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REVIEW ON DIFFERENT TECHNIQUES OF IMAGE REGISTRATION

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ABSTRACT: Image registration is a current area of research in many areas like medicine, remote sensing and many more. This paper illustrates the various techniques of image registration providing advantages and disadvantages of these techniques and an overall understanding of image registration. Image registration is a process of overlaying two or more images of the same scene taken at different times, from different viewpoints, or by different sensors. Image registration is a crucial step in all image analysis tasks. This paper would help the researchers to have a full understanding of image registration process.

KEYWORDS: Image registration, registration methodologies, geometric transformations, registration accuracy.

I. INTRODUCTION

Image registration is the process of transforming different sets of data into one coordinate system. Here, from data we mean multiple images. It is the determination of geometrical transformation that aligns points in one view of an image with corresponding points in another view of that image or the other image [2]. Basically, it geometrically aligns two images- the reference and the sensed images. The present differences between images are introduced due to different imaging conditions.

Image registration in required in remote sensing (weather forecasting, environmental monitoring) in medicine (monitoring tumor growth, treatment verification), in cartography (map updating), in computer vision (automatic quality control).

Applications of image registration can be broadly classified according to manner of image acquisition:

Multiview analysis (Different viewpoints): Images of the same scene are acquired from the different viewpoints. In this, images may differ in translation, rotation, and scaling, more complex transformations mainly due to camera positions [5]. Examples include: computer vision shape recovery.

*Multitemporal analysis (Different times)**:*** Images of the same scene may be acquired at different times or under different lightning conditions [5]. The aim is to find and evaluate changes in the scene which appeared between the consecutive images acquisitions. Examples includes: Medical image monitoring, remote sensing.

*Multimodal analysis (Different sensors)**:*** Images are acquired by different types of sensors [5]. Here, the aim is to integrate the information from two different sources and then to obtain more representation detail.

*Scene to model registration**:*** Images of a scene and model of a scene are registered [5]. The aim is to localize the acquired image in the model and to compare them. Examples include: Medical imaging.

II. PROCESS OF IMAGE REGISTRATION

The key step of image registration is to find a spatial transformation such that a chosen similarity metric between two or more images of the same scene achieves its maximum. It is useful in many aspects like gaining information from two images of same scene from different viewpoints or to align several images to make a single image. Generally, process of Image registration consists of four basic steps as shown in figure 1:

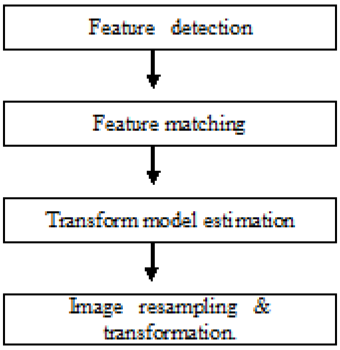

Figure1: Steps involved in Image Registration [8]

A) Feature Detection- Also called Control Point (CP) selection. In this step, salient and distinctive objects like edges, contours, corners are either automatically or manually selected. The detected features set in the reference and sensed images must have enough common elements.

B) Feature Matching- In this step, a match between the control points chosen in step 1 is established. Various feature descriptors and similarity measures along with spatial relationships among the features are used for this purpose. The feature descriptor should be invariant to the assumed degradation. The matching algorithm should be robust and efficient.

C) Transform Model Estimation- Here, the mapping functions along with its type and parameters are estimated to map the sensed image to reference image. The type of mapping function should be chosen according to the prior knowledge about the acquisition process and expected image degradation. The model should be flexible enough to handle all possible degradations.

D) Image Resampling- In this step, the target or the sensed image is transformed with the help of mapping functions. The choice of appropriate type of resampling technique depends upon the tradeoff between the demanded accuracy of the interpolation and the computational complexity.

Image registration can be done manually or automatically. In manual registration, the selection of control points is done by human operator. But in manual image registration, there are chances for human eye to discern the appropriate control points [6].
So, automatic image registration came into existence to detect features without human intervention. Not any registration algorithm can be directly applied to all type of applications, as every application has its own set of requirements. Registering and summing multiple exposures of the same scene improves signal to noise ratio, allowing one to see things previously impossible to see.

III. REGISTRATION METHODOLOGIES

Image registration can be mainly classified into two categories:

A) Iconic Registration

It is also known as Intensity- based registration. It maps certain pixels in each image to same location based on relative intensity patterns. This approach eliminates the feature extraction step by creating a cost function from the voxel intensity space directly. The main idea is to search iteratively for the geometric transformation that, when applied to moving image, optimizes i.e. maximizes or minimizes a similarity measure, also known as cost function [13]. This method deals with the images without attempting to detect salient objects. This method tries to search for a geometric transformation from a specific transformation space such that two intensities best match each other in terms of a similarity or dissimilarity metric defined directly by the observed image intensities. As shown in figure 2, the similarity measure is related to voxel intensity and is computed in overlapped regions of input images. The optimizer has the function of defining the search strategy. The aim of interpolator is to resample voxel intensity into new coordinate system according to geometric transformation found.

