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Determination the spectral composition of light for contactless morphometry of subcutaneous vascular bed in the near infrared spectrum

Final Report by

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Introduction

Using near-infrared (NIR) photography to identify the structure of the subcutaneous vascular bed started in the thirties of XX century. It was then opened the effect of manifestations surface blood vessels on a background of soft tissues on the NIR photographs of the surface of the human body. Shortly thereafter, some methods were developed for the application of NIR images in medical diagnostics, but they have not received widespread. Until recent times, the most probable cause of the lack of interest in methods of the NIR diagnostics has been the lack of suitable components. At present, this problem is solved - were invented cheap digital cameras, equipped with semiconductor photodetector arrays sensitive to the NIR radiation. Their usage, except solving a number of operational problems, allows providing applying of special software for digital image processing and offers great opportunities of automation the analysis of medical images.

The effectiveness of introducing a new technology depends on the extent of its compliance with medico-technical requirements, intelligently formulated which allow only the results of the objective physical research. Until now, for example, the task of clarifying the requirements for the spectral range in which the effect of subcutaneous vascular manifestations observed most clearly (with the highest contrast), is actual. It is known that the effect is observed in a wide range of wavelengths from 0.7 to 1.2 microns (Gibson H, 1978 Photography by Infrared), but as far as we know, works on determining the optimal combination of spectral characteristics of light, there is still no.

1. Methods

Determination of the best combination of spectral characteristics of light, providing maximum image contrast of subcutaneous vascular bed against the backdrop of soft tissue, was conducted in two directions. The first was to develop a mathematical model and its calculating, the second - in carrying out practical experiments of the NIR imaging.

1.1. The Mathematical model

The mathematical model based on the laws of interaction of electromagnetic waves with biological tissues, we used data on the absorption spectra and quantitative distribution of major chromophores surface of human tissue: water, melanin, oxyhemoglobin and deoxyhemoglobin. Figure1 shows how you can observe the effect of NIR imaging, such geometry was implemented in model calculation.

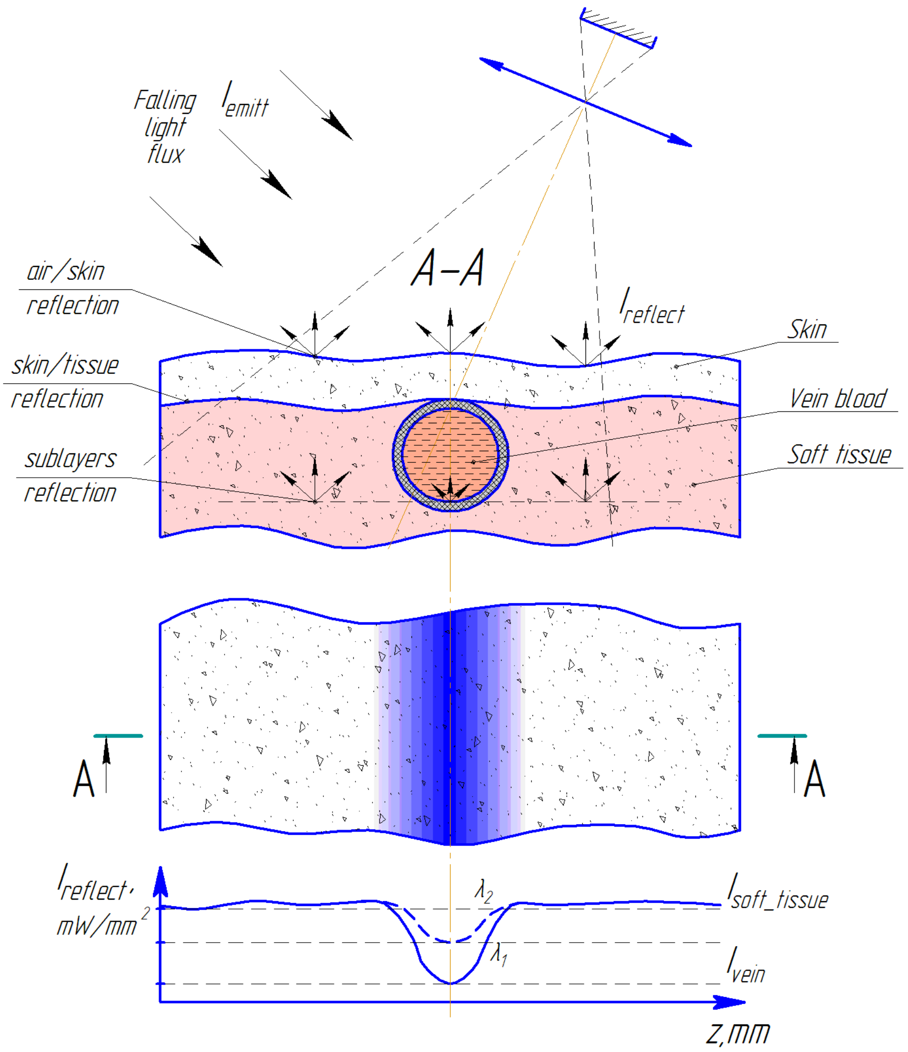

Figure1. The scheme of the NIR visualization of subcutaneous blood vessels

The calculation has allowed to receive dependence between the contrast of the images of subcutaneous blood vessels k against the peak wavelength λ_p and width of the emission line of the illumination light $\Delta\lambda_{0.7}$ (the form of the emission line was assumed a Gaussian shape).

