IWSSIP 2016 - The 23rd International Conference on Systems, Signals and Image Processing. 23-25 May 2016, Bratislava, Slovakia

Low Complexity Image Registration Techniques Based on Integral Projections

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Abstract **- A low complexity image registration based on integral projections is proposed. The scaling factor estimation involves resampling operations on one image integral projection vector. The rotation estimation use only convolutions with a variable length vector. It is shown that the proposed approach provides a promising alternative to more complex registration methods.**

Keywords – **Integral projection techniques; rotation estimation; scaling factor estimation; image registration.**

I. Introduction

Image registration is an important task [1] in video stabilization, medical imaging, etc. A digital image stabilization system estimate the unwanted translations, rotations and scaling factors and then apply corrections to the sequence of images [1].

For translation estimations there are many proposed approaches [2]-[10]. Among the most used techniques are those based on phase correlation method (e.g. [2]-[4]) and the integral projection (IP) method (e.g. [5]-[7]). The phase correlation method is based on the phase shift theorem [2] and a delta function offset is found by applying an inverse Fourier transform to the phase shift. This technique is very robust, but complex as well because of the use of several fast Fourier transforms (FFT). However, these techniques are complicate due to the use of FFT operations. On the other hand, the integral projection (IP) technique is very simple to implement. A pair of one-dimensional vectors is computed by summing the elements of each column or rows respectively. The projection vectors are correlated to find the best offset corresponding to the matched frames [5]. Also, the problem of estimating the motion in distorted 2-d images was shown to be related to the *nonlinear warping* between IP vectors [11].

Several approaches have been proposed for rotation estimation (e.g. [12]-[18]). For example they are based on pseudo-polar based estimation [12], on FFTs ([13]-[14]), Radon transform ([15]-[16]) etc. In [17] a simple to implement rotation estimation method base on IP vectors is presented.

Scaling estimation methods has been presented in [12], [16], [18], [19] etc. They are based on pseudo-polar transformation [12], Radon transform [16], ratio of means [18], integral projection [19] etc. The accuracy and the good behavior of the Radon based method in noisy environments was proved in [18]. However, some parts of this method (e.g. the rotation estimation technique) have heavily computational requirements.

In this paper, we propose a new registration method that combines only integral projection based approaches in order to register reference and distorted images. Our simulations have shown that scaling [19], rotation [17] and translation [9] parameters estimations performed in this order leads to the most accurate results. The overall low complexity in comparison with competing methods is emphasized and the results of testing the proposed method on hemangioma and cracked road images is included.

The paper is organized as follows: Section II describes the proposed IP based scaling, rotation and translation estimation methods. The robustness to different noise sources is also investigated. This section will be followed by the "Experiments and Results" section where the performance of the methods is compared with that based on the Radon transform. Finally a summary concludes the paper.

II. Low complexity integral projection techniques

A. *Scaling estimation*

The scaling or zoom factor can be obtained by using integral projection vectors [19]. If the images have a different number of pixels, the smaller image is padded with zeros around in order to have the same size with the bigger image.

One integral projection vector of one image is resampled with different resampling factors and compared with the integral projector vector corresponding to the other image. The resampling can be made by using a poly-phase implementation [20]. One example of an original IP vector and its resampled version with a 0.7 factor is shown in Fig. 1.

