registered image, it is also mandatory that the registration algorithms are computed by dedicated hardware such as VLSI architectures. Wavelet based image registration techniques are found to be most popular and also require higher computation time. In this paper, image registration techniques and wavelet based image registration techniques are reviewed, along with VLSI architectures for computation of image registration techniques.

Key Words: Automated image registration, Image registration, Satellite image, VLSI architectures, Wavelets.

1. Introduction

Technological developments in telecommunication technology and embedded systems have led to unprecedented demand for sophisticated and reliable systems for securing the border and detection of intrusions. India is one of largest democratic country, having population more than 1 billion and is said to become one of the super powers in next 20 years. India is being surrounded by many neighboring countries. The total perimeter of India border is 3,287,590 sq km out of which land is 2,973,190 sq km, water is water: 314,400 sq km. Land boundaries we share with other countries are 15106.7 km, and costal boundary is 7516.6 km. Table 1 below shows the border shared by India with other countries. Infiltrations occur along the border and thus destabilize the growth of India. Types of Intrusions/infiltrations are 1. Infiltrations along the border, 2. Migrants, terrorists, drug traffickers, animal poaching and smuggling and 3. Land intrusions. Human intrusions into India are recorded to be more than 2000 every year, and are increasing.

Table 1 India border distance

Country	Length of the Boarder
Bangladesh	4096.7 km
China	3488 km
Pakistan	3323 km
Nepal	1751 km
Myanmar	1643 km
Bhutan	699 km
Afghanistan	106 km

In 2009, violence came down, compared to 2008. At the same time, compared to 2008, last year attempts to infiltrate have gone up. It is a matter of serious concern to us," Antony (Defense Minister) told reporters. Similarly, land intrusions along the line of actual control (LAC) is 4,057 Km. Thus there is a immediate and futuristic need for securing Indian borders. Securing the border has the following advantages:

- Illegal migrants are not accountable and do not come under law, Threat to our national security (terrorists)
- Secured border fosters public safety
- Illegal migrations leads to downfall in economic growth
- Weapons smuggling and drugs trafficking
- Illegal money
- Animal poaching
- Defined boundaries (coastal regions, shared waterways, internal airspace, shared economies and critical infrastructure)

Currently there are various technologies adopted to secure the border, most advanced technology adopted by the US is securing the border using Radar sensors with Cameras with UAVs. Radar senses presence of humans, turns on camera and a signal is sent to a border patrol office and UAV is launched to track the criminal. Air surveillance is carried out with use of satellites, UAVs, low-flying patrol aircraft. Use of UAVs has been giving promising results to secure the border as they are cost effective and reliable. In addition they are not being detected by enemies, and thus offers security based detection. UAVs have high resolution cameras that capture the borders and the images are transmitted to the base station. Received images captured should be preprocessed and should be processed to detect the presence of human being and help in intrusion detection. The most frequently arising problems in the processing of (still) images is that of object registration. It arises in images containing objects, possibly overlapping, against a more-or-less uniform background. Objects may belong to one or more types or classes. Class identifying differences typically refer to the object morphology or shape, dimensions, color, opaqueness, surface texture and location / direction characteristics, [1], [5]. The aims of digital processing of an object image are numerous: Object detection, localization, recognition and classification constitute major goals. Furthermore, more detailed object characterization in terms of size, color, direction, scaling, shift or rotation might be of interest for specific applications. Finally, search of an image for the existence or not of a specific object prototype (under a given degree of flexibility as to the similarity level required in the match) is often of importance, [1]. Common in all the problems mentioned above is the processing of the images digitally, through an appropriate software package, either general-purpose or custom developed for the application at hand. Digital image processing is a mature field that offers to the researcher a variety of approaches. Given a field application, however, choice of the most suitable method or approach has not yet been fully automated.

