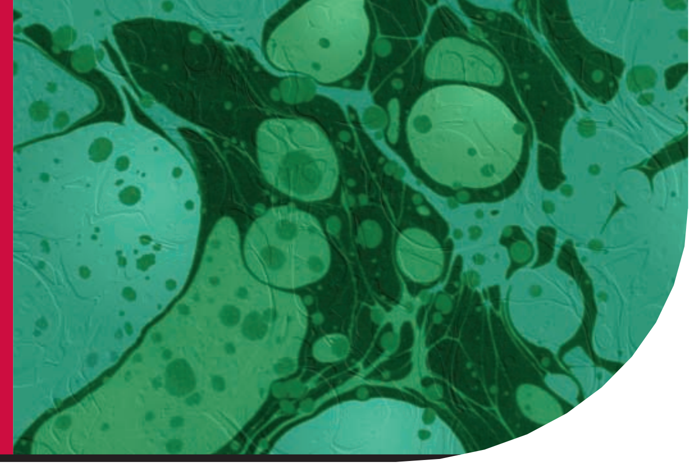
Research Focus



Artifact Removal from Spectral Domain OCT Images

Optical coherence tomography (OCT) is a high resolution, non-invasive imaging modality based on non-ionising optical radiation, which delivers three-dimensional (3D) images from microstructure components within the tissue [1]. The time domain (TD-) OCT produces three-dimensional images by using the transversal scan with two mirrors (XY scanners) and the axial scan by moving the reference arm. In contrary, in frequency domain (FD-) OCT the reference arm is fixed and the optical path length difference between the sample and the reference reflections is encoded by the frequency of the interferometric fringes as a function of the source spectrum. FD-OCT is broken down into two categories; spectral domain (SD-) OCT, which uses a grating to spatially scatter the spectrum across an array detector, and swept source (SS-) OCT. In this letter an implementation of denoising algorithm into a friendly user interface is presented. The noise investigated in this letter is a fixed-pattern high spatial frequency artifact superimposed with the SD-OCT images and is due to the lack of the quality of the system. The image obtained from the reference arm is considered as background image and is used to remove the unwanted signal in the noisy image. The algorithm was implemented in Matlab and a standalone C-based code was generated from the m-file afterwards [1]. The program prompts the user to input the background image and a set of noisy images, and removes the artifacts such that the output is cleaner images.

METHODOLOGY

A cross-section image taken by the SD-OCT when the reference arm is blocked is given in *Figure 1a*. This image was meant to be a completely black image as the object arm is blocked but due to the imperfection of the optical devices, the electronics noise, and the effect of the reference arm signal, such lines appear on the image. The algorithm of the denoising filter is as follows; removing low spatial frequency noise in the image by estimating the statistics of the noise and the Gaussian approximation of the noise, finding the high spatial frequency edges in the background image, removing the pixels in the location of edges in the image and replacing them with the average of the vertical adjacent pixels. To detect the high spatial frequency edges Sobel operator was used. Sobel operator converts the original image to gradient image by finding those points where the spatial gradient of the image is maximum. Sobel operator was chosen because it is fast, and simple to be implemented. A 3x3 Sobel operator is convolved with the background image to generate the gradient image following a simple thresholding, as shown in *Figure 1c*.

Figure 1a

+1	+2	+1
0	0	0
-1	-2	-1

Figure 1b

Figure 1c

Figure 1. Application of vertical-Sobel edge detector on background image; (a) background image; (b) vertical-Sobel mask; (c) edge detected image.

As the edges found in the image are in the both sides of the artifact, *Figure 2a*, and also some of the edges have not been detected, removing the artifact might not be feasible only by subtracting the background image from the OCT image. Two solutions are taken into account in the design of the denoising filter; one is to find the actual noisy lines based on the existing edges for which we used regression line estimation based on mean square error method. After applying this part of the algorithm, the edges, which are not due to the high frequency spatial noise are disappeared; we called the image obtained at this stage, the corrected edge detected image. The second issue is to find the rest of the edge points, which are missing and were not found in the previous stage. This problem was addressed by considering the points, which are in the lines with more than a certain number of edge points (this value is obtained empirically). The result of this stage is given in *Figure 2b*.

Figure 2a

Figure 2b

Figure 2. Corrected edge detected background image; (a) original edges; (b) corrected edges.

