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Laser Doppler Using Holographic

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Abstract

This paper describes the design and evaluation of a novel easy to use, . The system is based on the methods of Laser Doppler Flowmetry It is based on standard digital camera technology, Laser Doppler Flowmetry (LDF) is a rather method for visualization of blood f low over a large tissue area. The outcome of the method is a 3- dimensional map of blood perfusion. One of new methods to reconstruct the field from the interference pattern are surveyed, by using hologram and used to measure perfusion for two region of human body (hand and foot) by using hologram. lead to these method to distinguish between perfusion in foot and hand by using digital hologram. This is a first step toward laser Doppler imaging is used power density, leading to a much faster imaging procedure than with existing mechanical laser Doppler perfusion imagers by using matlab.

Key words: Laser Doppler perfusion imaging, digital hologram, Spectral interferometry, Fourier Transform

1.INTRODUCTION

The major advantage of laser Doppler techniques in general is their non invasiveness and the ability to measure the micro circulation of the tissue and fast changes of perfusion . Under certain conditions, the technique can measure perfusion quantitatively (although relative) in real time. LDPM is a one point measurement method which records the integrated perfusion in a sampling volume in real time. LDPI instruments [1]-[2] map the perfusion on a larger area by scanning the laser beam over the area of interest. the perfusion imaging technique has undergone a dramatic progress with the development of technology. Commercial scanning systems became available which can make color maps of perfusion on an area of tissue . It has been shown [3] that the scattering level of the tissue strongly affects a laser Dopplerimager signal due to the varying number of coherence areas involved in the detection, Wardell and Nilsson [3] introduced duplex laser Doppler perfusion imaging which allows studies of temporal blood flow changes by frequently updated single or multipoint recordings. Linden et al. [4] developed enhanced high resolution LDPI with a focused laser beam of FWHM less than 40 micrometer. Laser Doppler perfusion imaging (LDPI) [5, 6] is a non-invasive technique to measure blood flow maps on an area of tissue. The photodetector signal generated in a laser Doppler perfusion instrument can be considered to be generated by a large number of dynamic speckles (coherence areas). Rajan et al. [7] showed that the scattering level of the tissue strongly affects a laser Doppler imager signal due to the consequence of the number of speckles involved in the detection process. Forrester et al [8] was suggested called laser speckle imaging (LSI) and later named laser speckle perfusion imaging (LSPI) [9]. In this a CCD camera is used to make a series of speckle images from a sample with finite integration time. And the decor relation of the speckle pattern is related to blood flow**.** Full field LDPI requires a high speed camera, which is very expensive, so its future depends on the price development of CMOS imaging array technology. The diffusion of light in tissue suppresses the resolution of full field LDPI image because of the spreading of the backscattered light in tissue. Also the difference in gain of different pixel arrays in a CMOS camera results in a variation in response of the pixels for the same signal. We utilized a complementary metal oxide semiconductor video camera for fast flow imaging with the laser Doppler technique. A single sensor is used for both observation of the area of interest and measurements of the interference signal caused by dynamic light scattering from moving particles inside scattering objects. In particular, we demonstrate the possibility of imaging the distribution of the moving red blood cell concentration. This is a first step toward laser Doppler imaging without scanning parts, leading to a much faster imaging procedure than with existing mechanical laser Doppler perfusion imagers. Various techniques for blood f low imaging have been suggested. Two different LDPI systems were described by Wårdell *et al.*[10] and Essex and Byrne.[6] In these systems the tissue is illuminated by a narrow collimated laser beam, and a detector at 20–100-cm distance from the tissue is used to observe the light re-emitted from the illuminated area. Scanning the beam through a certain tissue area yields area yields a 2-D perfusion image. In both systems the scanning takes an appreciable amount of time, since the scanning speed is limited by the trade-off between the laser Doppler signal's lower cutoff frequency and image quality. **Serov** et al.,[11] based on a complementary metal oxide semiconductor (CMOS) image sensor. Basically, a CMOS image sensor is a 2-D matrix of photodiodes ,that can be addressed randomly at a high sampling rate.8 Although in CCD sensors the sampling rate of one pixel is limited to the frame rate, CMOS sensors are able to make a photographic image of the object of interest and detect rapid intensity changes at each point of the object. Another essential difference is the integration time inherent in CCD but not all CMOS sensors. In CMOS the photocurrent is continuously converted into an output voltage, unlike in CCD, in which the current is accumulated during a certain period of time.
M. Simonutti et al., which reported laser Doppler ophthalmoscope fund us imaging in the rat eye, with near infrared heterodyne. we have demonstrated the feasibility