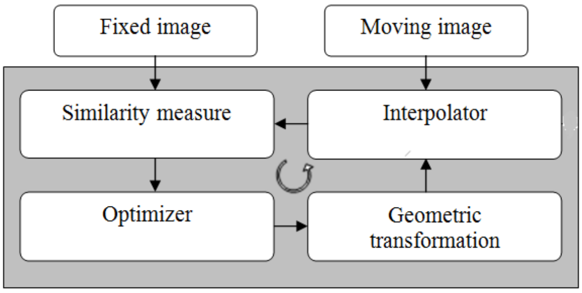

Figure 2: Intensity- based Registration [4]

B) Geometric Registration

It is also known as Feature- based registration. The aim is to find a pair- wise correspondence between control points (CP) using their spatial relations or various descriptors of features. Control Points involves point themselves, end points or center of line features center of gravity of regions, etc.

Methods Using Spatial Relations: This method is usually applied if detected features are ambiguous or if their neighborhoods are locally distorted. In this, the information about distance between the CPs and about their spatial distribution is exploited.
Methods Using Invariant Descriptors: Here, the correspondence between the features can be estimated using their description, preferably invariant to expected image deformation. Invariance, uniqueness, stability, independence are some conditions that a description need to fulfill.

For feature based registration, there are two approaches to search for optimal transformation:

a) The matching among some features is established using some criterion e.g. based on geometrical, physical or statistical properties.
b) The matching and the transformation defined concurrently based on the optimization of a similarity measure between the features extracted from the input images.

These approaches can be subdivided using extrinsic and intrinsic properties. Extrinsic properties methods rely on objects that are designed to be well visible.

IV. GEOMETRIC TRANSFORMATIONS

Geometric transformations modify the spatial relationship between pixels in an image. The images can be shifted, rotated, or stretched in a variety of ways.

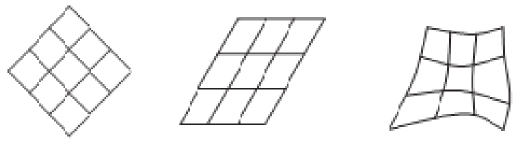

Figure 3: Rigid, Affine, Elastic Transformations respectively [14].

Transformation model serves two purposes:

- First, it controls how the image features can be moved relative to one another to improve the image similarity.
- Second, it interpolates between those features where there is no usable information.

A geometric transformation has the general form

(x, y) = T {(u, v)}

Where u, v are original pixel coordinates and x, y are transformed pixel coordinates. T is called a *forward transformation.* And if we take inverse of this equation, then the transformation is called *inverse transformation [3]*.

A) Forward Transformation:

- Methods based on forward mapping scan each input pixel in turn, copying its value into the output image at the location determined by T {(u, v)}.
- One problem with the forward mapping procedure is that two or more different pixels in the input image could be transformed into same pixel in the output image, raising the question of how to combine multiple input pixel values into a single output pixel value.
- No one- to- one correspondence.

B) Inverse Transformations:

- To guarantee that a value is generated for every pixel in the output image, we must consider each output pixel in turn and use the inverse mapping to determine the position in the input image.
- To assign intensity values to these locations, we need to use some form of intensity *interpolation.*
- Interpolation is the process of using known data to estimate unknown values.

C) *Rigid Transformations:* It is also known as linear transformations. Rigid transformations are defined as geometric transformations that preserve all the distances. These transformations also preserves the straightness of lines and all non zero angles between straight lines. Rigid transformations are simple to specify.

- These transformations are global in nature, thus not being able to model local deformations.
- Rigid transformations can only correct for rotational and translational differences.
- A rigid body transformation is composed of a combination of a rotation, a translation and a scale change.

D) Affine Transformation: Used for within- subject registration when there is global gross over distortion [15]. The affine transformation preserves the straightness of lines, and hence, the planarity of the surfaces and it preserves parallelism, but it allows angles between lines to change.

- All rigid transformations are affine transformations, but all affine transformations are not rigid transformations.
- An affine transformation involves rotation, shearing, translation, scaling as shown in figure 4.