Modelling Results

Maximum value reaches the value of contrast at wavelengths of 780 nm and 920 nm (0.148) at the minimum line width ($\Delta\lambda_{0.7}$ less than 1 nm). The increase in emission line width leads to a monotonic decrease in the maximum contrast (Figure2).

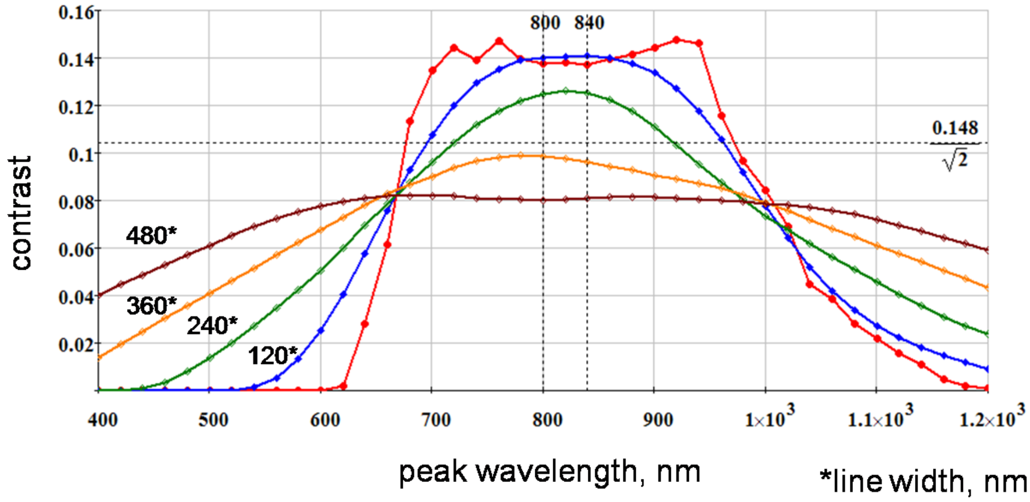

Figure2. The cross sections of the calculated contrast surface

With increasing bandwidth $\Delta\lambda_{0.7}$ of the radiation over 280 nm bound of the maximum contrast (0.104) becomes at 3 dBl less than the maximum assessment for the monochromatic light(0.148), the corresponding peak wavelength of the emission line is shifted to a value of 800 nm. Also, according to the model calculation, work in the spectral range with $\lambda_p = 850 \pm 10\ nm$ and $\Delta\lambda_{0.7} \leq 100\ nm$, allows to realize a contrast no less than 95% of the maximum attainable for monochrome light case.

1.2. The practical study

The practical research was conducted on nine male individuals from a range of age 22 -24 years. The study was performed using images the dorsal surface of the hands. Image registration was carried out inside the camera impervious to radiation in the visible and NIR ranges. The camera was equipped with a lighting system that allows illuminating the object of research by uniform beams with known spectral characteristics. As the video device was used digital video camera VAC-135USB2.0 with lens INFINITY SCVHMA04FIR.

Each study participant put alternately left and right hand inside the chamber. After that, take photographs image series (10 pieces in the series) with an interval of time between shots 1s. After each series of images the spectral characteristics of illumination inside the chamber was being purposefully changed, and a new series was being conducted. Total we used five settings of illumination (470/50, 525/50, 660/25, 880/50, 940/50, here the first number is the peak wavelength [nm], the second – line width [nm]), for their creation were used semiconductor light-emitting diodes. The post-processing of the captured images was consisted in to the studying of their brightness histograms and calculating the estimate of contrast subcutaneous vascular bed (Figure3).

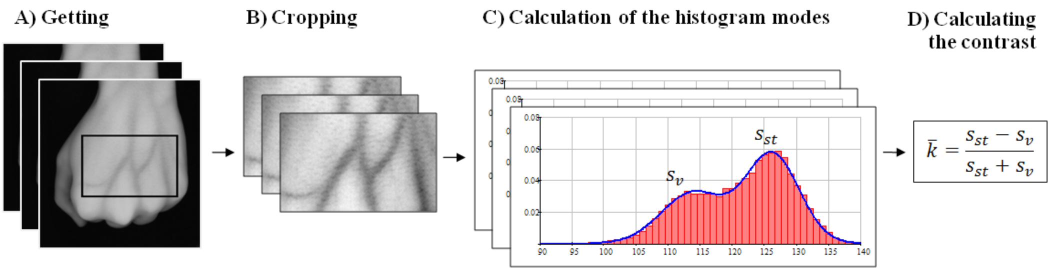

Figure3. The contrast evaluation algorithm

Results of practical research

Application of the first three settings of illumination (470/50, 525/50, 660/25) is not allowed to get a picture of subcutaneous blood vessels in the images of the back of the hand (Figure4).