A widespread survey of image registration methods was published in 1992 by Brown [1]. A comprehensive survey of image registration methods is presented by Barbara Zitova and Jan Flusser [2]. They have classified the image registration techniques as area based methods and feature based methods. J. B. Antoine Maintz presented a survey of medical image registration in 1998. [3].Leszek Chmielewski presented various methods of image registration in 2001. [4].Mohammad Essadiki presented a technique for combining panchromatic and multispectral spot images [5]. Subunku in his thesis presented various entropy based image registration techniques [6]. S. K. Bose presented various tools for medical image registration [7].J. Flusser used moment based approach to correct affine distortion, he has also done degraded image analysis to locate invariants in images[8, 9]. Sangit Mitra and B.S. Manjunath explained various contour based approaches for multispectral image registration in their different papers [11]. Cahill, N D Williams, C. M. Shoupu propose an approach to incorporate spatial information into the estimate of entropy to improve multimodal image registration [15]. J.P.W. Plum presented another servey on medical image registration [16]. Frederik Maes and Andre Collignon apply mutual information to measure the statistical dependence or information redundancy between the image intensities of corresponding voxels in both images [17]. Xiaoxiang Wang and Jie Tian in their paper proposed a mutual information based registration method using gradient information rather than pixel intensity information [18]. Frederik Maes, Andre present novel histogram based method for estimating and maximizing mutual information between two multimodal and possibly multiband signals [19]. J. P. Queiroz developed method for automatic registration of satellite images acquired on different dates, for both geometric and radiometric correction with respect to reference image [20]. Shannon's paper, titled "A mathematical theory of communication "is widely accepted as the origin of information theory. In this paper, Shannon used probability theory to modal information sources, i.e. data produced by a source is treated as a random variable [21]. Haim Schweitzer in his paper proposed that large collection of images can be indexed by projections on a few " eigenfeatures " , the dominant eigenvectors of the images covariance matrix [22]. Ma Debao and Liwagao introduced the new matrix characteristic methods like eigenvalues and eigenvectors and achievable accuracy is derived theoretically and verified by tests using simulated interferometric data.[23]. Haim Schweitzer demonstrated that eigenspace based algorithm registers multiple images and produces improved eigenfeatures[24].Wen Cao and Bicheng proposed PCAT (principal component analysis transform) and WPT (wavelet packet transform) for remotely sensed image fusion[25]. YuTe Wu, Takeo Kanade, Ching-Chung Li and Jeffrey Cohn proposed that their wavelet-based algorithm produced better motion estimates with error distributions having a smaller mean and smaller standard deviation [26]. Tarek A El-hazawi explained wavelet based image registration [27]. Hala S. Own and Aboul Ella Hassanien in their paper present an efficient image registration technique using the Q-shift complex wavelet transform (Q-shift CWT). The experimental results proved that the proposed algorithm improves the computational efficiency and yields robust and consistent image registration compared with the classical wavelet transform [28].Azhar Quddus and Otman Basir proposed a novel, fully automatic, multistage wavelet-based image registration technique for image retrieval applications. They used multiscale wavelet representation with mutual information (MI) to facilitate matching of important anatomical structures at multiple resolutions. The proposed approach has several novel aspects including the use of MI in multistage wavelet domain [29].Stone, Harold S.,Le Moigne, Jacqueline; McGuire and Morgan proposed fast image registration by progressively registering wavelet representations at different resolutions[30]. Ghazaw presented wavelet based image registration on parallel computing[31]. Jiangsheng explained image matching techniques by using Radon transform [32].

2. Image Registration

Image representation of data captured by image sensors provides visual interpretation of information. Images captured at different instants of time, due to movements in the non-rigid objects in the image provide distinct information. Image registration is a process of aligning digital images captured at different time intervals [1]-[2]. Registration is also a process where images captured using various sensors is aligned [3]. Medical image registration is the process of aligning digital medical images so that corresponding features can be compared. By registering these images, a doctor can observe changes in a patient's condition over time (e.g. intra-subject) or compare a healthy patient to a diseased patient (e.g. inter-subject). Image registration has evolved from the mid-1980s from a minor niche into a major sub-discipline. Registration of image requires two inputs, a reference image and an image to be registered. Registration process produces one out, which is termed as registered image. Image registration consists of four steps: Feature extraction, feature matching, transform estimation and resampling and transformation. Remote sensing, hyperspectral imaging, whether forecasting, medical image processing, object tracking are some of the applications where image registration plays a pivotal role [4]. Image registration is a process of registering two images that are of the, same scene taken at different instants of time, taken from different viewpoints and or different sensors. Image registration is also defined as a transform T that will map one image onto another image of the same object such that some image quality criterion is maximized. Figure 1 presents the block diagram of image registration [5]. Image to be registered is compared with reference image and the registration process performs image registration and generates a registered image.

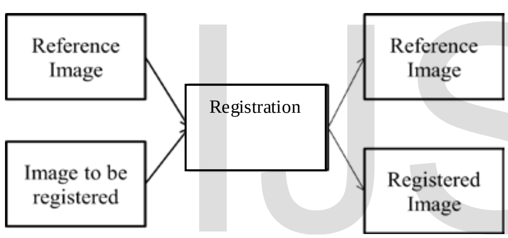

Figure 1 Image registration process

The registered image is also compared with reference image for validation. Figure 2 illustrates the image registration process. As shown in Figure 2, the general image registration problem is, given two *N*-dimensional sensor readings, fi nd the function *F* that best maps the reading from sensor 2, $S2(x1, \ldots, xn)$ onto the reading from sensor 1, $S1(x1, \ldots, xn)$. Ideally, $F(S2(x1, \ldots, xn)) = S1(x1, \ldots, xn)$.

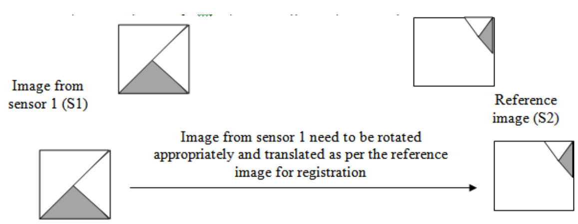

Figure 2 image registration method [4]

Because all sensor readings contain some amount of measurement error or noise, the ideal case rarely occurs. Many processes require that data from one image, called the *observed image*, be compared with or mapped to another image, called the *reference image* [4]. Hence, a wide range of critical applications depends on image registration.