of holographic laser Doppler ophthalmoscope with near infrared radiation holography [12**].**

2.THEORY

In a digital holography (DH) setup, a digital camera replaces the film [13]. To record a hologram, a laser beam is often split into a beam that scatters off the object of interest, and a "reference" beam that interferes with the "unknown" scattered beam. The algorithm varies with the experimental setup: two common arrangements involve using collinear unknown an reference beams (on-axis configuration), or crossing them at a small angle (off-axis configuration). Off-axis DH is the spatial-domain counterpart of being Fourier-transform spectral interferometer (FTSI) where the delay between the unknown and reference pulses is replaced by a crossing angle. (see Fig. 1).

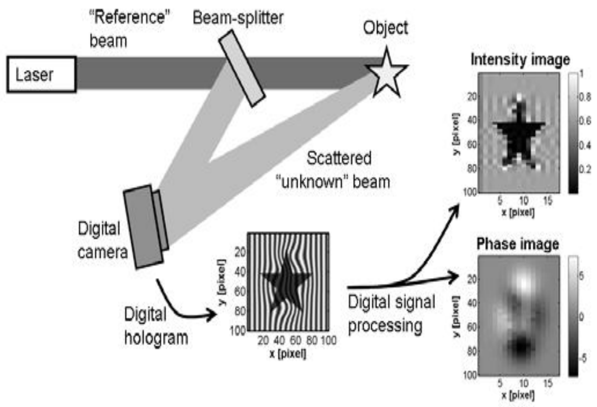


Figure 1 Setup for off-axis digital holography, showing the recording and reconstruction steps.

The digital hologram recorded under c.w. illumination and for a small crossing angle $\theta \ll 1$
Formalizing the description of holography;
The complex amplitude of the object wave and the reference wave are written as:

$$O(x, y) = o(x, y)\, e^{i\phi_o(x,y)} \qquad (1)$$

$$R(x, y) = r(x, y)\, e^{i\phi_r(x,y)} \qquad (2)$$

where o and r are the real amplitudes and ϕ_o and ϕ_r are the phases. These two waves will interfere and the resulting intensity in the plane of the hologram is:

$$I(x, y) = |O(x, y) + R(x, y)|^2$$
$$= R(x, y)R^*(x, y) + O(x, y)O^*(x, y)$$
$$+ O(x, y)R^*(x, y) + R(x, y)O^*(x, y)$$
$$= |R|^2(x, y) + |O|^2(x, y) + O(x, y)R^*(x, y) + R(x, y)O^*(x, y) \qquad (3)$$

with _ denoting the complex conjugate. The amplitude transmission function h(x, y) is proportional to the intensity and can be written as:

$$h(x, y) = h_0 + \beta\tau I(x, y) \qquad (4)$$

where β is a constant, τ is the exposure time, and h_0 is the amplitude transmission function of an unexposed photographic plate. The reconstruction of the hologram is
done by multiplying the amplitude transmission function with the reference wave:

$$R(x, y)h(x, y) = [h_0 + \beta\tau(r^2 + o^2)]R(x, y) + \beta\tau r^2 O(x, y) + \beta\tau R^2(x, y)O^*(x, y) \qquad (5)$$

