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New Adaptive Filtering Technique for Local Image Registration

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Abstract: This paper involves a new adaptive filtering framework for local image registration, which compensates for the effect of local distortions/displacements without explicitly estimating a distortion/displacement field. Here local image registration is formulated as a two-dimensional (2-D) system identification problem with spatially varying system parameters and utilize a 2-D adaptive filtering framework to identify the locally varying system parameters. The proposed 2-D adaptive filtering framework is very successful in modeling and compensation of both local distortions, such as Stirmark attacks, and local motion, such as in the presence of a parallax field. In particular, the proposed method can provide image registration to: a) enable reliable detection of watermarks, b) compensate for lens distortions, and c) align multi-view images with nonparametric local motion.

Keywords: local image registration, nonparametric image registration, alteration, adaptive filtering, image registration.

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.

Image Registration is the determination of a geometrical transformation that aligns points in one view of an object with corresponding points in another view of that object or another object. Relationship between type of distortion and the type of image registration is the most important task. There are two types of distortions can be distinguished. First type is those which are type of misregistration i.e. they are the cause of misalignment between two images. The second type of distortions is usually effect of intensity values. The basic need of image registration is for integrating information taken from different sources, finding changes in images taken at different time or at different conditions. Image registration is the process of overlaying images (two or more named reference and sensed images) captured from the same scene but at different times and view points, or even by using different sensors. Therefore, it is a crucial step of most image processing tasks in which the final information is obtained from a combination of various data sources and images are not designed. These include image fusion, change detection, robotic vision, archaeology, medical imaging, and multichannel image restoration. Typically, image registration is required in remote sensing applications such as change detection, multispectral classification, environmental monitoring, weather forecasting, super resolution images, and integrating information into Geographic Information Systems (GIS). It is also used in biomedical image processing applications for combining computer tomography (CT) and magnetic resonance imaging (MRI) data to obtain more complete information about the patient, monitoring tumor growth, treatment verification, and comparison of patients' data with anatomical atlases. It is also used in cartography (for map updating), computer vision (for target localization), automatic quality control, motion analysis, and target tracking.

The most fundamental characteristics of image registration technique is the type of transformation used to properly overlay two images. The primary general transformations are affine, projective, perspective and polynomial. These are all defined well mapping of one image into another. Basic image registration can be categorized in two modalities, Monomodal Image Registration and Multimodal Image Registration. Modalities refers to the means by which the images to be registered are acquired. When image registration is done with the two images of object with same sensor, it can be treated as monomodal image registration whereas with the images from different sensors it is known as Multimodal image registration. Multimodality registration methods are often used in medical imaging as images are obtained from different scanners. It includes CT, MRI or whole body Positron Emission Tomography (PET). These images are used for tumour localization, segmentation of specific part of body and registration of ultrasound and CT images for prostate localization in radiotherapy.

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. 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, in which the normalized cross-power spectrum between the two images is computed in the frequency domain.

II. Background of Adaptive Filter

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. Because of the complexity of the optimization algorithms, most adaptive filters are digital filters. Adaptive filters are required for some applications because some parameters of the desired processing operation (for instance, the locations of reflective surfaces in a reverberant space) are not known in advance or are changing.

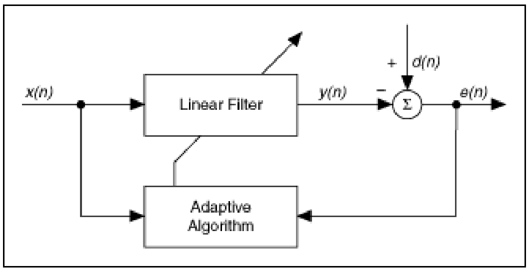

Fig: Block diagram of adaptive filter

Above figure shows a block diagram in which a sample from a digital input signal x(n) is fed into a device, called an adaptive filter, that computes a corresponding output signal sample y(n) at time n. For the moment, the structure of the adaptive filter is not important, except for the fact that it contains adjustable parameters whose values affect how y(n) is computed. The output signal is compared to a second signal d(n), called the desired response signal, by subtracting the two samples at time n. This difference signal, given by