3. Types of IR (image registration) techniques

J.V.Chapnick, M.E.Noz, G.Q. Maguire, E.L.Kramer, J.J.Sanger, B.A.Birnbaum, A.J.Megibow [10] have mentioned the different approaches of image registration way back in 1993. The approaches are Transformations using Fourier Analysis, Cross correlation approach using Fourier Analysis, Sum of squares search technique, Eigen Value Decomposition, Moment matching techniques, Warping Techniques, Procedural approach, Anatomic Atlas and Internal landmarks. The different steps in IR are listed as follows:

Feature detection: Detection of features in acquired image like points edges /lines/intersections or corners manually or automatically (Barbara Zitova, Jan Flusser and J. B. Maintz). Medical images are not so rich in distinctive and easily detectable objects and therefore this method had limited application in medical IR. There are numerous feature extraction techniques available in the literature (P. Bas, J. M. Chassery, Jignesh. N. Sarvaiya). Wavelet based methods are found to produce remarkable results in the feature extraction process even when applied to medical images.

Feature Matching: Matching of the detected features from the acquired image with the reference image. Spatial relation and feature description s are used depending on the application (R. J. Althof, M. G. I. Wind). The limitations in feature matching methods are that corresponding features may be hard to detect and / or the features may be unstable with respect to time.

Transform model Estimation: Estimation of transformed model, i.e. Parameters of mapping functions aligned with reference image type are estimated (J. Flusser). Global mapping models is based on the assumed CP (Control Points) , slight variation in the assumptions mode will lead to higher order polynomial models (3 or more) . This increase in the order leads to warping of the sensed image in the areas away from the CPs when aligning with the reference image. Radial basis function method using thin plate splins gives rise to high computations time if the number of control points is high. As per R. Bajcsy, the elastic registration method doesn't yield good result in case of localized image deformation.

M. Bro. Neilson, C. Gramkow, H. Lester found the fluid registration method has a blurring effect introduced during the registration process and can be best used in medical IR to find the correspondence to CPs and transform the same using CPs.

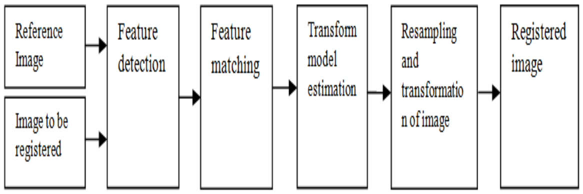

Figure 5 Processing steps in image registration

Resampling and transformation of image: The transformation of the sensed image is done in a forward or backward manner. Every pixel from the sensed image can be directly transformed by the use of the mapping functions estimated in the above step. As per E. H. W. Meijering, J. P. Thirion , the forward method produces overlaps and / or holes in the output due to rounding descretization. Hence it is complicated to implement. The backward method overcomes the above disadvantage; however the computation cost is high since interpolation is involved. Many other methods were tried and only marginal improvements were found. Nearest neighbor interpolation introduces artifacts in the images which are resampled. Higher order bilinear interpolation methods give higher accuracy with higher computational complexity. Figure 5 summarizes processing steps in image registration. Figure 4 summarizes the types of image registration process.