The first term is the undiffracted reference wave, the second is the reconstructed object wave, and the third is a distorted real image of the object. In digital holography it is possible to record the reference wave and the object wave separately with a CMOS. Hence the undiffracted reference wave will not contain the terms r^2 and o^2 which are included in the first term on the right hand side of equation (5). The logic of this reasoning may be found more accessible by consulting equation (3) [14]-[15]. Equivalent deductions can be found in Schnars and Jüptner [14] and Gustafsson et al [15]. Can represent eq.(5) another deep relation by spectral interferometry (SI), the combined spectrum of the unknown ($E_{unk}(\omega)$) and reference ($E_{ref}(\omega)$) pulses is measured [16].

$$H(x,y) = |E_{unk}(x,y)|^2 + |E_{ref}(x,y)|^2 + 2|E_{unk}(x,y)E_{ref}(x,y)|\cos(\phi_{unk}(x,y) - \phi_{ref}(x,y) + x\,w/c\;\theta) \qquad (6)$$

A two-dimensional Fourier transform is applied H(*x*,*y*) as shown in fig.(1). The reference field, *R*(*x*,*y*), is removed from the remaining data, to obtain $E_{unk}(x,y)^2$)and $\varphi_{unk}(x,y)$ as shown in Fig. 2(b) and (c),

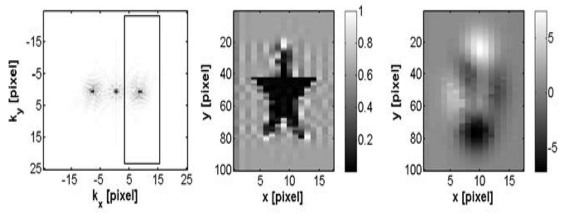


Figure 2 (a) Two-dimensional Fourier transform of the digital hologram. The rectangle (black solid line) shows the region that is used to reconstruct the unknown image. **(b)** Intensity of the reconstructed unknown field. **(c)** Unwrapped phase of the unknown field. Note the reduced spatial resolution along the *x* coordinate in the last two images. One way to perform the reconstruction is to record multiple phase-shifted holograms, similarly to what is done in phase-shifting spectral interferometry. Another way is to use an unknown and reference beams with different radii of curvature. In this case, a Fresnel transform can be used to reconstruct the unknown field [17, 18]. On-axis digital holography has found numerous applications in biomedical imaging of small structures because these objects naturally scatter diverging beams which are needed for the reconstruction algorithm [19].

3.METHOD

Recording of a digital holography is very simple. With the exact same set-up for the film holography, shown as figure (3) replace the film with CMOS Camera was used). First, record the interference pattern of the reference beam and the object beam. Save it as tie file so that it is possible to use it for program appendix with camera. the coding in MatLab (for this project, MathWorks MatLab programming language was used to calculated the average blood flow . In the same way, block the object beam and record the reference beam alone. It generally takes 10 ms to 50 ms to record for this particular situation. Since it is recorded on the CMOS, there is no developing process needed, no wet chemicals. For the reconstruction process, first numerical approximation with discrete Fresnel transform . Experiments were performed *in vivo* with the dorsalis pedis on foot human and hand.The examinations was taken in numerical approximation with discrete Fourier transform was programmed in Mat Lab. In order to achieve a power spectrum, the size of the image needs to be at least 1600×1200 pixels, Photographic image and the concentration maps were obtained with a single CMOS camera.

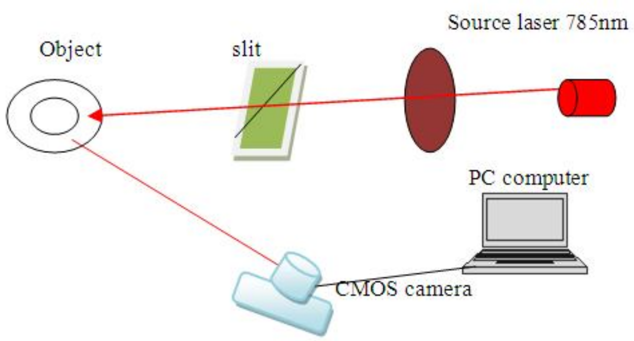


Figure 3 Schematic of the experimental setup for digital hologram using CMOS camera .