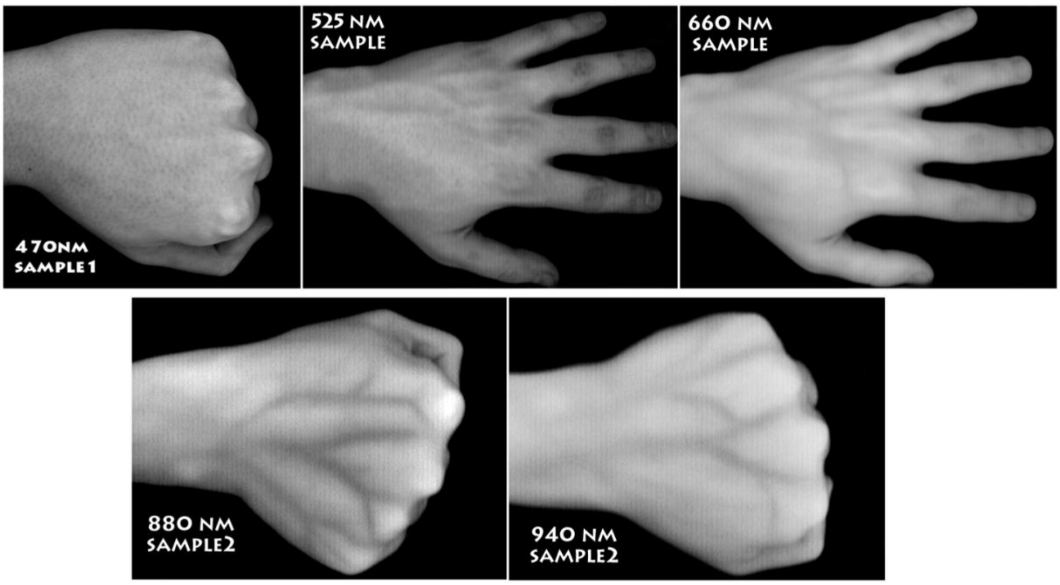

Figure4. Examples of recorded images

Observation of the subcutaneous vascular bed is only possible when lighting conditions 880/50 and 940/50. In addition, statistically significant difference between the values of contrast, for one individual, for these settings, we could not find. At the same time, the average contrast of subcutaneous vascular bed is strongly (more than 10%) different for different individuals (Table1).

Table1. The table of practical results for three randomly chosen individuals

№	Hand	Spectral characteristics									
		BetLux-L513UB 470/50nm		BetLux-L513PGC 525/50nm		BetLux-L513LR 660/25nm		BetLux-L513IRBC 880/50nm		BetLux-L513IRAB 940/50nm	
		$\bar{k}$	s_k	$\bar{k}$	s_k	$\bar{k}$	s_k	$\bar{k}$	s_k	$\bar{k}$	s_k
1.	left	0.078	0.029	0.062	0.026	0.220	0. 022	0.330	0.027	0.298	0.029
	right	0.105	0.031	0.121	0.034	0.223	0.028	0.352	0.026	0.310	0.025
2.	left	0.219	0.017	0.262	0.007	0.189	0.017	0.228	0.014	0.248	0.021
	right	0.221	0.020	0.211	0.014	0.201	0.019	0.234	0.021	0.221	0.021
3.	left	0.123	0.025	0.113	0.021	0.219	0.014	0.281	0.022	0.307	0.026
	right	0.084	0.019	0.094	0.022	0.211	0.019	0.292	0.027	0.290	0.025

*In the table: $\bar{k}$ means sample average of the contrast, and s_k means sample standard deviation of the contrast

Such practical results are in good agreement with theoretical calculations, that allows to speak about the adequacy of the developed mathematical model and possibilities of its application to define requirements to advanced contactless devices for NIR morphometry of subcutaneous vascular bed.

2. Conclusion

The presented work is devoted to studying the possibilities of imaging of subcutaneous vascular bed in the near infrared spectrum. Calculations of theoretical models predict the existence of an effective spectral window, work in which allows to observe the subcutaneous blood vessels more clearly. The predicted position of the effective spectral window in the short near-infrared region, that allows us to observe the effect by using most models of modern digital cameras and camcorders with semiconductor photosensors.

The paper describes one of the theoretical approaches to the determination of the spectral dependence of the contrast, held its numerical calculation and the new requirements to the spectral characteristics of NIR imaging of subcutaneous vascular bed. In practical research We have demonstrated the possibility of using the modern technology of digital photography for NIR visualization of the subcutaneous vascular bed and have confirmed the calculated dependence between the contrast and the spectral range of visualization.

The main result of the work is the justification of requirements to the spectral composition of light for NIR visualization of the subcutaneous vascular bed: the maximum contrast of the NIR images of the subcutaneous vascular bed can be achieved if the spectral sensitivity of visualization system is limited by the wavelength range 800 - 880 nm. This requirement can be achieved by using IR-LEDs, as a light source in the visualization system, or by using photographic infrared filters (in this case as a light source can be used: ambient light, halogen or conventional bulb light). Anyway for NIR visualization of subcutaneous blood vessels you must work at wavelength region 800-880.

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