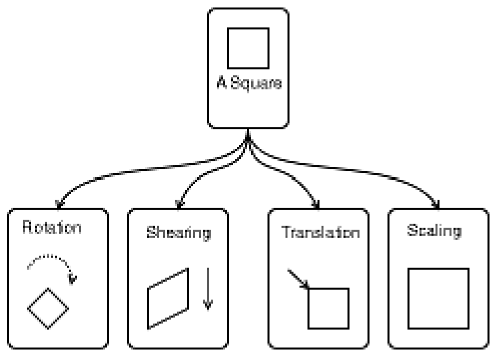

Figure 4: Affine Transformations [5]

- Affine transformations are represented in homogeneous coordinates because the transformation of point A by any affine transformations can be expressed by the multiplication of a 3*3 matrix and a 3*1 point vector [11].

E) *Elastic Transformations:* These are also called nonrigid transformations. These transformations are based on the model of elasticity theory and describe local deformations. These have no matrix representations. The central idea behind these transformations is to consider images as continuous bodies and to model the geometric differences between images such that they have been caused by an elastic deformation [7].

- Nonrigid transformations are not only important for applications to nonrigid anatomy, but also for inter patient registration of rigid anatomy and intra patient registration of rigid anatomy when there are non rigid distortions in the image acquisition procedure.
- The simplest nonrigid transformations are rigid except for scaling.
- Here, distances change, but lines remains straight.
- Here, the advantage of this method lies in the fact that feature matching and mapping function design steps of registration are done simultaneously.

- One of the most important transformations is the family of splines that have been used in various forms for around 15 years.
- Spline based registration algorithms use control points, in the source and the target image and a spline function to define correspondences away from these points.
  a) *Thin plate splines (tps):* TPS are an interpolation and smoothing technique, the generalizations of splines so that they may be used with two or more dimensions [6]. These provide a smooth interpolation between a set of control points.
     - These belong to set of radial basis function.
     - It interpolates a surface that passes through each control point. A set of three points will thus generate a flat plane. It is easy to think of control points as position constraints on a bending surface. The ideal surface is one that bends the least.
     - TPS has been widely used as the non – rigid transformations model in image alignment and shape matching.
     - Here, the model has no free parameters that need manual tuning, the interpolation is smooth with derivative of any order, and there is a physical explanation for its energy function.
     - But, as the control points has the global influence, thus it limits the ability to model complex and localizes deformations and as the no of control point increases, the computational cost associated with moving a single point rises steeply.

  b) *B-splines*: B-spline is short for basis-spline.
     - A function is represented as a linear combination of basis function.
     - B-splines are only defined in the vicinity of each control point; perturbing the position of one control point only affects the transformations in the neighborhood of the point [8]. So, B-splines are always referred to as having local support.
     - B-splines are popular due to their general applicability, transparency and computing efficiency.
     - Their main disadvantage is that special measures are sometimes required to prevent folding of the deformation field and these measures become more difficult to enforce at finer resolutions.
     - These are not suitable for point registration because the control points must lie on a regular grid.

V. EVALUATION OF IMAGE REGISTRATION ACCURACY

Estimation of accuracy of registration algorithm is a substantial part of registration process. Without quantitative evaluation, no registration method can be accepted for practical utilization [1]. In this section, we review basic error classes and method for measuring the registration accuracy.

A) *Localization Error:* Displacements of the CP coordinates due to inaccurate detection is called localization error.

- Localization error can be reduced by selecting an optimal feature detection algorithm for the given data but usually there is a tradeoff between the number of detected CP candidates and the mean localization error.
- Sometimes we prefer to have more CP with higher localization error rather than only few of them, yet detected more precisely.

B) *Matching Error:* Matching error can be measured by the number of false matches when establishing the correspondence between the CP candidates.

- It is a serious mistake which usually leads to failure of the registration process and should be avoided.
- Fortunately, in most cases it can be ensured by robust matching algorithms.
- False match can be identified by consistency check.

C) *Alignment Error:* by the term alignment error we denote the difference between mapping model used for registration and the between- image geometric distortion. Alignment error can be evaluated in several ways.

- The simplest measure is a mean square error at the CP's (CPE). But, it is not good alignment error measure.
- In fact, it only quantifies how well the CP coordinates can be fitted by the chosen mapping model.
- Also Test point error (TPE) is used for this purpose.
- Test points are CP's that were deliberately excluded from the calculation of the mapping parameters.
- TPE cannot be set to zero by over fitting which makes it more meaningful than CPE.

Finally, the oldest method of registration accuracy estimation- visual assessment by a domain expert- should be mentioned. It is still in use at least as a complement of the above mentioned objective error measures.

VI. CONCLUSION AND PROPOSED WORK

The image registration problem was turned into the process to find the optimal geometric transformation parameters which ensure the mutual information of the original images to reach maximum. This mutual information helps to find the features in the two images. In the current paper we have presented different techniques and processes involved in the image registration, we have also covered the advantages and disadvantages for each technique. From the reviews we have concluded that many techniques can be merged to form the hybrid registration process. So, our future work will be image registration using hybrid method.

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