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Genetic programming based blind image deconvolution for surveillance systems

Muhammad Tariq Mahmood [a], Abdul Majid [b], Jongwoo Han [a], Young Kyu Choi [a,*]

[a] School of Computer Science and Engineering, Korea University of Education and Technology, Republic of Korea

[b] Department of Information and Computer Sciences, Pakistan Institute of Engineering and Applied Sciences, Nilore, Islamabad, Pakistan

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ABSTRACT

Image acquisition, segmentation, object detection and tracking are essential parts of surveillance systems. Usually, image filtering approaches are employed as preprocessing step to reduce the effect of motion or out-of-focus blur problem. In this paper, we propose genetic programming (GP) based blind-image deconvolution filter. A GP based numerical expression is developed for image restoration which optimally combines and exploits dependencies among features of the blurred image. In order to develop such function, first, a set of feature vectors is formed by considering a small neighborhood around each pixel. At second stage, the estimator is trained and developed through GP process that automatically selects and combines the useful feature information under a fitness criterion. The developed function is then applied to estimate the image pixel intensity of the degraded images. The performance of filter function is estimated using various degraded image sequences. Our comparative analysis highlight the effectiveness of GP based proposed filter.

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1. Introduction

In surveillance systems, the success of the down-stream stages such as image acquisition (Jakubek and Strasser, 2004), segmentation (Chen and Tai, 2010), detection (Tan et al., 2007; Byttner et al., 2011) and tracking (Şaykol, Güdükbay et al., 2010) is highly dependent on prior efficient filtering. In literature many approaches have been proposed for surveillance systems and these systems have been used for practical applications. Image analysis based surveillance systems were developed for quality monitoring (Chatterjee and Bhattacherjee, 2012), mobile robot control (Posadas et al., 2008), control behavioral patterns (Boussemart and Cummings, 2011). and Learning of traffic signals (Bazzan et al., 2010). An efficient multi-object recognition scheme was proposed for surveillance based on interest points of objects (Kim et al., in press). The intelligent approaches based surveillance systems have also been proposed and are becoming popular for diverse applications (Vallejo et al., 2011). In intelligent surveillance systems, high-level interpretation of events within the scene requires low-level vision computing of the image and the moving objects. In real applications, these systems are developed for motion detection (Delgado et al., 2010; Huang and Cheng, in press), fault detection (Jakubek and Strasser, 2004; Tan et al., 2007; Byttner et al., 2011), road detection (Chen and Tai, 2010), heterogeneous network (Leu et al., in press), smart home environment (Kang et al., in press), scenario-based video-surveillance (Şaykol et al., 2010) and real time skin color detection based surveillance system (Chen et al., in press).

Restoring visual information from the blurred and noisy image is essential in surveillance systems (Vallejo et al., 2011). Fig. 1 shows the basic components of surveillance system. In this regards, the performance of conventional imaging devices with long focal lengths suffer from the limited depth of field. In the captured frames, some parts of the scene may be well-focused while other parts de-focused (Mahmood et al., 2011). Further, during the image capturing process, due to the relative motion of objects or camera lens, blurring may introduced in the acquired frames. This effect is formulated through the point spread function (PSF). The amount of blurring introduced can be adjusted through this function. The objective of image restoration is to obtain an estimate of true image $f(i,j)$ from its degraded image $g(i,j)$. The resultant degraded image is obtained due to the convolution of the actual image with Gaussian function $h(i,j)$. The degraded image is expressed as

$$g(i,j)=f(i,j)^{*}h(i,j)+n(i,j), \quad (1)$$

where * denotes 2-D linear convolution operator and $n(i,j)$ is the additive noise.

The first category of linear restoration approaches requires the complete knowledge of blur function and noise statistics. However, in practice, it is not easy to compute all the necessary parameters in advance. To restore the noisy blurred image, the

* Corresponding author. Tel.: +8241 560 1353; fax: +8241 560 1462.
E-mail addresses: tariq@koreatech.ac.kr (M.T. Mahmood), abdulmajiid@pieas.edu.pk (A. Majid), hanu@koreatech.ac.kr (J. Han), ykchoi@koreatech.ac.kr (Y.K. Choi).

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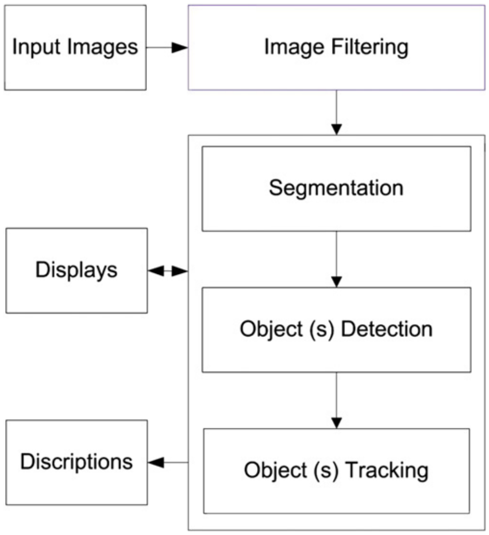

Fig. 1. Basic components in a surveillance system.

blind image deconvolution approaches involve the complete knowledge of the PSF (Li et al., 2007). These approaches are useful when the original object is not available. However, both linear and nonlinear blind image restoration approaches face ill-posed problem (Sezan and Tekalp, 1988; Chong and Tanaka, 2010). The ill-conditioned problem is addressed in regularization or bayesian theory based methods by incorporating additional constraints. The proposed algorithms restore the original image by minimizing the cost function. It is believed that nonlinear probabilistic methods are superior to conventional linear methods. However, there is no guarantee about the uniqueness convergence of the linear and nonlinear algorithms. At high noise levels, these algorithms may diverge.