$$e(n) = d(n) - y(n) ,$$

is known as the error signal. The error signal is fed into a procedure which alters or adapts the parameters of the filter from time n to time (n + 1) in a well-defined manner. This process of adaptation is represented by the oblique arrow that pierces the adaptive filter block in the figure. As the time index n is incremented, it is hoped that the output of the adaptive filter becomes a better and better match to the desired response signal through this adaptation process, such that the magnitude of e(n) decreases over time. In this context, what is meant by "better" is specified by the form of the adaptive algorithm used to adjust the parameters of the adaptive filter. In the adaptive filtering task, adaptation refers to the method by which the parameters of the system are changed from time index n to time index (n + 1). The number and types of parameters within this system depend on the computational structure chosen for the system.

III. Analysis of Problem

One of the important factors to achieving accurately registered images is the model that describes the (spatial) mapping between the images to be registered. Image registration techniques can be classified into two main groups: 1) global image registration methods that employ parametric spatial transformations and 2) local image registration methods that can handle spatially varying deformations. The global transformations are valid under restrictive assumptions on the images being registered. The accuracy of global registration methods proves insufficient when the underlying assumptions are not valid; hence, the globally modeled parametric motion shows systematic local deviations. Hence an alternative local registration method is required. Local image registration methods are motivated by two main applications: 1) correction of locally varying image distortions, such as random bending attacks, e.g., Stirmark and spatially-varying lens distortions, and 2) compensation of locally varying motions in the presence of a parallax field.

In this paper, we present a new local image registration technique based on adaptive filtering, for both space-varying distortion and motion compensation, which does not require explicit estimation of the local distortion/displacement field. Adaptive filters have been successfully applied to a number of one-dimensional (1-D) system-identification problems, such as echo-cancellation. In these applications, adaptive filters not only allow for the estimation of an unknown system but also incorporate the capability to track smoothly varying changes in the system. In this paper, we formulate local image registration as a 2-D system identification problem with spatially varying system parameters.

Local image registration methods have also been employed to compensate for geometric distortion attacks, such as those intended to disable watermarks. These include transform-domain approaches, feature-based methods, and direct techniques. In the context of image restoration, recently ˇSroubeketal have also proposed integration of registration into the restoration process for translational misregistration. In this paper, we present a new local image registration technique based on adaptive filtering, for both space-varying distortion and motion compensation, which does not require explicit estimation of the local distortion/displacement field. Adaptive filters have been successfully applied to a number of one-dimensional (1-D) system identification problems, such as echo-cancellation. In these applications, adaptive filters not only allow for the estimation of an unknown system but also incorporate the capability to track smoothly varying changes in the system. In this paper, we formulate local image registration as a 2-D system identification problem with spatially varying system parameters. The successive update procedure in the adaptive filtering is inherently 1-D, we map the 2-D image plane into a 1-D sequence using space-filling curves. This ensures spatial contiguity in the 2-D image plane, which is a prerequisite for filter convergence and tracking. The proposed method is computationally simpler than other approaches for local image registration.

Local Image Registration as a 2-D System Identification Problem

The problem of image registration can now be considered as a System Identification Problem. Adaptive filters have been used extensively for system identification for *1-D* (temporal) systems. In order to establish the context and to highlight the differences in the subsequent development, first consider adaptive filtering for 1-D temporal signals, which typically consists of a two step process:

1. A filtering step, where the filter coefficients $\hat{h}(t,t_0)$, are convolved with the input signal, $v_1(t)$, to produce an estimate of the desired response, $v_2(t_0)$, and
2. An adaptive process where the set of filter coefficients are adjusted using the resulting estimation error, $e(t_0)$.

