Microvascular Research 107 (2016) 106–109

Contents lists available at ScienceDirect

Microvascular Research

journal homepage: www.elsevier.com/locate/ymvre

Short Communication

Visualization of perfusion changes with laser speckle contrast imaging using the method of motion history image

Mohammad Zaheer Ansari [a,*], Anne Humeau-Heurtier [b], Nikolas Offenhauser [c], Jens P. Dreier [c,d,e], Anil Kumar Nirala [a]

[a] Biomedical Optics Laboratory, Department of Applied Physics, Indian School of Mines, Dhanbad, 826004, Jharkhand, India
[b] University of Angers, LARIS, Laboratoire Angevin de Recherche en Ingénierie des Systèmes, 62 Avenue Notre-Dame du Lac, 49000 Angers, France
[c] Department of Experimental Neurology, Charité University Medicine Berlin, Charitéplatz 1, 10117 Berlin, Germany
[d] Department of Neurology, Charité University Medicine Berlin, Charitéplatz 1, 10117 Berlin, Germany
[e] Center for Stroke Research, Charité University Medicine Berlin, Charitéplatz 1, 10117 Berlin, Germany

ARTICLE INFO

Article history:
Received 20 May 2016
Revised 15 June 2016
Accepted 15 June 2016
Available online 16 June 2016

Keywords:
Laser speckle contrast imaging
Motion history image
Generalized differences
Spreading depolarization

ABSTRACT

Laser speckle contrast imaging (LSCI) is a real-time imaging modality reflecting microvascular perfusion. We report on the application of the motion history image (MHI) method on LSCI data obtained from the two hemispheres of a mouse. Through the generation of a single image, MHI stresses the microvascular perfusion changes. Our experimental results performed during a pinprick-triggered spreading depolarization demonstrate the effectiveness of MHI: MHI allows the visualization of perfusion changes without loss of resolution and definition. Moreover, MHI provides close results to the ones given by the generalized differences (GD) algorithm. However, MHI has the advantage of giving information on the temporal evolution of the perfusion variations, which GD does not.

1. Introduction

The monitoring of microvascular blood flow is now of interest for the follow-up or the diagnosis of many pathologies. Indeed, it has been shown that, for some cases, microvascular perfusion alterations are visible long before organ dysfunctions become clinically manifest (Jung et al., 2013; Singh et al., 2003). The monitoring of microvascular perfusion can be performed with several technologies (Bi et al., 2015; Cracowski and Roustit, 2015). One of them, the laser speckle contrast imaging technique, is gaining an increased interest because it is non-invasive, easy to use, real-time, and gives reproducible results (Humeau-Heurtier et al., 2013; Roustit et al., 2010; Briers and Webster, 1996). However, due to the lack of absolute units of LSCI data (Duncan and Kirkpatrick, 2008), the laser speckle contrast images are often recorded before and after a stimulus. Thus, the evolution of the perfusion is studied with time. Unfortunately, for images representing a large area, it is often difficult to visualize precisely and rapidly all the regions of interest where the perfusion evolves (and the way how it evolves).

Recently, a method based on the generalized differences (GD) has been proposed to overcome this problem (Humeau-Heurtier et al., 2015). However the GD method, by definition, loses the time dimension. To obtain information on the time evolution of the perfusion changes, the user has to split the stack of images in several sub-stacks and has to compute the GD image for each sub-stack. Unfortunately, this gives rise to several GD images, which is not ideal for the clinicians. We therefore herein propose another method generating a single image, the so-called *motion history image* (MHI), where the perfusion variations are underlined and where the temporal information of these variations is visible on the image itself: MHI is a scalar-valued image in which the intensity is function of the recency of the variations. MHI therefore enables the identification of variations within a stack of images recorded in time. We herein propose to use this method to evaluate the perfusion variations in images recorded with LSCI.

2. Materials and methods

2.1. Theory

The MHI approach is a view-based temporal template method (Bobick and Davis, 2001; Davis and Bobick, 1997). It gives a (single)

* Corresponding author.
E-mail address: mohamedzaheer1@gmail.com (M.Z. Ansari).

http://dx.doi.org/10.1016/j.mvr.2016.06.003
0026-2862/

image from an image sequence where each pixel value of the new image is a function of recency of motion (perfusion variations in our case) in the image sequence. The MHI $H_{\tau_k}(i,j)$ can be computed from an update function $\psi_k(i,j)$ as (Davis and Bobick, 1997; Ahad et al., 2012)

$$H_{\tau_k}(i,j) = \begin{cases} \tau & \text{if} \quad \psi_k(i,j) = 1, \\ \max(0, H_{\tau_{k-1}}(i,j) - \delta) & \text{otherwise}, \end{cases} \tag{1}$$

where $\psi_k(i,j)$ mentions motion in the current image sequence. The duration τ allows choosing the temporal extent of the movement in terms of frames and δ is the decay parameter. Usually, the MHI is computed from a binarized image obtained from frame subtraction using a threshold ξ

$$\psi_k(i,j) = \begin{cases} 1 & \text{if} \quad D_k(i,j) \geq \xi, \\ 0 & \text{otherwise}, \end{cases} \tag{2}$$

where $D_k(i,j)$ is defined with difference distance Δ as

$$D_k(i,j) = |PU_k(i,j) - PU_{k\pm\Delta}(i,j)|, \tag{3}$$

where $PU_k(i,j)$ is the perfusion value for the pixel situated at the coordinates (i,j) in the k-th image of the perfusion sequence.