We compare the performance of the proposed approach scheme with Richardson–Lucy (LR) deconvolution algorithm and Wiener filtering approaches. Due to their effectiveness, both Richardson–Lucy (LR) deconvolution algorithm (Richardson, 1972) and Wiener filtering (Grimble, 1984) has gained considerable attention. This maximum likelihood estimate (MLE) based the LR algorithm is effective when complete information of the spread function and little information about the additive noise is known. Maximum a posteriori estimate (MAPE) is another probabilistic based approach, which is closely related to the MLE method. However, this probabilistic method incorporates a prior distribution over the original scene to iteratively restores the degraded image (Xu and Lam, 2009). The major limitation of these nonlinear iterative techniques is their slow convergence because they offer computationally intensive solution. The MLE based methods begin to amplify the noise after a certain number of iterations. Wiener filtering is commonly used for the digital image reconstruction, deblurring and de-noising. This filter reduces the difference between the filtered noisy and the true image in the least squares sense. Wiener filter is completely deterministic and the user has to tune its parameters according to the situation. The performance of the filter depends on the spatial-invariant blur and stationary Gaussian noise.

Under such situation, machine learning based methods can offer an alternate approach for effective blind image deconvolution (Li et al., 2007). In practices, the overall characteristics of original or degraded images are different from each another. However, there exit some common features in all the images degraded with diverse types of blur. For example, all types of blur average the neighboring pixels. This common property found in most frequently exist Gaussian noise. The problem is how to select this local useful information and then optimally combine to develop a generalized mapping function that perform equally well under diverse type of noisy environment. To address this problem, adaptive neuro-fuzzy (Anfis), support vector machine (SVM) and artificial neural network (ANN) intelligent approaches are proposed to learn the common features for image restoration (Dávila and Hunt, 2000; Jakubek and Strasser, 2004; Li et al., 2007; Tan et al., 2007). An adaptive neuro-fuzzy (Anfis) impulsive noise filter was developed for distorted images (Beşdok, 2004). Recently, a multiscale dictionary learning approach is introduced for the removal of image noise. In this approach, first images are represented by a translation invariant dictionary and coefficients are then denoised using learned multiscale dictionaries (Yang et al., in press). Both SVR and ANN approaches optimize the model parameters. However, due to the poor generalization of ANN, an alternative SVR approach develops a mapping by selecting support vectors from the input examples. The performance of SVR approach is dependent on the characteristics of the input examples. Therefore, these approaches are lack of developing an example-independent mapping function. Developing a reliable and generalized technique is still a major challenge.

Under this scenario, we introduce the Genetic Programming (GP) based blind image deconvolution approach that automatically extracts and combines the useful features to develop an optimal function under a fitness criterion. GP based optimization technique has widely used in the applications of pattern recognition (Khan et al., 2008), information systems (Mahmood et al., 2011), and computer vision (Petrovic and Crnojevic, 2008; Majid et al., 2010). GP searches solution in the defined problem space. GP is effectively in developing mathematical models by combining focus measures for depth estimation (Mahmood et al., 2011). These models are very useful for 3D shape recovery of microscopic images (Majid et al., 2010). GP based function was develop for impulse noise detector (Petrovic and Crnojevic, 2008). However, in (Majid et al., 2011), convolution kernels were used in the noise detection stage and filtering is carried out by developing noise-free pixels based filter. During GP based training phase, an improved performance estimator function is developed by taking advantages of local information of degraded images. In the proposed approach, local pixels information of degraded images is used as input features and the corresponding pixels information of the true images are used as targets. During GP evolution, a numerical mapping establishes a common high performance framework that can handle various types of blurs and other noisy information. In this method, the step of blur identification is automatically incorporated. The experimental results are evaluated under various metrics. Our comparative analysis demonstrates the effectiveness of the GP based proposed scheme.

The organization of the rest of the paper is as follows. In Section 1, a brief introduction to surveillance systems and its possible application areas is given. In Section 2, GP based proposed scheme is explained in detail. Experimental results and discussion are presented in Section 3. Finally, Section 4 concludes this study.

2. Proposed scheme

GP technique is based on the principles of natural selection and recombination to search the space of all possible solutions. Through GP evolution cycle, the most optimal solution in the form of a numerical function is developed. The proposed scheme is divided into three modules; (1) *Preprocessing module*, (2) *GP module*, and (3) *Estimation module*. In *Preprocessing module*, training data is formed by computing the grey scale features of the object. During GP process, optimal estimation function is developed using the training data.

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