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Research Article

# Interpreting Blood Perfusion Variations in Laser Doppler Imaging

**MZ Ansari* and A Mujeeb**

*International School of Photonics, Cochin University of Science and Technology, Kochi, India*

***Corresponding Author:** MZ Ansari, International School of Photonics, Cochin University of Science and Technology, Kochi, India.

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## Abstract

We report on the feasible application of a motion based temporal template algorithm, the motion history image (MHI) on laser Doppler imaging (LDI) to follow blood perfusion variations. MHI was implemented on the LDI data to visualize perfusion changes during an arterial occlusion in a healthy subject. MHI effectively illustrated the locations where perfusion evolves with time. MHI rely on a rather simple algorithm that generates a static image template using a buffer of a temporal sequence of images, reflecting a temporal evolution of the perfusion changes. To help the clinicians and researchers, MHI can be tested on LDI data for the analysis of perfusion fluctuations.

***Keywords:*** *Laser Doppler Imaging; Motion History Image; Perfusion Variations*

## Introduction

Laser Doppler imaging (LDI) as a full-field imaging technique has widely been used for research, and clinical applications [1,2]. Today commercial LDI instruments are available that can assess blood perfusion over a surface >1000 $cm^2$ [3]. The sampling depth that depends on the laser wavelength and properties of the tissue is typically from 1 to 2 mm [4].

LDI finds many biomedical applications, such as to diagnose burns [1,3,5-10], to study cerebral blood flow [11], for drug uptake studies [12], to measure microvascular dysfunction in Raynaud's phenomenon, and diabetes [13,14], assessment of microvascular perfusion in the skin [15] and many other applications including chronic pain [16], cancer and angiogenesis [17,18] and brain [19].

To follow the perfusion variations for clinical and research applications, an average perfusion value is often computed (in a given ROI) over time by using the LDI perfusion maps [20]. This, however, breaks the bidimensional nature of the LDI maps and undermines the advantage of the technique [22,23,25].

To aid in performing this task, recently a view based temporal template method, the motion history image (MHI) has been used for laser speckle contrast imaging (LSCI) [23] and laser fluorescent imaging [24]. MHI rely on a rather simple algorithm and allows obtaining information on the temporal evolution of the perfusion changes without computing a mean value over an ROI [22,23]. Thus, a grayscale bidimensional map representing the perfusion variations with time is generated [22-24]. So far the MHI technique has only been implemented on the LSCI and fluorescent imaging data.

In the present study, we report on the feasible application of the MHI algorithm on LDI data. MHI was implemented on LDI data to visualize perfusion changes during an arterial occlusion in a healthy subject. MHI effectively illustrated the locations where perfusion evolves with time. The results were analyzed and discussed and a conclusion is proposed.

## Materials and Methods

### Materials

An LDI case study was performed on the fingers of a volunteer subjected to an arterial occlusion using a blood pressure cuff [20]. Real-time LDI measurement was conducted to monitor blood perfusion over an area of up to 50 $cm^2$. An LDI instrument consists of a 150 mW near-infrared laser emitting at 808 nm and CMOS sensor of a pixel size of 14×14 $\mu m^2$ with a quantum efficiency of 18% was used. Details of the experimental technique can be studied using Ref. [20].

### Image processing algorithm: motion history image (MHI)

An MHI is a view based temporal template method that allows generating a map of temporal sequence movements within a scene under observation [21-23]. Recently it has been applied to various LSCI data as well as to dynamic fluorescent imaging to obtain information on the temporal evolution of the perfusion variations [22,24]. In the generated scalar-valued image (so-called MHI), pixel intensity is a function of motion history at that location. An MHI is computed from a temporal difference binary image Ψ(x,y,t) defined as:

$$\Psi(x,y,t)=\begin{cases}1 & \text{f} \quad |I(x,y,t)-I(x,y,t-1)|\geq\xi \\ 0 & \text{otherwise}\end{cases},$$

where I(x,y,t) is the pixel intensity at coordinate (x,y) in the tth frame of the image sequence and ξ is a gray-level threshold value. Proper selection of ξ avoids noise and identifies exact motion locations in the right places. The MHI Hτ can then be computed as follows [23]:

$$H_\tau(x,y,t)=\begin{cases}\tau & \text{f} \quad \psi(x,y,t)=1 \\ \max(0,H_\tau(x,y,t-1)-1) & \text{otherwise}\end{cases},$$

where (x,y) and t are the position and time coordinates respectively, τ is temporal extent called image lifetime of the movement in terms of frames.