4. RESULTS AND DISCUSSION

Digital holography using a computer program such as MATLAB according the following steps: Load, or create, the n×m *complex* unknown amplitude image, although digital cameras often provide n>1000. In MATLAB, Fourier Transform Spectral Interferometer is the most commonly used reconstruction algorithm for spectral interferometer see fig 4(a) ,(b) and (c). Phase-shifting techniques address two limitations of interferometer, namely the presence of a background fig 4 (a), and of a twin image (or two interference terms) fig 4 (b) as shown as the "twin image" separation problem. This difficulty arises because the cosine of an angle ϕ does not unambiguously determine that angle: ϕ and $-\phi$ are both solutions. Now, if we are trying to reconstruct a *function* $\psi(\omega)$ from its cosine, there is a sign ambiguity at each point ω. As a result, the use of function in a computer program can result in a reconstructed phase difference that is physically different from the "true" phase difference function. Another way to observe this is to decompose the interference. the visibility of the fringes is a function of the temporal and spectral local overlap of the two pulses. Although this dependence of the fringe visibility calls for some experimental care, it can also be used to detect couplings that may exist between space and time, or space and frequency. When collimated beams are measured, the presence of spatial-temporal couplings changes the shape of the fringes. Note that if no spatial-temporal couplings are present then the fringes are vertical. Because the spectra at every position *y* are also measured, y-ω couplings in the intensity (spatial chirp) can also be visualized (see Fig. 4(a)). Fig.(4(b)) and(4(c)) show the traces when the unknown beam has pulse-front tilt and pulse-front curvature.. a linear spectral phase difference (group delay) in a fringe tilt (Fig. 4(b)), and a quadratic phase difference (group delay dispersion) in a fringe curvature (Fig. 4(c)).

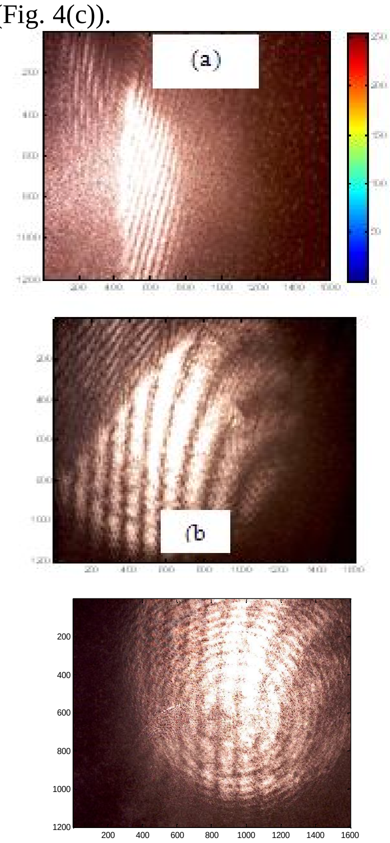
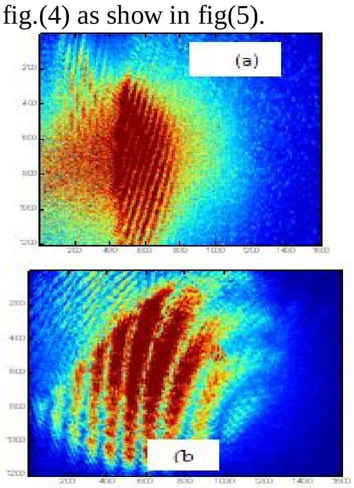


Figure 4 Digital hologram to (a) to foot the male 63 years (b) hand of female of 26 years old &(c) hand of male 63 years.

RGB used to show the images region blood flow in foot and hands in fig.(4) as show in fig(5).



