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A new algorithm for lane detection and tracking on pulsed field gel electrophoresis images

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ABSTRACT

In this paper, a new method is presented for lane detection and extraction on the pulsed field gel electrophoresis (PFGE) images. Average lane width and lane curvature are the most important parameters that are required for automatic image processing of PFGE images. For this purpose, a new algorithm based on computing the power spectrum density (PSD) is proposed for automatic lane detection and tracking. The PSD is used to calculate the average lane width and then partitioning original images to sub-images, tolerating some overlaps. The performance of the proposed algorithm has been evaluated on 30 PFGE images which totally form 300 lanes. Results show that the new algorithm has better performance in lane width detection compared to the other methods such as intersection of the horizontal lines and reaches 99.66%. Finally, it can also be used as a software tool for automatic analysis of PFGE images.

1. Introduction

Standard gel electrophoresis methods for separation of Deoxyribonucleic acid (DNA) molecules provide several advantages for molecular biology researches. However, it is not able to separate very large molecules of DNA, effectively. To overcome this problem, a technique was developed in 1984, in which the large parts of DNA can be separated by changing the direction of the electric current and it is currently known as Pulsed-Field Gel Electrophoresis (PFGE). PFGE is one of the common methods for molecular typing and epidemiological studies [1].

PFGE images contain several vertical stripes called *lane*. Each lane consists of a group of DNA fragments which form the horizontal bands, having nearly constant width [2]. The advent of digital image technology provided a direct method for creating gel electrophoresis images in a specific format for forthcoming analysis [3]. Digital gel electrophoresis images are widely used to extract valuable information from biological materials in various molecular biology applications [4]. For example, it is used to find the relationship between an unknown biological specimen and a known biological one by comparing their DNA patterns [2]. On the other hand, manual analyzing and evaluation of images is not only a boring task but also it probably rises human errors [5,6].

Today, analysis and processing of these images such as lane extraction and band localizing are carried out by computers [3]. Different factors including electrical charge of particles, temperature and pH of the surrounding environment affect the quality of the produced images which give rise to the process of lane extraction and band localizing to be more difficult. It should be pointed out that the main purpose of the image analysis is to properly detect bands and then to compare the lanes using the obtained band location. Consequently, in the first step the lanes should be correctly extracted and then individual lane be prepared for future analysis.

Since PFGE and Polymerase Chain Reaction (PCR) images have similar characteristics, it is helpful to use the studies which were conducted on PCR images. Therefore, several methods were suggested to solve the problem of visual analysis which was time consuming and inaccurate [7]. The first step in processing of PFGE images is lane extraction which is also called lane tracking [8]. Because the accuracy of band detection depends on the accuracy of lane detection, it is necessary to apply techniques for better lane detection. Akbari and his colleagues presented, a semi-automatic method for lane detection [7]. In their proposed method, the number of lanes in the image must be entered manually by the user. Meanwhile, a commercial software is also designed [3]. By determining the number of lanes, their average width can be estimated which is a very important factor for the succeeding steps of lane detection such as smoothing signal, removing the undesirable centers or connecting the desirable lane centers in all of the sub-images. Most semi-automatic and automatic methods proposed for lane detection are based on the visual

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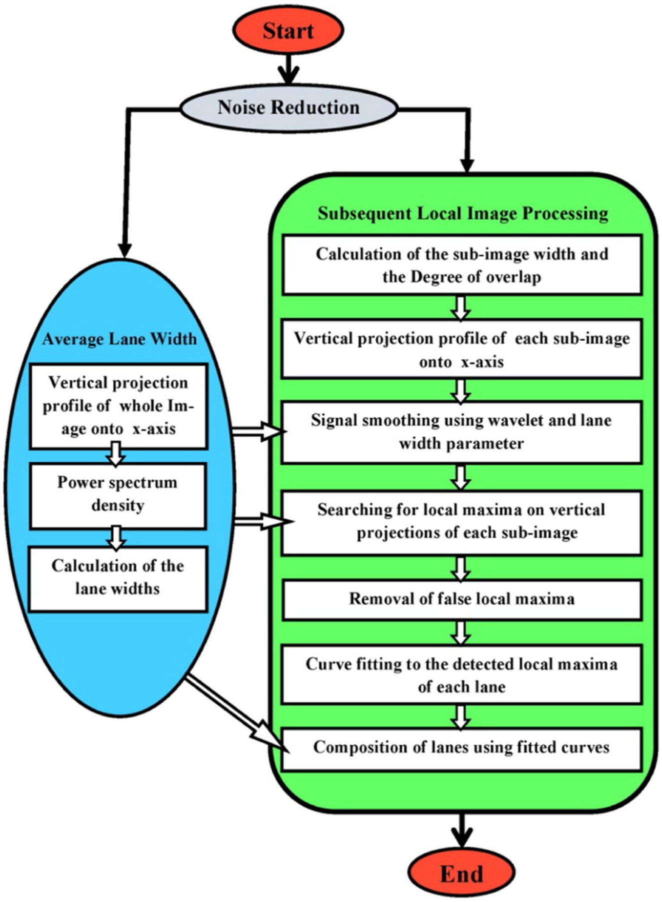