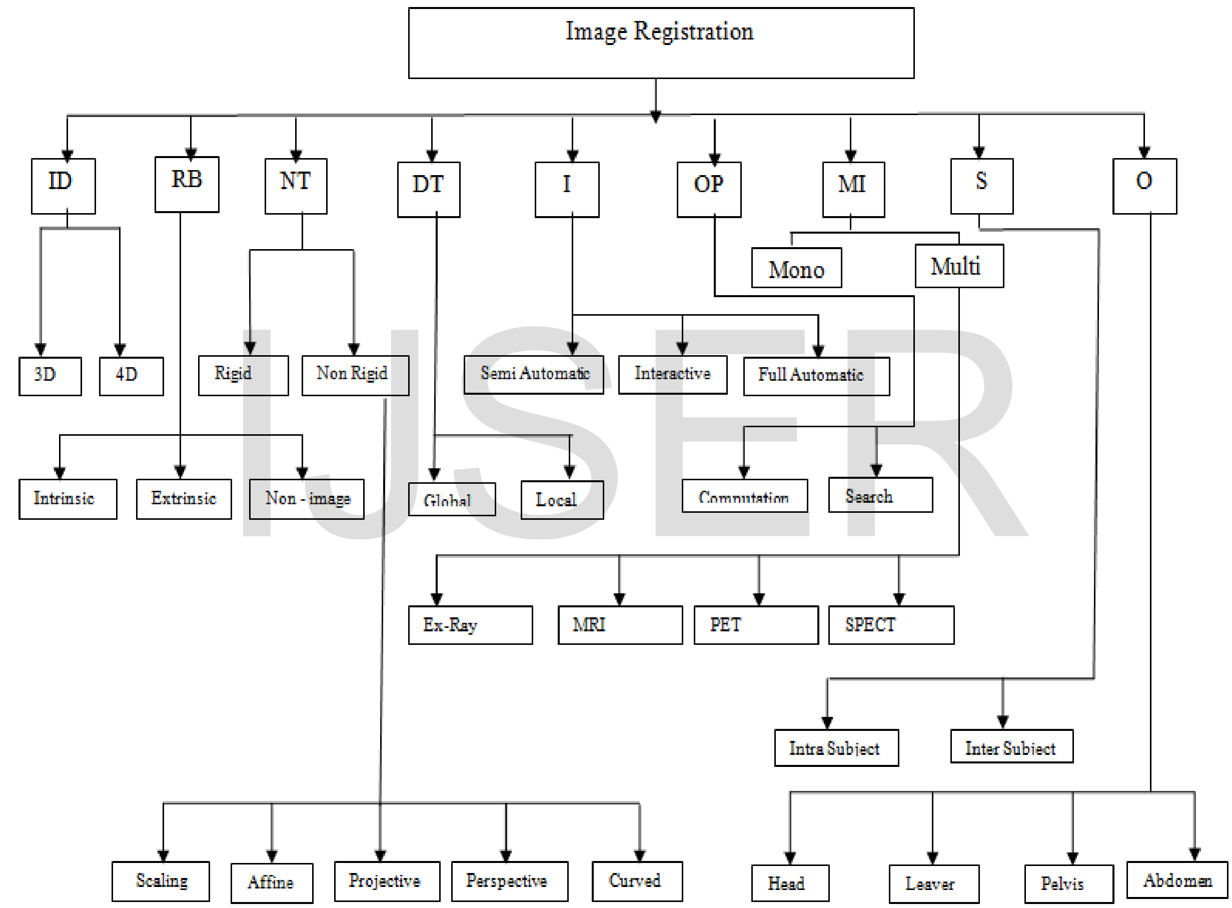

Figure 4. Summarizes the classification techniques for image registration

The IR methods are classified depending on various factors as detailed below:

1. ID (Image Dimensionality): Refers to the number of geometrical dimensions of the image spaces involved like 2 dimensional or 3 / 4 dimensional.

2. RB (Registration Basis) : This deals with the different aspects of two views used to affect the registration and is divided into three sub categories. Extrinsic or Prospective which is based on foreign reference points / surface attached to the anatomy, Intrinsic or Retrospective based on anatomic features only and non image based where imaging coordinates of the two devices are matched.

3. NT (Nature of Transformation) : This can be either rigid or non rigid transformation. The rigid transformation preserves all distances, straightness of lines, surface planarity non zero angles between straight lines. Non rigid transformation can be further classified as scaling, affine, projective, perspective and curved. Each transformation is

closely related to each other and is very close to rigid transformation.

4. DT (Domain of Transformation): This domain may be global where the whole image undergoes registration or local where only a part of the image under goes registration.

5. I (Interaction): The degree of interaction refers to the control exerted by a human operator over the registration algorithm like initialization of certain parameters (Semi automatic), adjustment through the registration process in response to the visual alignment or other measures of intermediate registration success (Interactive). Fully automatic algorithm is ideal which requires no interaction.

6. OP (Optimization Procedure): This can be either direct parameter computation or search for the parameters. The former case is algorithmic registration in which the quality of registration is estimated continuously during registration process in terms of some function of image and the mapping between them. In the latter case the global extremism is found among the local ones by means of iterative search, forming a closed form solution.

Wavelet based approaches are gaining popularity for image registration. Several novel approaches of efficient image registration are proposed. These algorithms utilize different techniques spanning on various scientific fields as information theory, optimization and search statistics, image processing and signal processing (wavelets), artificial intelligence techniques. Each has its own advantages and disadvantages over the others. A Fast Algorithm for Image Registration without Predetermining Correspondences was proposed in the year 1996 that applied wavelet transforms to extract a number of feature points as the basis for registrations. The multi-resolution analysis of DWT enables us to obtain good localized time/frequency characteristics, such as abrupt changes, spikes, drifts and trends. Therefore, WT has been widely used to extract features for signal classification. Next section review wavelet transforms for image registration.

4. Wavelet based image registration techniques

Wavelet analysis is a windowing technique with variable sized regions, which allows the use of long time intervals where precise low frequency information is required and short regions where we want high frequency information. The wavelet transform is the convolution of a wavelet function Ψ(t) with a signal x(t) as in Eq. (1)

$$T(a,b) = \int_{-\infty}^{+\infty} x(t)\,\Psi_{a,b}^{*}(t)\,dt \qquad (1)$$

Where x(t) is a one dimensional continuous signal, Ψ(t) is a wavelet function and T(a,b) represents wavelet coefficients of signal x(t).

At many locations, b and scales a as in Eq. (2)

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\, c\left(\frac{t-b}{a}\right) \qquad (2)$$

Where b represents time shift and a denotes the scaling of the wavelets. The wavelet function Ψ(t) should satisfy the conditions of zero mean and the existence of the inverse transform. The equation 1 can be implemented by using discrete wavelet transforms using dyadic scale as in Eq. (3)

$$T_{m,n} = \frac{1}{\sqrt{2^m}} \int_{-\infty}^{\infty} x(t)\,\Psi^{*}\left(\frac{t-n2^m}{2^m}\right) dt. \qquad (3)$$

Where n is the number of data points in the signal, $n2^m$ represents the size of the steps between locations (time shift) and 2^m is the scale as in Eq. (4)

$$\Phi_{m,n}(t) = \frac{1}{\sqrt{2^m}}\, \emptyset\left(\frac{t-n2^m}{2^m}\right), \qquad (4)$$

$\Phi_{m,n}(t)$ represents the scaling function of dyadic discrete wavelet transform, the mean of which is equal to one. The convolution of above scaling function with the signal produces smoothed or averaged version of the signal represented as S_{mn} as in Eq. (5)

$$S_{m,n} = \int_{-\infty}^{\infty} x(t)\,\emptyset_{m,n}(t)\,dt. \qquad (5)$$

The wavelet coefficient $T_{m,n}$ from equation 3 provide the details to obtain the original signal from the smoothed signal. Higher dimensional wavelets like separable and non separable wavelets designed in multiple dimensions and use non rectangular grids.