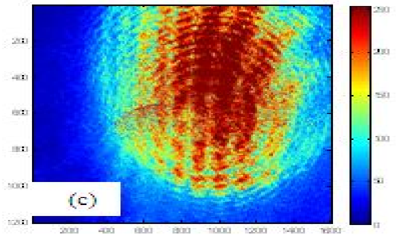
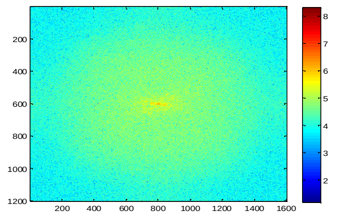
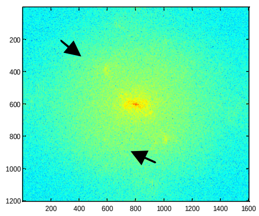


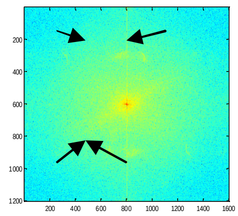
Figure 5 RGB map of image in Fig. 4(a),4(b) and 4(c).

- Create a reference amplitude image REF, also n×m, that corresponds to an image with an uniform intensity, but the image X can be generated using the function plot. - Create the digital hologram H using H = abs(fft2), and its 2D Fourier transform FT with the functions fft2 and fftshift - Select an n×p (p < n) sub-region of FT that corresponds to the next step is to invert (or “reconstruct”) the unknown electric field, UNK, and FFT of the difference of two consecutive frames as shown in fig(6). then used Fourier transform using fftshift and plot (see fig(7).



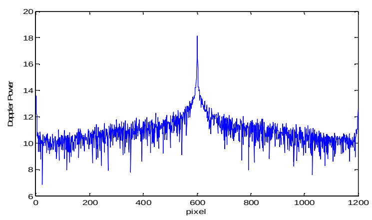
(a)



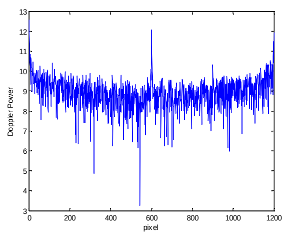


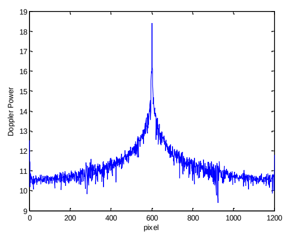
(b) **(c)**

Figure 6 The dominating noise is gathered in the low spatial frequencies. FFT of the difference of two consecutive frames from fig (5(a),(b) and (c)



(a)





(b) **(c)**

Figure 7 Doppler power vs. pixel for subjects in (DH) of fig(4).

To obtain the reconstructed intensity and phase of UNK and experiment with the values of blood flow the corresponding mean2 of FT, show that small values of LDF as shown in table(1).

Table 1: LDF values at foot and hand for different subjects .

N	Gen.	Posi-tion	Age	Height	Weigh	BMI	LDF
1	M	foot	63	1.732	75.1	25.0	8.94
2	F	hand	28	1.68	71	25.4	6.45
3	M	hand	63	1.53	55.2	23.4	4.1

5 . CONCLUSION

A reconstruction program for digital holography has been created, tested and implemented. With the aid of this program in holography was successfully carried out with the goal of this research. Although there are many improvements that can - and should - be done, this is a first step towards successfully performing holography . Although there are many improvements that can - and should - be done, this is a first step towards successfully performing holography with near infrared radiation. There are two main areas in which an improvement of the reconstruction of hologram would be useful such as foot and hand. A digital hologram can be made in a similar way, with the same set-up without any developing process, yet it requires better understanding of holography in physics, minimum programming skills, and possibly more accurate physical set-ups. Holography is believed to have the potential to be used for many applications in many other fields. These method prove was successfully to distinguish between LDF hand and foot. This is a first step toward laser Doppler imaging, leading to a much faster imaging procedure than with existing mechanical laser Doppler perfusion imagers by using matlab.

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