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Polar Transform in Image Registration

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Abstract- We present a robust APT-based approach to scale-invariant image registration Image registration is an essential step in many image processing applications that need visual information from multiple images for comparison, integration, or analysis. Combining APT with an innovative projection transform along with a matching mechanism, the proposed method yields less computational load and more accurate registration than that of the conventional LPT. Translation between the registered images is recovered with new search scheme using Gabor feature extraction to accelerate the localization procedure the new search scheme using Gabor feature extraction to accelerate the localization procedure. Moreover an image comparison scheme is proposed for locating the area where the image pairs differ. Experiments on real images demonstrate the effectiveness and robustness of the proposed approach for registering images that are subjected to occlusion and alteration in addition to scale, rotation, and translation.

Keywords :- Adaptive polar transform (APT), alteration, image registration, occlusion, rotation, scale, translation.

I. Introduction

Image registration is the process of overlaying images of the same scene taken at different times, from different viewpoints, by different sensors. The registration geometrically aligns two images (the reference and sensed images). The reviewed approaches are classified according to their nature (area based and feature-based) and according to four basic steps of image registration procedure: feature detection, feature matching, mapping function design, and image transformation and sampling. It geometrically aligns two images—the reference and sensed images. The present differences between images are introduced due to different imaging conditions. Image registration is a crucial step in all image analysis tasks in which the final information is gained from the combination of various data sources like in image fusion, change detection, and multichannel image restoration.

The detected feature sets in the reference and sensed images must have enough common elements, even in situations when the images do not cover exactly the same scene or when there are object occlusions or other unexpected changes. The detection methods should have good localization accuracy and should not be sensitive to the assumed image degradation. LPT (Log Polar Transform) is a well known tool for image processing for its rotation and scale invariant properties. Scale and rotation in the Cartesian coordinates appear as translation or shifting in the log-polar domain. These invariant properties make LPT based image registration is robust to scale and rotation. However, LPT suffers from the non uniform sampling. One major problem of that is the high computational cost in the transformation process, which comes from the oversampling at the fovea in the spatial domain. Since no information is gained from oversampling, this computation is wasted. Another major problem of LPT is the bias matching. With LPT, the matching mechanism focuses only at the fovea or the area close to the centre point of the transformation, while the peripheral area is given less consideration. Furthermore, occlusions and alterations between the two images may occur which is not considered by LPT.

There are many method of image registration which can be categorized into two major groups: the feature-based approach and the area-based approach. The feature-based approach uses only the correspondence between the features in the two images for registration. The features can be color gradient, edges, geometric shape and contour, image skeleton, or feature points. Since only the features are involved in the registration, the feature-based approach has advantages in registering images that are subjected to alteration or occlusion. However, the use of the feature-based approach is recommended only when the images contain enough distinctive features. As a result, for some applications such as medical imaging, in which the images are not rich in detail and features are difficult to be distinguished from one another, the feature-based approach may not perform effectively. This problem can be overcome by the area-based approach. The common area-based approach is the normalized cross correlation [7]. Another correlation based technique which is more robust to noise and changes in the image intensity than the cross-correlation technique is the phase correlation [8], in which the normalized cross-power spectrum between the two images is computed in the frequency domain.

II. BACKGROUND OF THE CONVENTIONAL LPT

For image processing applications, LPT is a nonlinear and nonuniform sampling method used to convert image from the Cartesian coordinates $I(x, y)$ to the log-polar coordinates $ILP(\rho, \theta)$. The mathematical expression of the mapping procedur is shown as follows:

$$\rho = Log_{Base}\sqrt{(x-x_c)^2+(y-y_c)^2}$$

$$\theta = \tan^{-1}\frac{(y-y_c)}{(x-x_c)}$$

where (x_c, y_c) is the center pixel of the transformation in the Cartesian coordinates.(x ,y) denotes the sampling pixel in the Cartesian coordinates and (ρ ,θ) denotes the log-radius and the angular position in the log-polar coordinates. For the sake of simplicity, we assume the natural logarithmic is used in this paper. Image pixels close to the center are oversampled while image pixels further away from the center are under sampled or missed. The advantage of using log-polar over the Cartesian coordinate representation is that any rotation and scale in the Cartesian coordinates is represented as shifting in the angular and the log-radius directions in the log-polar coordinates.

III. Analysis Of Problem

A. Problem Statement

LPT suffers from the non uniform sampling. One major problem of that is the high computational cost in the transformation process, which comes from the oversampling at the fovea in the spatial domain. Since no information is gained from oversampling, this computation is wasted. Another major problem of LPT is the bias matching. With LPT, the matching mechanism focuses only at the fovea or the area close to the center point of the transformation, while the peripheral area is given less consideration. Furthermore, occlusions and alterations between the two images may occur which is not considered by LPT. For example, the satellite images of the same location but taken at different times may contain occlusion due to climate change or cloud. In order to effectively register the two images, image registration method that is invariant to occlusion and alteration is needed.

B. Motivation

Motivated by these observations of the conventional LPT, our work attempts to effectively register two images that are subjected to occlusion and alteration in addition to scale, rotation and translation. We introduce adaptive polar transform (APT) technique in the spatial domain that evenly samples the image. We further apply the projection transform to the transformed image to reduce the image from 2-D to 1-D vector. With APT and the projection transform, rotation and scale in the Cartesian appear as shifting and variable-scale in the transformed domain. The new method requires less computational cost in the transformation process than that of the conventional LPT, while maintaining the robustness to the changes in scale and rotation. We further introduce a new search method that efficiently uses the scale and rotation invariant feature points to eliminate the exhaustive search for all the possible translations of the model image. Another contribution of this work is the image comparison scheme in the projection domains that is designed for locating the areas that are subjected to occlusions and alterations in the image. This information is useful for many applications such as medical imaging or scene change detection.