Yinpeng Jin, Elsa Angelini disucss about wavelet transforms for image registration. Consider f(n), a one dimensional signal of length N. The discrete orthogonal wavelet transform can be organized as a sequence of discrete functions as in Eq. (6)

$$L_m(f) = Lf(n2^m, n2^m) \text{ and}$$

$$W_m(f) = Wf(n2^m, n2^m) \qquad (6)$$

according to the scale parameter, s= 2^m . A pair of CMF(conjugate mirror filters) are used for fast implementation of filter bank algorithms , h and g are constructed from scaling function Φ and wavelet function Ψ as given in Eq. (7)

$$h(n) = \frac{1}{\sqrt{2}}\emptyset\left(\frac{t}{2}\right), \emptyset(t-n) \quad \text{and}$$

$$g(n) = \frac{1}{\sqrt{2}}\Psi\left(\frac{t}{2}\right), \Psi(t-n) \qquad (7)$$

Where h is a low pass filter and g is a high pass filter. (Jin Daubechies (1992). The discrete orthogonal wavelet decomposition in equation (6) implemented by applying these two filters to the input signal, and recursively decomposing the low frequency band as shown in Figure 6.

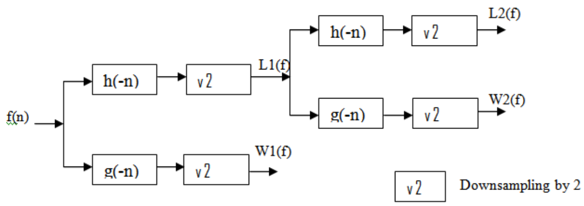

Fig. 6: Illustration of orthogonal wavelet transform of a discrete signal f(n) with CMF (Conjugate mirror filters), a two level expansion. (Yinpeng Jin et.al)

The same pair of filters can be used to get back the original signal as shown in Figure 7. The discrete dyadic wavelet transform , both decomposition and reconstruction can be implemented with a fast filter bank scheme using a pair of decomposition filters H,G and a reconstruction filter K (Jin_Mallat_1992b) as shown in Figure 8. With Φ(x) as the scaling function, Ψ (x) as the wavelet function, X(w) as the reconstruction function as in Eq. (8) – Eq. (10),

$$\Phi(2w) = e^{-jws}H(w)\Phi(w) \quad (8)$$

$$\Psi(2w) = e^{-jws}G(w)\Psi(w) \quad (9)$$

$$X(2w) = e^{-jws}K(w)X(w) \quad (10)$$

Where s is a Ψ (x) dependent sampling shift. The three filters H, G, K satisfy as in Eq. (11)

$$Mod(H(w))^2 + G(w)H(w) = 1 \quad (11)$$

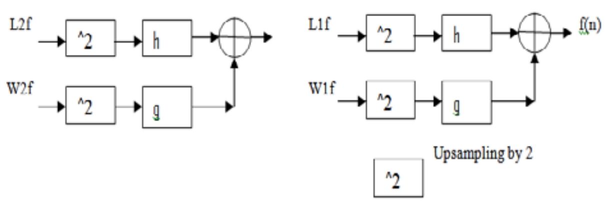

Fig. 7: Illustration of inverse wavelet transform implemented with CMF , a two level expansion. (Yinpeng Jin et.al)

The filter implementation of discrete dyadic wavelet transform shown in fig. 5 is constructed by defining:

$F_s(w) = e^{-jws}$ F(w) and

F is either G or H or K

This implementation has a complexity that increases linearly with the number of analysis levels.(Jin_holschneider_1989; Jin_shensa_1992). In Image processing applications, we often deal with two, three or even higher dimensional data. This extension to higher dimension is quite straight forward.

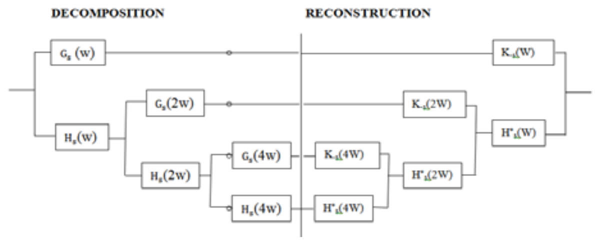

Fig. 8: Filter bank implementation of wavelet transforms decomposition and reconstruction for three levels of analysis. (Yinpeng Jin et.al) ($H^*_s(W)$ denotes the complex conjugate of $H_s(W)$).