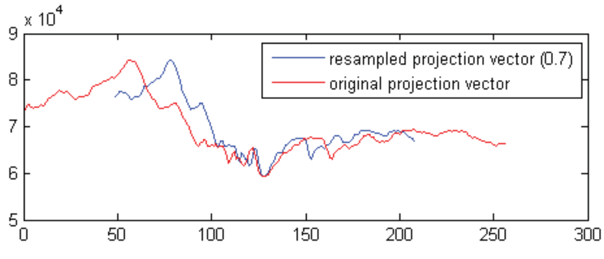
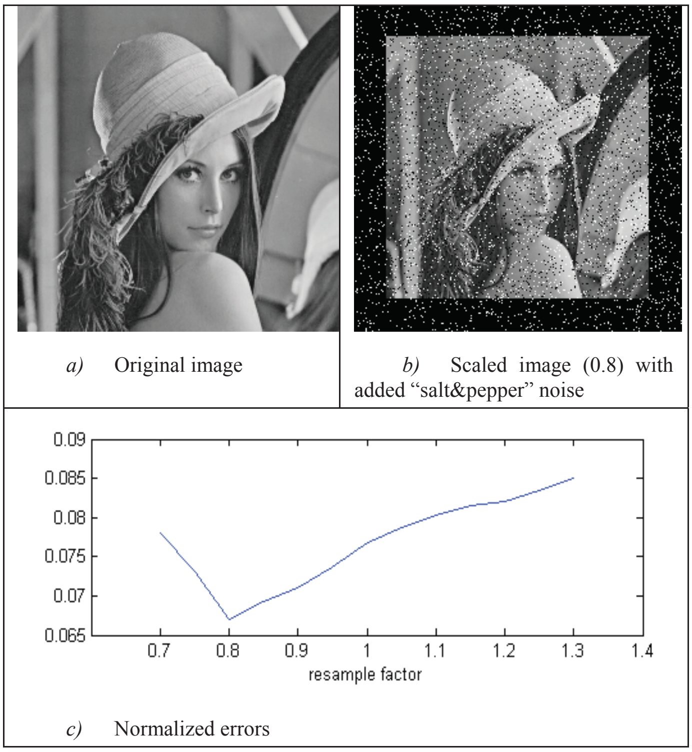


Figure 1. The original integral projection vector and the resampled projection vector (0.7)

The comparison involves the absolute sum of the difference between the resampled IP vectors of one image and the IP vector of the other image computed on the common central part. Then, the resampling factor that leads to the minimum value over the selected range estimates the zoom or scaling factor between images [19]. The proposed method can be used in order to find different scaling factors on horizontal and vertical directions.

In Fig. 2a the Lena image is illustrated while in Fig. 2b the scaled image with a scaling factor of 0.8 with “salt & pepper” noise with 0.1 noise density is shown. In Fig. 2c the normalized errors of the sums of absolute differences between the differently resampled integral projection vectors of one image and the integral projection vectors of the second image is shown. The minimum clearly appears at scale factor 0.8. The simulation also shows the robustness to “salt & pepper” noise. This integral projection based method involves simple convolution operations and allows finding discrete zoom factors with few computations.



a) Original image

b) Scaled image (0.8) with added “salt&pepper” noise

c) Normalized errors

Figure 2

In order to resize the scaled image the same approach from [18] is used. Using a computed mask image with a threshold of 40, the centroids are calculated [18]. The scaling factor is then used to resize one image to match that of the second image and the rotation estimation procedure follows.

B. *Rotation estimation*

It has been observed in [17] that the gradient of integral projection vectors obtained from lines passing through the binary image centered at different angles has one higher positive spike and one higher negative spike. In Fig. 3a an example for a 512x512 image and three angles (4, 7 and 10 degrees) is shown. The amplitude of the spikes decreases with the rotation angle due to a normalization step with a projection of the sum of non-null binary pixels. It was also noticed that the distance from the central position of the vector increases with the rotation angle and varies inversely proportional with the image size [17]. The ripples between spikes can be set to zero by imposing a threshold depending on the maximum vector value. If the image has C columns, and the rotation in radians is α, we have $N = [\alpha C]$ where $[x]$ is the integer part of x [17].

In the rotation based IP method, one IP vector (horizontal or vertical) is successively convoluted with variable length vectors and the second one is convoluted with a fixed vector ([-1 1]). The sum of the absolute differences of the common part of the filtered vectors is computed, and the length of the filter N that leads to the minimum value over the selected range is related to the rotation between two pictures.