Fig. 1. The flowchart of the proposed algorithm.

projection profile (VPP) onto the x-axis [9]. To smooth the signals from the VPP, the wavelet transform can be used [10]. Furthermore, for choosing the appropriate parameters of wavelet, it is necessary to use the average width of individual lane.

One common method to estimate the lane average width is to intersect a horizontal line with the signal obtained from the VPP and then find the distance from the sequential cut-off points as the lane width and finally calculate the average value of all lane widths. This procedure is called intersection horizontal line (IHL) [11]. Clearly, the aforementioned method is not an accurate estimation of the lane average width. Therefore, in the current research, a new method based on power spectral density of the VPP is proposed to calculate the average width of the lane in PFGE images. In this case, the VPP is acquired for the whole PFGE image and then power spectrum density of the signal is computed. It will be shown that the second frequency which has the higher amplitude could be considered as the value corresponding to the average width of the lane.

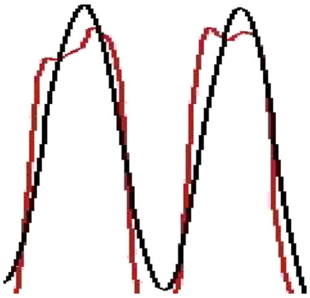

Fig. 3. Black signal is the result of the smoothing of red signal. As it can be seen, undesirable local maxima have been removed. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Another challenge in the process of lane tracking is the lane curvature. In [11], a new method was developed to solve this challenge. They were able to approximately detect the curvature of lane by partitioning individual image into N sub-images along x-axis. Nevertheless, there was a limitation on the number of sub-images. Indeed, partitioning the original image into more sub-images leads to the better detection of the lane curvature. However, it increases the amount of noise which can cause incorrect detection of lane centers in each sub-image. This is due to the reduced width of sub-images. Consequently, in this paper, to overcome this limitation, partitioning of the original images into sub-images is performed by allowing some overlaps between sub-images.

The rest of paper is organized as follows: Section 2 describes data set, the proposed method for lane tracking, including image preprocessing steps, calculating the lane average width based on power spectral density and partitioning the original image. Results and Discussion are explained in Sections 3 and 4, respectively and finally, Section 5 concludes the paper.

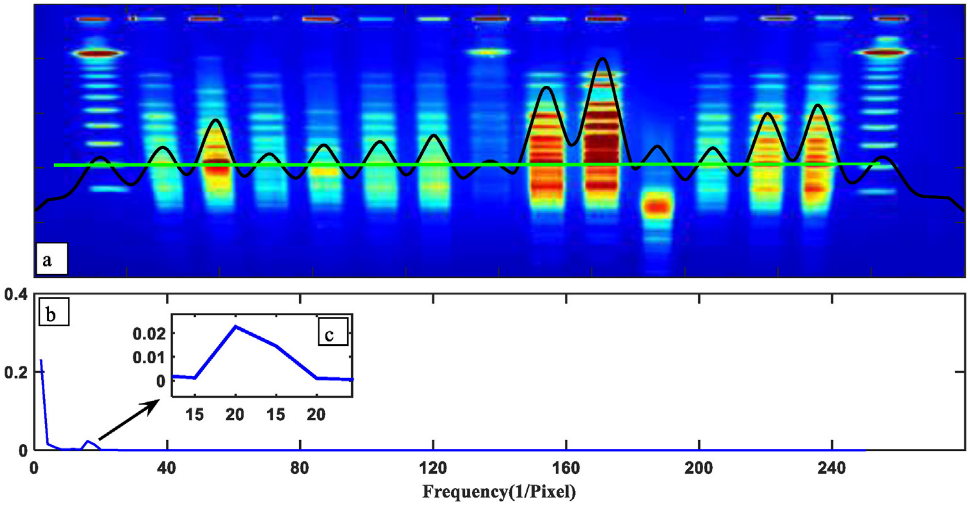

Fig. 2. Calculating the average lane width using PSD: (a) an example of typical PFGE images. (b) Corresponding power spectrum density graph. (c) The magnified portion of (b) in which the second peak has inverse relationship with the average lane width.