5. Translation and rotation invariance

The variation in discrete wavelet transform is large with rotation and translation because a small change in location of an object can result in great variation of corresponding wavelet coefficient. Hence it is required to overcome rotation variance to make the wavelet co efficient useful in registration. The translation variance is caused by down sampling of data at each level of wavelet decomposition. The significant variation in the wavelet co efficient is significantly found for signals that differ only by translation. In the tensor product wavelets, the rotation variance is due to the strong coupling of the wavelets with the orientation of the axes, and the features aligned with axes and at diagonals are highlighted. The features will align with different axes and be high lightened in different sub-band of the transform when an object is rotated. Non separable wavelets also vary with rotation because they are not symmetrical. Hill. P. R, et. al. have made efforts to develop invariant versions of the discrete wavelet transform, but were not very successful as either shift or rotational invariance were solved, while otherwise produced redundant representations. Registration of 3D images is finding prominence in most of the medical processing applications, due to the additional information present in the registered image that improves doctors to diagnose the diseases and develop report, thus assisting accuracy in detecting diseases. Next section discusses 3D image registration techniques.

6. 3D Image Registration Techniques

Geometric feature based IR and voxel comparison based IR are the two methods for 3D object registration. Voxel based method is slow but is accurate, geometric based method is faster but may not be accurate. In geometric based method, features of images such as points, curvatures, ridges or segments are used as features for aligning objects. These algorithms and methods cannot be applied to polyhedral or voxelized models, as they do not have mathematical representation. In voxel based methods, alignment is based on voxel representations of objects, color, intensity, illumination and reflectance. The computation time in this method is large due to selection of all possible discrete features to perform registration.

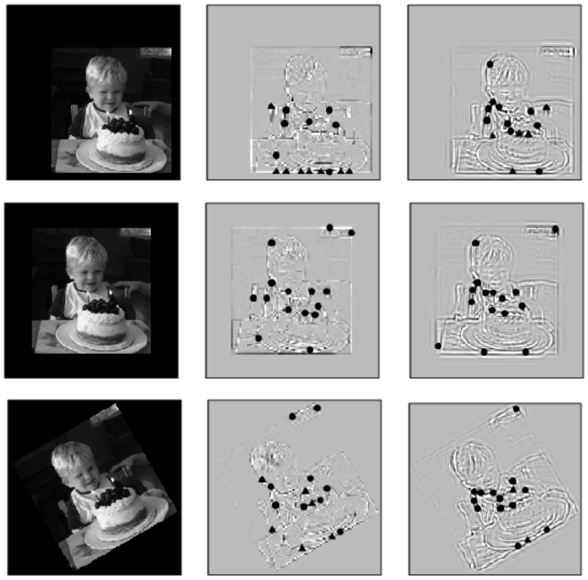

Figure 9 Comparison of DWT and DTCWT extrema in rotation and translation.

7. 3D Image Registration Using Wavelets

The wavelet decomposition of signal to a hierarchy of sub-bands with sequential decrease in resolution is very useful when multi-resolution is needed. Hence it is very useful in Image registration. Further a signal can be analyzed with a multi-resolution frame work into a spatial frequency framework. Distinct noise components can be separated easily from a noisy signal based on spatial-frequency characteristics by carefully selecting the wavelet function and space-frequency plane tilting of the transforms. Wavelet domain provides more effective registration algorithms because it's feature characteristics were proven to be potentially more efficient and reliable compared to spatial analysis only (Yinpeng Jin, Elsa Angelini, and Andrew Laine**).** The Image Registration method using two different similarity measures, MI(Mutual Information) and SAD(Sum of Absolute Differences) in one multi resolution scheme , the wavelet pyramid has proved to perform better compared to the conventional MI methods. But SAD is not effective in multi-modal registration because even when perfectly registered, images from different modalities are different in intensity. Hence MI is used at high resolution levels to ensure accuracy. However, SAD works well in lower resolution registration because only the global features are preserved. The complex wavelets outperforms on wavelets in the field of medical imaging. It gives very good alignment results. Medical images have lot of phase information, curves and textured information for which the complex wavelet is ideal. Also it retains the good qualities of wavelets like robustness, accuracy and multimodality. A new technique for multimodal automatic Image registration is presented by Milad Ghantous and group which proves that this technique has superior accuracy compared to the discrete wavelet transform method. High speed is achieved due to the application of algorithm in pyramidal fashion based on Dual tree complex wavelet transform. Matching in the lowest level is based on cross correlation and at higher levels the search interval is then refined using MI as the matching criteria due to it's ability to register multimodal images and as well as uni-modal cases. Hala. S. Own introduced an Image registration algorithm based on Q-shift Complex wavelet transform and proved that Complex wavelet transform is potentially good domain for registration. The shift invariant property of the Complex wavelet transform is used to invert geometric distortion. Sukriti and others developed an algorithm for medical image registration based on Genetic algorithm using complex wavelets and demonstrated that the complex wavelets, which are called the next generation wavelets gave robust and accurate solution in different applications. Surface based methods are extensively used in image registration and voxel based methods are almost absent because it is relatively easy to obtain a surface from the patient through, either using laser scanning, probes, 2D imagery etc., while obtaining reliable image information for voxel property based methods is more difficult. Also the surface based methods are, on the average , still faster than voxel property based methods. The main drawback of surface based methods is that they cannot cope with shift of relevant anatomy relative to the surface used in registration. This may be severely restraining to intra-operative application. Here the voxel based method can be used.