## Results and Discussion

### Visualization of perfusion variations in microcirculation in healthy skin

Figure 1 presents LDI maps showing the perfusion variations before, during and after the arterial occlusion. LDI measurement was performed on the fingers of a volunteer subjected to an arterial occlusion using a blood pressure cuff [20].

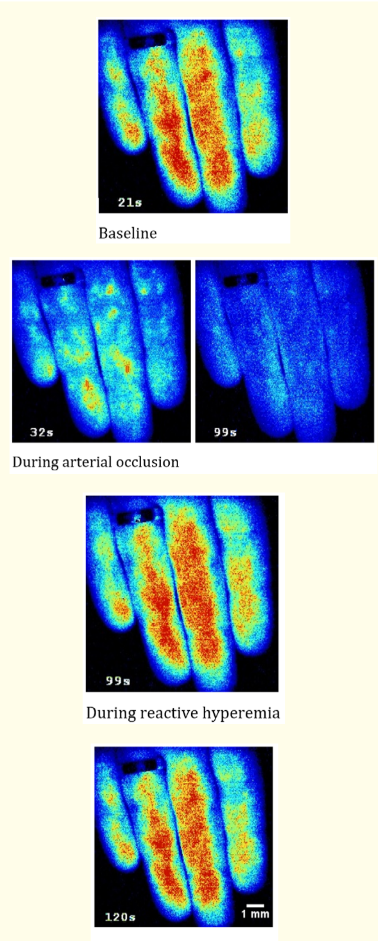


***Figure 1:*** *LDI maps (Reproduced with permission from [20]. Copyright (2011) by the Optical Society of America, USA) showing perfusion variations before, during and after an arterial occlusion in a healthy subject. The blue color indicates low and the red, high perfusion level. Frames were extracted from a video sequence containing LDI images (14 fps).*

In order to follow the perfusion variations during the process, we used a view based temporal template algorithm, the MHI on the LDI images sequence. Figure 2 presents a bidimensional map of the perfusion evolution in time generated using the LDI images (around the frames shown in figure 1). MHI effectively illustrated the locations where there are fluctuations in blood flow before, during and after the arterial occlusion.

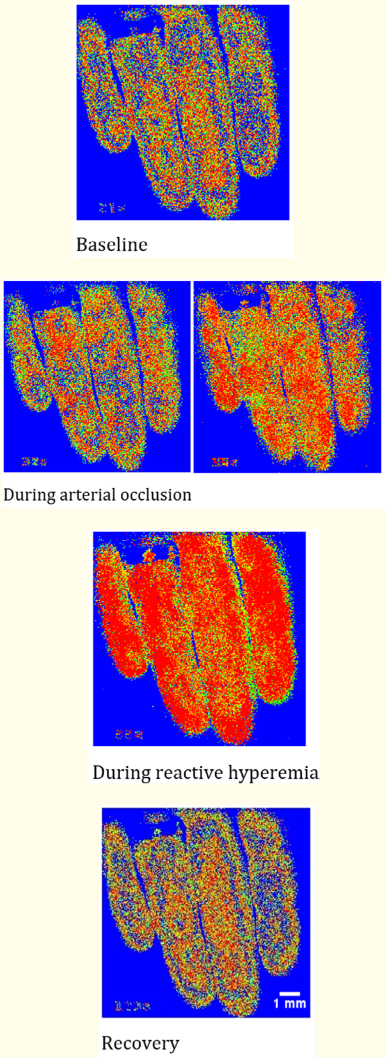


***Figure 2:*** *Bidimensional MHI perfusion maps showing perfusion variations before, during and after arterial occlusion. All the MHIs have been computed from the corresponding LDI perfusion maps shown in figure 1. For the computation, a buffer size of 7 images with a threshold value of 41 was used.*

It can be noted that the MHI has the same resolution as the original LDI data (Figure 1). However, the perfusion image resolution can have an influence on the resulting MHI maps as was reported earlier [23]. MHI can also be influenced by the sampling frequency of the LDI perfusion data. Under such circumstances, the quality of the MHI maps can be enhanced by proper adjustment of its parameter values such as the buffer size and the threshold level [23].

## Conclusions

We have implemented the MHI method on the LDI data to visualize perfusion changes during an arterial occlusion in a healthy subject. The results of MHI effectively illustrated the locations where perfusion evolves with time. MHI generates a static image reflecting a temporal evolution of the perfusion changes and it can be tested on several other LDI data for the analysis of perfusion variations.

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## Declaration of Conflicting Interests

The author(s) declared no conflicts of interest with respect to the research, authorship, and publication of this article.

## Ethical Approval

All procedures were performed on the published supplementary data (of Biomedical Optics Express, OSA) of reference [20]. Ethical approval was not needed.

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