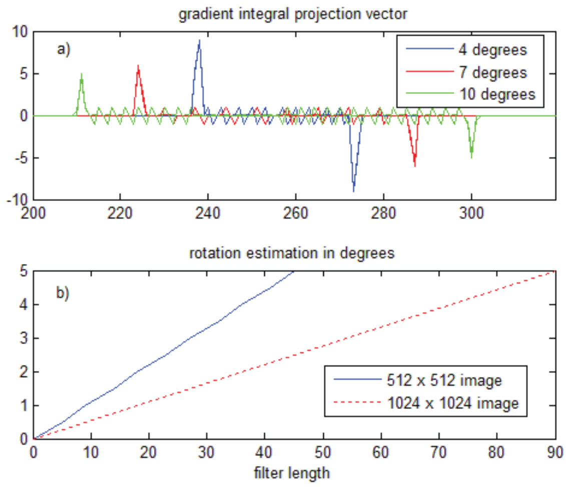


Figure 3 a) The gradient integral projection vectors for different angles; b) The estimated rotation angle in degree as a function of the filter length

The convolution computations are not numerically intensive and the filters can be saved in LUT for each specific image size. In the rotation estimation method based on simplified IP method, one IP vector is successively convoluted with variable length vectors [-1, 0,…,0, 1] (N, the number of zeros is varied), and the output is divided by (N +1). The second IP vector is convoluted with a fixed vector, [-1, 1] (corresponding to 0 degrees) [17]. The estimated rotation is found as above.

In Fig. 4a a 1024 x 1024 hemangioma image is considered. These medical images typically contains more rounded and irregular shapes that do not resemble lines. The image is rotated with 2.4 degrees and a speckle noise added with 0.04 variance. The rotation angle is varied from 0 to 2.7 degrees with a 0.1 incrementing value. In Fig. 4b the normalized errors for various filter length is shown. It can be noticed in Fig. 4b that the minimum is obtained for N = 42 that corresponds to 2.4 degrees for the 1024 x 1024 image (see Fig. 3b). For the investigated rotation range, the absolute maximum rotation estimation error between the true rotation and the estimated rotation is 0.2. However, it can be seen from Fig. 4c that the accuracy of the IP method for small rotations is generally higher than that of [18]. Both IP rotation estimation method

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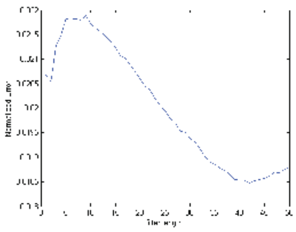
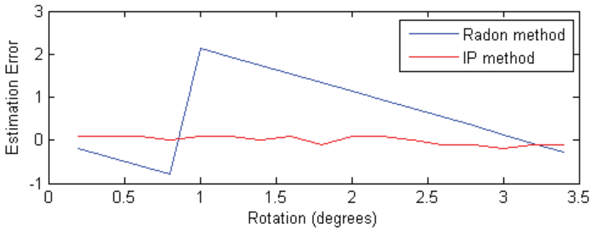
and the simplified IP method gives similar results and the simulations proves their robustness to speckle noise. The integral projection based methods are less complex than the Radon based method that requires complicate trigonometric and multiple FFT operations for each angle investigation. The convolution are basic signal processing operations that have very efficient hardware and software implementations. The IP based complexity is only linear with the image size. Therefore, the numerical savings are higher for bigger images.

a) Original image



b) Normalized errors for different filter lengths



c) The estimation errors for different rotations and methods (the IP based method and Radon method [18])

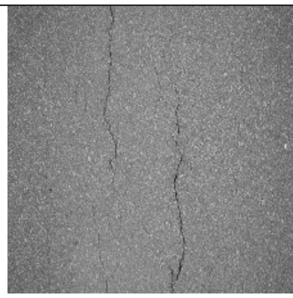
Figure 4

After the rotation angle is found, the image is rotated back in order to compensate for the orientation difference. Next, the translation estimation is performed. For translation estimation, the sign projection method proposed in [9] is used. Each pixel value is compared with two thresholds. The thresholds are computed as a percentage of the dynamic range of the image crop pixel values [9]. A pair of one-dimensional IP vectors (horizontal and vertical) is obtained by computing the sum of transformed value pixels. The projection vectors are correlated in order to find the best offset corresponding to the matched images. The method gives displacement estimations on sufficiently large regions of both images [9]. It was also shown in [9] that the sign projection method is much less complex than the phase compensation method [2]. It is also less complex than the estimation methods proposed in [4], [12]-[14] because it does not use complex FFT operations.