Julie S. Chalfant and others developed an algorithm for three dimensional Object Registration using wavelet features. This algorithm is used to conduct rigid registration of voxelised three dimensional objects using wavelet transform for the objects grossly misaligned and brings them close into alignment. Global alignment is achieved without the need for initial alignment and fine registration may be conducted using elastic registration methods. This method is faster than other geometric feature registration methods and significantly faster than the voxel intensity methods. Hence this method has become a pre-processing step for voxel intensity methods feasible. Image Registration has become very successful in the last two decades with variety of applications. Most obvious reason is the fast and convenient access of data due to the development in data digital data archiving and communication. This has provided platform for registration of multimodal images in various disciplines. Image Registration has become a component of image analysis. Further segmentation is an important process in image analysis to determine the areas of interest and accurate demarcation of objects yield valuable information. In medical application quantification is often the ultimate goal. The physician needs a quantified data after diagnosis to determine the extent of progression of a disease. Hence the progress in Image Registration should go hand in hand with other areas. With development in technology, and growth of sophistication in the field of medicine, it is required to adopt technology to meet the requirements of common man. Thus there is convergence of medical image techniques and communication systems that lead to telemedicine and remote facility. In a primary health centre, with the availability of medical equipments, capturing real time images of patients, it is required to transmit the data to remote locations on the doctor's mobile devices for diagnosis. Thus it is required to develop a hardware based module that can capture images and compress images and transmit the same to remote locations. In this scenario, it is required to develop dedicated hardware for compression and registration using System on Chip platforms. The next section reviews literature on high speed VLSI architectures for DWT realization for image registration.

8. VLSI architectures for DWT realization

The paper "Low-Power And High-Speed VLSI Architecture For Lifting-Based Forward And Inverse Wavelet Transform"[1] proposed by Xuguang Lan and Nanning Zheng, presents the low-power, high-speed architecture which performs two-dimension forward and inverse DWT (discrete wavelet transform) for the set of filters in JPEG2000 using line based and lifting scheme. It consists of one row processor and one column processor each of which contains four sub-filters. And the row processor which is time-multiplexed performs in parallel with the column processor. Optimized shift-add operations are substituted for multiplications, and edge extension is implemented by embedded circuit. The whole architecture which is optimized in the pipeline design way to speed up and achieve higher hardware utilization has been demonstrated in FPGA. Two pixels per clock cycle can be encoded at 100MHz. The architecture can be used as a compact and independent IP core for JPEG2000 VLSI implementation and various real-time image/video applications. This architecture can be easily adopted for image registration techniques.

Anirban Das, Anindya Hazra, and Swapna Banerjee have proposed the architecture of the lifting based running 3-D discrete wavelet transform (DWT), which is a powerful image and video compression algorithm in the paper "An Efficient Architecture for 3-D Discrete Wavelet Transform"[2]. The proposed design is one of the first lifting based complete 3-DDWT architectures without group of pictures restriction. The new computing technique based on analysis of lifting signal flow graph minimizes the storage requirement. Proposed architecture reduces memory referencing and related low power consumption, low latency, and high throughput. The proposed architecture has been successfully implemented on Xilinx Virtex-IV series field-programmable gate array, offering a speed of 321 MHz, making it suitable for real time compression even with large frame dimensions. The architecture reported in this work need to be scaled to larger size, so that it can be used to extract features for image registration. Suitable modification to this architecture would enable image registration.

Chin-Fa Hsieh , Tsung-Han Tsai , Neng-Jye Hsu , and Chih-Hung Lai , proposed[3] a novel, efficient VLSI architecture for the implementation of one-dimension, lifting-based discrete wavelet transform (DWT). Both folded and the pipelined schemes are applied in the proposed architecture the former scheme supports higher hardware utilization and the latter scheme speed up the clock rate of the DWT. The architecture has been coded in Verilog HDL, and then verified successfully by the platform of Quartus-II of version 5.0. The proposed architecture effectively shortens the critical path and therefore enhances the clock period, without adding the number of adders and multipliers/shifters. Latency and through put can be further enhanced to meet medical applications.

Jen-Shiun Chiang, and Chih-Hsien Hsia have proposed a highly efficient VLSI architecture for 2-D lifting-based 5/3 filter discrete wavelet transform (DWT) in "An Efficient VLSI Architecture for 2-D DWT using Lifting Scheme"[4]paper. The architecture is based on the pipelined and folding scheme processing to achieve near 100% hardware utilization ratio and reduce the silicon area. Proposed efficient 2-D lifting-based DWT VLSI architecture uses lossless 5/3 filter and pipelined processing. The architecture can have almost 100% hardware utilization. The advantages of the proposed DWT have the characteristics of higher hardware utilization, less memory requirement, and regular data flow. For medical images, the architecture proposed in this paper can be extended to process 4D images.