As an example, let us consider a hand moving (see Fig. 1a and b). The resulting MHI is shown in Fig. 1c. We can observe the trail of the movement made by the hand where the final motion locations are shown in red in the MHI static image.

In our work, the MHI results are compared with the method of GD computed as (Humeau-Heurtier et al., 2015)

$$PU_{GD}(i,j) = \sum_{k=1}^{N-1} \sum_{l=k+1}^{N} |PU_k(i,j) - PU_l(i,j)|. \tag{4}$$

2.2. Data acquisition

The data have been recorded on the two hemispheres of a mouse, through the skull (Humeau-Heurtier et al., 2015). The perfusion acquisition has been performed with a PeriCam PSI System (Perimed, Sweden) having a laser wavelength of 785 nm and an exposure time of 6 ms. For the acquisition, a sampling frequency of 0.1 Hz was chosen and the distance between the laser head to the skull was set at 10.4 cm (Mahe et al., 2011) which gave images with a resolution of around 0.02 mm. The experiment has been done in compliance with institutional guidelines and international standards on animal welfare and approved according to local and national regulations for animal care and use for research purposes. The mouse was anesthetized with isoflurane (2.5% induction, 1.5–2% during surgery) in 70% N_2O and 30% O_2. After the end of the preparation isoflurane anesthesia was reduced to 1.1–1.2%. The temperature was continuously measured and maintained at 37.8 °C by the use of an automatic controlled homeothermic blanket system. The mouse was placed in a stereotaxic frame and the skin was removed above both hemispheres to enable cerebral blood flow measurements by LSCI. The perfusion variations were monitored during a pinprick in one of the hemispheres that induced a spreading depolarization (SD). SD is characterized by abrupt, sustained depolarization of neurons en masse and near-complete breakdown of the ion gradients across the cellular membrane. It typically propagates at velocities of around 3 mm/min in gray matter of the brain and causes characteristic changes of regional cerebral blood flow (rCBF). These show some peculiarities in the mouse in contrast to other mammals. In the mouse, the cerebrovascular response to SD thus starts with pronounced initial hypoperfusion, followed by a short peak that barely reaches baseline, and renewed, very prolonged rCBF reduction by about 60%. The cerebral metabolic rate of oxygen drops, severe hemoglobin desaturation suggests that oxygen metabolism becomes at least partially supply limited, and decrease in blood volume implies vasoconstriction as the mechanism. Nonetheless, the response has not been rated as a fully ischemic one (Dreier and Reiffurth, 2015). It may be added that other mammals, including humans, show a predominantly hyperemic cerebrovascular response to SD that is followed by mild oligemia under normal conditions.

3. Results and discussion

In the MHI process, we used a buffer of 6 images with a threshold value of 80, over a collection of 25 images. The results are shown in Fig. 2b. From the latter we note that MHI clearly shows the induced wave of hypoperfusion following the pinprick. The MHI image preserves both the resolution and dimension of the original images. The results given by the GD method is shown in Fig. 2c. We observe that MHI, with the specific threshold and buffer size, shows a behaviour consistent with the one given by the GD algorithm.

The quality of MHI results can be enhanced by proper adjustment of its parameters, particularly related to the buffer size and level of threshold (Godinho et al., 2012). Fig. 3 shows three levels of threshold (80, 60 and 40 with a buffer size of 6). The adjustment of threshold reinforces the ability of MHI to separate different degrees of activities in distinct areas. Moreover, the buffer size enhances the ability to see lower activities, acting as a digital integrator (Godinho et al., 2012). A quantitative analysis could be performed through the colorbar of the generated MHI images. By definition MHI is a view-based temporal template method and the MHI is an image in which the intensity is function of the recency of the variations. It could therefore now be interesting to compare the MHI images (through their colorbar) obtained with different parameters values.

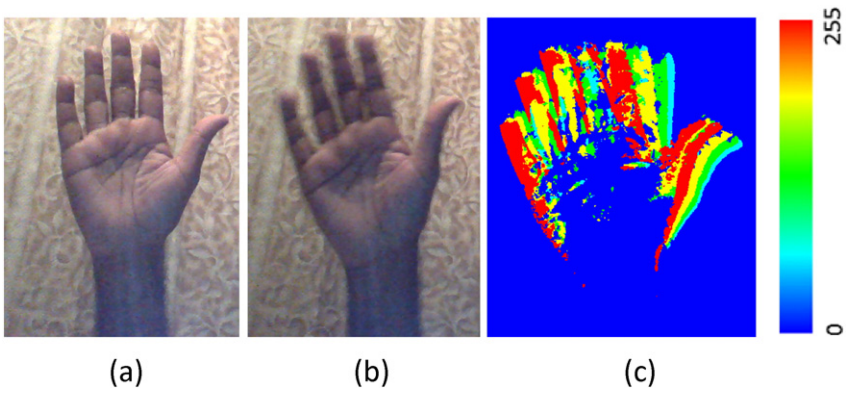

Fig. 1. (a) Image of the hand; (b) Movement of the hand; (c) Motion history image where the final motion locations are shown in red.