RESULTS

We have utilised our bulk SD-OCT system to collect cross section (B-Scan) images from a 600×400 microns squared piece of paper to evaluate the algorithm. The source is an SLD with the central wavelength of 795nm and the spectral bandwidth of 30nm. The axial and lateral resolution of the system is measured as 20 micron and 10 micron, respectively. The size of the image produced by the OCT is 512×512 pixels. The B-scan images have then been denoised by the algorithm. The results are given in *Figure 3a* and *b*.

Author Details:

Mohammad R. N. Avanaki, S. A.
Research and Development Centre,
School of Biosciences,
University of Kent, Canterbury,
Kent, CT2 7PD, United Kingdom
Email: mn96@kent.ac.uk

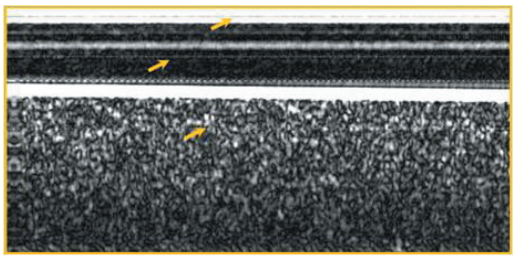


Figure 3a

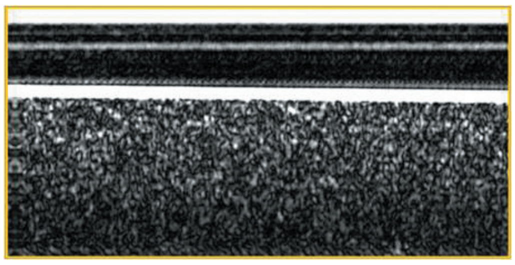


Figure 3. Denoising the SD-OCT images; (a) noisy image, the yellow arrows show the extra lines, which need to be removed; (b) denoised image based on the algorithm.

Visual evaluation of the results obtained by applying a smoothing filter, which is the most common method to deal with the artifact discussed here shows that smoothing results in a more blurred image than the original one. This problem is less pronounced in the images denoised by our denoising filter.

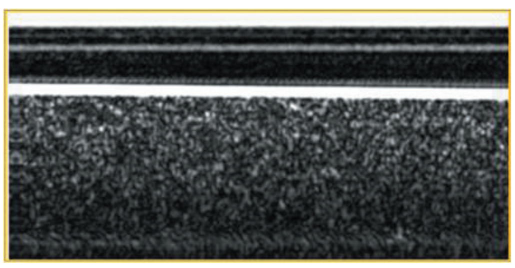


Figure 4. Denoised image shown in Figure 3a using smoothing filter.