A low bit rate three dimensional decomposition algorithm for video compression with simple computational complexity is proposed [5] by Awad Kh. Al-Asmari and Abdulaziz Al-Rayes. The algorithm performs the temporal decomposition of a video sequence in a more efficient way by using 4-tap short symmetric kernel filter (Haar filters) with decimation factor of 4:1 instead of 2:1 used in the classical 3D-wavelet algorithms. The pyramid coding decomposition concept is then used for the spatial domain. The main goal is to design a simple encoding algorithm with a very high performance. Local adaptive vector quantization (LAVQ) is used to encode some of the spatial subbands. The codebook of LAVQ is simple and robust to the motion which occurs in the video sequences and which seldom captures from a single training sequence. The other subbands are encoded using the very simple coding algorithm called absolute moment block truncation code (AMBTC). The AMBTC is used for the bands that are highly correlated and with no motion or sparks information. The algorithm proposed in this work, does not perform better on real time images and medical images. Thus preprocessing of the images prior to feature extraction is required.

M.F. L´opez, S.G. Rodr´ýguez, J.P. Ortiz, J.M. Dana, V.G. Ruiz and I. Garc´ýa have proposed "Fully Scalable Video Coding with Packed Stream"[6] where Scalable video coding is a technique which allows a compressed video stream to be decoded in several different ways. This ability allows a user to adaptively recover a specific version of a video depending on its own requirements. Video sequences have temporal, spatial and quality scalabilities. In this work they have introduce a novel fully scalable video codec. It is based on a motion-compensated temporal filtering (MCTF) of the video sequences and it uses some of the basic elements of JPEG 2000. The techniques adopted for video coding can be extended to perform medical image registration.

In the paper [7], "3D Discrete Wavelet Transform VLSI Architecture for Image Processing" Malay Ranjan Tripathy, Kapil Sachdeva, and Rachid Talhi have proposed an improved version of lifting based 3D Discrete Wavelet Transform (DWT) VLSI architecture which uses bi-orthogonal 9/7 filter processing. This is implemented in FPGA by using VHDL codes. The lifting based DWT architecture has the advantage of lower computational complexities transforming signals with extension and regular data flow. This is suitable for VLSI implementation. It uses a cascade combination of three 1-D wavelet transform along with a set of in-chip memory buffers between the stages. These units are simulated, synthesized and optimized for Spartan-II FPGA chips using Active-HDL Version 7.2 design tools. The timing analysis tools of this (Active-HDL), reports the frequency above 100MHz and ensures 100% hardware utilization. The architecture is very slow in terms of latency and throughput, hence suitable modifications to this architecture enhances the throughput and latency. To achieve this, images sequences can be divided into sub images or voxels, processing of individual voxels can improve the processing speed of the architecture.

"An Efficient Architecture For Lifting-Based Forward And Inverse Discrete Wavelet Transform" [8]is proposed by Aroutchelvame, S. M. and K. Raahemifar where architecture performs both forward and inverse lifting-based discrete wavelet transform . The proposed architecture reduces the hardware requirement by exploiting the redundancy in the arithmetic operation involved in DWT computation. The proposed architecture does not require any extra memory to store intermediate results. The proposed architecture consists of predict module, update module, address generation module, control unit and a set of registers to establish data communication between predict and update modules. The symmetrical extension of images at the boundary to reduce distorted images has been incorporated in the proposed architecture as mentioned in JPEG2000. This architecture has been described in VHDL at the RTL level and simulated successfully using ModelSim simulation environment. For real time processing of medical images, the architecture proposed in this work should be extended into 4D space, thus making it suitable for 4D image registration.

9. Conclusion

Various methods are reported in literature to register images which are in same band. In pixel based method cross correlation is used as similarity measure. It is observed that in natural images like buildings or scenery, correlation method shows match at multiple points. The feature based method makes use of features like point of intersection, edges, corners, centers of contours etc. for matching sample template with reference image. But this method is manual and hence time consuming. The method combining image features with correlation method have many advantageous properties of both feature-based and intensity based. It overcomes the limitation of intensity based method. Contour based methods do not use the gray values for matching and hence overcomes the limitations of spatial methods. Feature based method filter out the redundant information. Accuracy of this method is more but the limitation is, it is manual and slow. In frequency based method accuracy is more than correlation method but less as compared to other methods. But if we extract image features and then apply Fourier method accuracy increases. In frequency domain it should be noted that some form of interpolation must be used. These are some of the conclusions about methods used for registration of images which are in same spectral band. Image registration is difficult when images are obtained through different sensor types. Mutual Information, Hotelling Transform, Fuzzy logic are some of the approaches that can be used for multimodal image registration. In this work, we presented an application of the genetic algorithms approach to the problem of localization of objects Although there certainly exist automated solutions, the issue of quality along with the critical nature of the results, often necessitate manual / visual treatment by the human expert. We propose the genetic algorithms approach here, because, as it will become clear through the results obtained, it was seen to be well suited to the morphology of the objects in the images treated. A genetic algorithm is a non-linear optimization method that seeks the optimal solution of a problem via a nonexhaustive search among randomly generated solutions. Randomness is controlled through a set of parameters, thus turning genetic algorithms into exceptionally flexible and robust alternatives to conventional optimization methods. Genetic algorithms suffer a few disadvantages: they are not suitable for real time applications and take long to converge to the optimal solution. Convergence time cannot be predicted either. Nevertheless, they have become a strong optimization tool, while current research focuses on their combination with fuzzy logic and neural network techniques. In its simplest form, a genetic algorithm consists of three (3) mechanisms: (i) *parent selection*, (ii) *genetic operation* for the production of descendants (offspring), and (iii) *replacement of parents* by their descendants.

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