III. EXPERIMENTS AND RESULTS

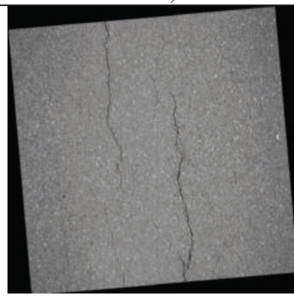
We have investigated the efficiency of the proposed integral projection based methods for a medical sets of images (hemangioma images) and cracked road images. In Fig. 5 the following images are shown: the original images, the distorted images, the processed image results using the method from [18] and the proposed IP method respectively. In the presented simulation the following parameters were used: a scaling factor of 0.8, a rotation of 5 degrees, and translation shifts of (4, 4). It can be noticed from Fig. 5 that the processed results of the proposed method are close to those of the more complex method from [18]. Some differences are explained by the small rotation and scaling estimation errors that occurs.

a)



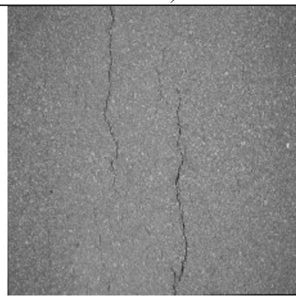
b)

c)



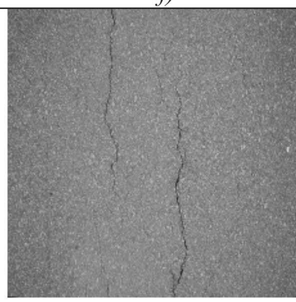
d)

e)



f)

g)



h)

Figure 5 a) Original medical image; b) Original cracked road image; c) Distorted medical image; d) Distorted cracked road image; e) Processed medical image with method from [18]; f) Processed cracked road image with method from [18]; g) Processed medical image with the proposed method; h) Processed cracked road image with the proposed method.

The method of [18] uses three forward 2D FFT, two inverse 2D FFT and 2 Radon transforms. The integral projection based

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method uses only 1D convolutions that could be replaced efficiently by 1D FFTs for large images. The 1D FFTs are far less complex than 2D FFTs.

Table I shows the estimated parameters for two Gaussian noise levels (σ_n) values in case of hemangioma image. It can be noticed that the accuracy of the proposed method is slightly affected in the presence of Gaussian noise on images.

TABLE I. ESTIMATED PARAMETERS

Noise level	**Method** **Original**	**Scale** **0.8**	**Rotation** **3 degrees**	**Translation** **(10, 10)**
$\sigma_n = 0$	Proposed method	0.8	3	(10, 10)
	Method of [18]	0.80	2.8	(10, 10)
$\sigma_n = 30$	Proposed method	0.8	3.4	(10, 10)
	Method of [18]	0.82	2.8	(10, 10)

We found by simulations that the results of the proposed method is comparable with that of the more complex method of [18] especially for scaling factors between 0.7 and 1.3, and rotations of less than 15 degrees. It does not work very well in case of large translations relative to image size (e.g. higher than 100 for the investigated cases) if big rotations, scaling or blurring is affecting one image. Our simulation have shown that the proposed parameter estimation order (i.e. scaling, rotation, translation) lead to the best results. Also, the results are slightly more accurate on medical images than on cracked road images. In the latter case, the projector vectors are noisy and this fact leads to a reduced matching precision.

Future work will be focused on improving the accuracy of the proposed method by using the approaches described in [21]-[24].

IV. CONCLUSION

A fully integral projection based technique was proposed for image registration. Its performance is evaluated and it is proved that it can provide similar motion estimation accuracy with a more complex Radon based estimation method. Due to its simplicity, the method can have an efficient hardware or software implementation. The robustness to Gaussian noise was also investigated.

ACKNOWLEDGMENT

This work was supported by UEFISCDI Romania under Grants PN-II-PT-PCCA-2013-4-0201, PN-II-PT-PCCA-2013-4-1762 and PN-II-ID-PCE-2011-3-0097.

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