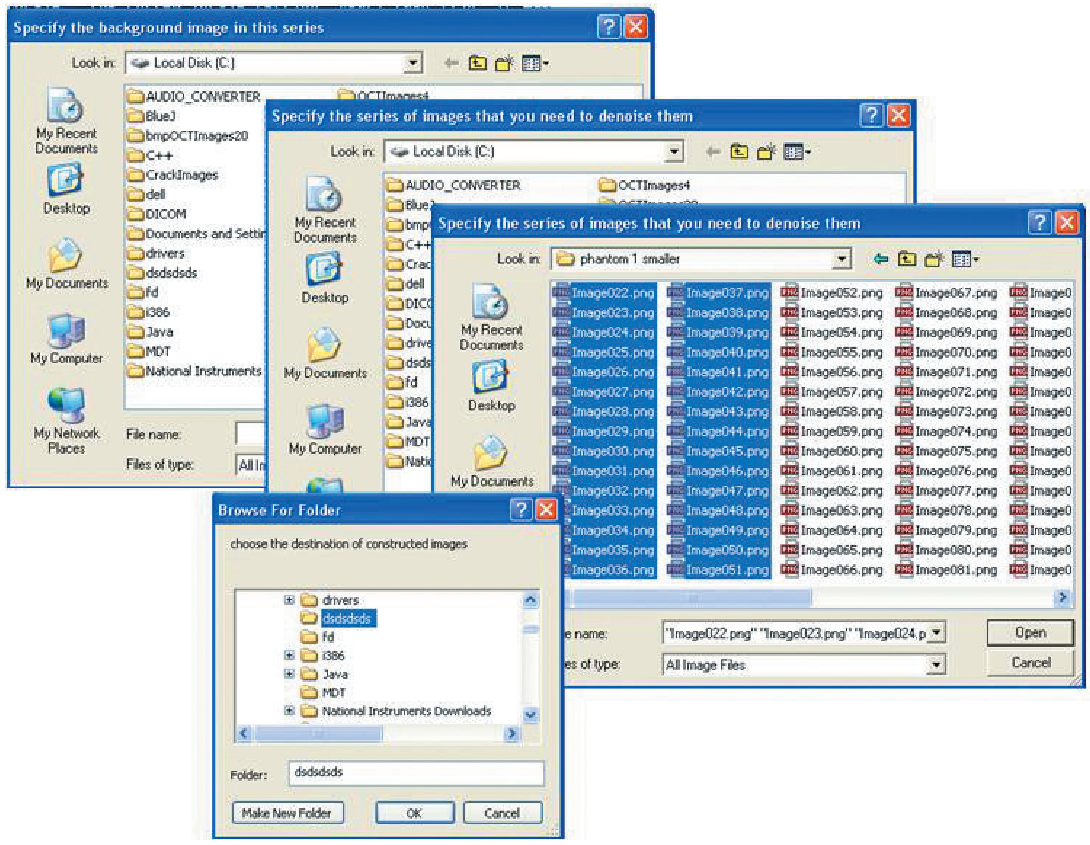


Figure 5. Denoising software view with the stages of denoising

A friendly user interface environment has been devised for the algorithm to denoise the SD-OCT images. The software requires the background image and a set of image, which are to be denoised. A destination is then specified to save the denoised images. After running the software, the denoised images will be saved automatically to the specified destination.

ACKNOWLEDGEMENT

The authors would like to thank Professor Adrian Podeleanu and Dr Adrian Bradu for providing the images.

REFERENCES

[1] M. V. Sarunic, B. E. Applegate and J. A. Izatt, 'Spectral domain second-harmonic optical coherence tomography', Opt. Lett., Vol. 30, pp. 2391-2393, 2005.

[2] Canny, John, 'A Computational Approach to Edge Detection', IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-8, No. 6, 1986, pp. 679-698

Easy-To-Use, Compact, Benchtop Fermentors & Bioreactors

A new range of high-performance, yet simple and easy-to-use Fermentors and Bioreactors have been introduced by laboratory specialists **Cleaver Scientific** (CSL). These compact, benchtop systems are ideal for fermentation and cell culture techniques typically performed within university teaching labs, research and development facilities of biofuel and biotech companies, pharmaceutical organisations and food and beverage manufacturers.

Each system is supplied as a customised solution, complete with vessel, impeller, control station and probes for growth of different microbes, yeast, mammalian, insect and plant cells. This ensures that the problems sometimes associated with other brands of equipment selection, set up and operation, are eliminated.

Features include a simple-to-use 10.4" colour touch screen interface within the control station allowing for easy setting and real-time pictorial display of agitation speed, temperature, pH and dissolved oxygen (DO). They also include 4 assignable built-in peristaltic pumps, which act in tandem with the corresponding pH, foam and DO probes within the vessel to control acid, base, antifoam and substrate feeds. Each probe is connected to an easily accessible side panel that also houses quick-fit connectors for rapid set-up of the heating system and ancillary equipment for aeration and cooling.

All Cleaver Scientific fermentors and reactors are pre-programmed with fermentation and cell culture operating modes allowing each user to user to adapt the equipment according to their specific needs. All five interchangeable single-wall, heat-blanketed, jacketed and air lifter vessels are available in 3 to 20 litre volumes and are made from autoclavable borosilicate. These can be operated from the control station, either thermostatically or as a dry heating system using the base unit or heating jacket. Other features and benefits include: storage capacity for nearly 60,000 programmes, adjustable flow meter and DO cascade function, ethernet remote control by optional PC, a low-maintenance brushless motor and choice of impellers for different cell types, USB for data transfer and logging capability for 10 process monitoring data files.

LAB PRODUCTS Circle no. 603

Large Area Filters for Catalyst Recovery

Porvair Filtration Group has developed expertise in the production of high performance filters for the recovery and retention of valuable catalyst fines emitted or lost from industrial processes.

For this application - Porvair Filtration are able to supply metallic and polymeric large area (20m²) filter media in both cartridge (pleated) and element (cylindrical) forms with a variety of end hardware to suit any housing or vessel configuration.

The metallic filters utilise sintered metal powder (Sinterflo® P) and sintered metal fibre (Sinterflo® F) with woven wire meshes where necessary. The ability to enhance or modify the filter media ensures performance criteria can be achieved to meet specific process conditions.

Drawing upon specialist fabrication skills and techniques at their UK and US manufacturing and cleanroom facilities - Porvair Filtration Group is able to produce complete element or cartridge builds, along with the construction of complete tubeplate and vessel assemblies.

LAB PRODUCTS Circle no. 604