IV. Proposed Work

The objective of our proposed APT is to address the two major problems of the conventional LPT: the uneven sampling to the entire transformed image, and the computational waste due to the oversampling at the fovea. It can be seen that the cause of the problems comes from the fact that the number of samples of the conventional LPT increases exponentially from the peripheral to the fovea. Hence, when the transformed image is used for matching, more consideration is given to the fovea than to the other area of the image. To address these problems, we propose a novel APT approach that yields robustness in registering images that subjects to occlusion and alteration, while maintaining sufficiently low computational cost during the transformation. The APT method consists of three major components: localization, in which the translation between the model image and target image is recovered, APT matching, an effective mechanism using APT and the projection transform to match and accurately obtain the scale and the rotation parameters between the two images, and image comparison, a novel image comparison scheme in the projection domain that can effectively and automatically locate the altered area without sacrificing additional computational cost to the system.

A. *Localization:* In order to fully exploit the advantage of APT, the translation parameter between the two images has to be found. The simplest solution is to perform the exhaustive search, in which the APT is computed for every pixel in the target image and the translation parameter is found from the image pixel that yields the best matching result to the APT of the model image. Since it is computationally expensive to perform the exhaustive search, an innovative method to reduce the space of search is needed. In order to avoid the exhaustive search of the target image for the model image, we reduce the search from every pixel of the target image to a set of feature points only. These feature points are obtained by applying Gabor transform to every pixel and selecting those pixels which generate high energy in the wavelet domain. Apparently, the number of feature points is much smaller than that of the pixels in the target image, while the computation of the Gabor wavelet transform is much lower than that of APT. Thus, the computation load is much lighter than the exhaustive search using APT. The reason we choose Gabor wavelet for extracting feature points is due to its invariant properties to scale, rotation, and noise.

B. *APT Matching:* After extracting feature points in the model image and selecting one feature point P_k^M as the center point for computing the projections R^M and Θ^M using the APT approach, the next step is to find the corresponding feature point P_k^T in the target image and obtain both the scale and the rotation parameters between the two images. Given a set of feature points in the target image and the radius size of the APT transformation R_{max} to be the same as for computing the projections R^M and Θ^M, we use each feature point in the target image as a center point for computing APT creating the set of candidate projections $R^T = \{R_1^T, \ldots R_{nT}^T\}$ and $\Theta^T = \{\Theta_1^T, \ldots \Theta_{nt}^T\}$. By matching R^M and Θ^M with every member in the sets of projections R^T and Θ^T , respectively, the translation, scale, and rotation parameters are obtained simultaneously. The matching results have three dimensions: the scale parameter, the rotation parameter, and the distance coefficient. The translation parameter is the offset between the location of P_k^M to the feature point P_k^T in the target image that yields the lowest distance coefficient.

C. Image Comparison: This work extends the use of image registration to the environment where images contain occlusion or alteration. Hence, it is important to be able to locate the area such changes take place in the target image, which will be useful for many applications such as medical image registration and scene change detection. Using the advantages of APT, we propose a fast and simple image comparison scheme that can effectively and automatically locate the altered area or the area where the registered image pair differs without scarifying additional computational cost. It should be noted that image comparison to find altered area between two images can be done by any registration algorithm if image registration can be achieved. Our method is robust in the sense that the image with altered area even in the center can still be registered plus the reservation of the LPT advantages scale and rotating invariant. Furthermore, the altered area can be identified without further computational cost. For most registration algorithms, in order to compare two images that involve the 2-D geometric transformation, additional computations are required as post processes such as image alignment, geometric transformation to transform both images to the same coordinates prior to the comparison, and image normalization. For the proposed image registration approach, since both the model image and the target image are already transformed to the projections of the APT domain, image comparison can be performed directly and simultaneously while obtaining scale and rotation parameters.

V. Algorith Of Apt

Below is the complete steps of the proposed algorithm.

i. Extract feature points in both the reference and the target images.
ii. Create the model image by selecting one of the feature points in the reference imag as the origin. Then crop circular image patch that covers the area desired to be registered to the target image.
iii. Compute the projections using the proposed APT approach and the projection transform.
iv. Use each feature point in the target image and crop a circular image patches with the radius size .
v. Compute the sets of candidate projections .
vi. Match each candidate with the model using the proposed APT matching algorithm. Translation is the point that yields the lowest distance coefficient. The scale and rotation parameters are obtained simultaneously in this step.
vii. Find the altered area .

VI. Conclusion

Although LPT has been widely used in many image processing applications, it suffers from nonuniform sampling. Hence, there are two major problems of the conventional LPT: the high computational cost in the transformation process, which comes from the oversampling at the fovea in the spatial domain, and the bias matching, in which the matching mechanism focuses only on the fovea or central area while the peripheral area is given less consideration. Previous works on image registration using the conventional LPT indicate successful results in the ideal conditions as when registering images with different orientations and scales. In reality, however, occlusions and alterations between the two images need to be taken into consideration. Inspired by this fact, this paper presents a new image registration algorithm based on the novel APT approach. By evenly and effectively sampling the image in the Cartesian coordinates and using the innovative projection transform to reduce the dimensions, the proposed APT yields faster sampling than that of the conventional LPT and provides more effective and unbias matching. A matching search scheme using the scale and rotation invariant Gabor feature points is introduced to reduce the search space for recovering the translation of the model image in the target image. The image comparison scheme on the APT projection domain is then proposed to effectively locate the occlusion and alteration between the two images without scarifying additional computational cost. This information is useful for some applications that intend to further analyze the registered images such as in medical image analysis or scene change detection. Experimental results indicate that our proposed image registration approach outperforms the conventional LPT based approach and yields robustness to image occlusion and alteration.

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