For this least-mean-square (LMS) is commonly used as adaptation algorithm, the adaptive filtering process is given as

$$\hat{v}_2(t_o) = \sum_{(t \in U)} \hat{h}(t, t_o) v_1(t)$$
$$e(t_o) = v_2(t_o) - \hat{v}_2(t_o)$$
$$\hat{h}(t, t_o + 1) = \hat{h}(t, t_o) + \beta e(t_o) v_1(t), \quad \forall\, t \in U$$

where β and U denote the adaptation step-size and the support of the 1-D filter respectively. The adaptive filtering process consists of a prediction step and a filter adaptation step. Assuming that the LMS adaptation algorithm is used for the update, the process can be mathematically expressed as follows.

1) Filter output (Prediction step)

$$\hat{I}_2(x_o, y_o) = \sum_{(x,y \in R)} \hat{h}_b(x, y; x_o, y_o) I_1(x, y).$$

2) Estimation error

$$e(x_o, y_o) = I_2(x_o, y_o) - \hat{I}_2(x_o, y_o).$$

3) Filter adaptation (Update phase)

$$\hat{h}_a(x, y; x_o, y_o) = \hat{h}_b(x, y; x_o, y_o) + \beta e(x_o, y_o) I_1(x, y), \quad \forall\, (x, y) \in R.$$

4) Initializing the filter for the next pixel, (x_n, y_n)

$$\hat{h}_b(x, y; x_n, y_n) = \hat{h}_a(x, y; x_o, y_o), \quad \forall\, (x, y) \in R$$

Where $\hat{h}(.)$ denotes the 2-D adaptive filter, R denotes the support of the filter, and β is the adaptation step-size. The subscripts b and a denote before and after adaptation respectively. Large displacements among the images may require a very large adaptive filter. However, filter size cannot be simply increased in the adaptation process because it will affect the convergence characteristic of the filter and increase the computational burden. In order to be able to use a filter with a constant size in the adaptation process, and still keep tracking large locally varying changes in the mis-registration, adaptive filter is shifted to its center of mass after each update, and integer pixel shifts are saved along with the filter coefficients. Another important variable in the proposed adaptive filtering framework is the adaptation step-size, β. This variable determines the rate at which the adaptive filter coefficients *h(x,y;xo,yo)* are adapted. However, there is a trade-off between the convergence characteristic and tracking capability of the filter. A large β can provide a better tracking of the system response, when there is a significant variation in the system model, *ho(x,y;xo,yo),* though it may result in large gradient estimation noise, and prevent the filter to converge. In order to provide fast tracking capability and also prevent gradient noise amplification, we apply normalized version of the LMS adaptation algorithm. The proposed image registration technique is designed to solve local mis-registration among the images. Therefore, it should follow an initial global alignment phase in order to handle large displacements between the images and coarsely align them.

Algorithm of LMS adaptive filter

The LMS algorithm is a linear adaptive filtering algorithm, which, in general, consists of two basic processes:

1) A filtering process, which involves

i) computing the output of a linear filter in response to an input signal and

ii) generating an estimation error by comparing this output with a desired response.

2) *An adaptive process, which involves the automatic adjustment of the parameters of the filter in accordance with the estimation error. The standard LMS algorithm performs the following operations to update the coefficients of an adaptive filter:*

1. Calculates the output signal y(n) from the adaptive filter.
2. Calculates the error signal $e(n)$ by using the following equation: $e(n) = d(n) - y(n)$.
3. Updates the filter coefficients by using the following equation:

$$\vec{w}(n+1) = \vec{w}(n) + \mu \cdot e(n) \cdot \vec{u}(n)$$

where μ is the step size of the adaptive filter, $W(n)$ is the filter coefficients vector, and $u(n)$ is the filter input vector.

IV. Conclusion

Image registration is the process of transforming different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, from different times, or from different viewpoints. In this system, the proposed local image registration technique based on an adaptive filtering framework can handle smooth spatial variations in image registration. In this paper, we propose a new local image registration technique based on an adaptive filtering framework that can handle smooth spatial variations in registration. The proposed technique can be used to register images perturbed using Stirmark (for the purpose of watermark recovery), images with radial lens distortion, and multi-view images with small camera motion where parametric models are inadequate. In these applications, the technique offers significant improvements over global registration alone and over other common local registration techniques. The proposed method may be computationally simpler than other approaches for local image registration.

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