# Full Field 3D Deformation Tracking with Optical Coherence Tomography

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## Introduction

We are developing an optical coherence tomography (OCT) based diagnostic tool that uses phase sensitivity to accurately map deformation fields in tissue. This capability will facilitate the characterisation of meso-scale tissue properties, such as the relationship between tissue structure and its viscoelastic behavior. This may be applied clinically to the detection of diseases such as skin cancers, which have high prevalence around the world and especially in New Zealand. [1]

This project focuses on applying polarisation-sensitive OCT (PS-OCT) to the field of dermatology. Conventional OCT measures the intensity of back-reflected light induced by local refractive index changes in a sample. [2] PS-OCT is a technique that makes use of the polarisation state of back-reflected light to provide additional information and contrast.

The aim of this study is to assess and compare the accuracy of phase-based cross-correlation (PCC) techniques on structural and retardance images, both for deformation and strain mapping.

## System

- Swept source laser (*Axsun Technologies Inc*), 18 mW.
- Center wavelength of $\lambda = 1310$ nm.
- Bandwidth $\Delta\lambda = 100$ nm.
- Axial resolution of ~10 µm in air.
- Lateral resolution = 26 µm.
- After back-reflection and interference the light contains information about intensity, birefringence and the optical axis.

A schematic of the experimental setup is shown in Figure 1.

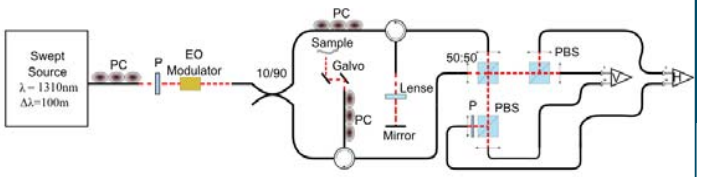


**Figure 1** – Experimental set up of PS-OCT system.

## Method

- 3D images of sheep skin were acquired *in vitro* before and after a 10±1µm axial shift.
- PCC methods were used to find the displacement. [3]

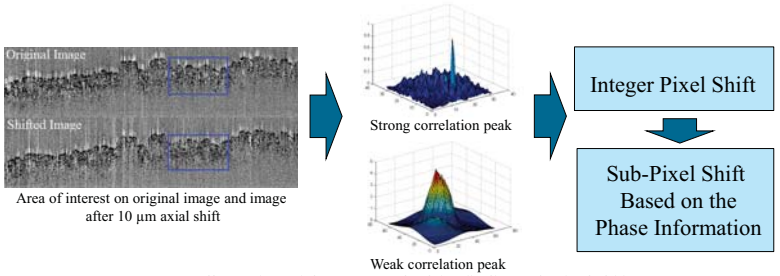


**Figure 2** – Illustration of the PCC method for finding sub-pixel shifts.

## Results

- Regional displacements were determined determined using PCC with an image subset size of 64 x 64 pixels. [3]
- Smaller errors were found using structural images over retardance images. For a 10 µm displacement, PCC on structural images estimated a 9.2 µm shift (0.921 pixels) compared to a 11.26 µm (1.126 pixel) shift in the retardance image.

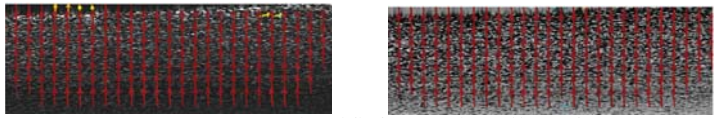

**Figure 3** – Vector mapping of displacements in a uniform polymer , structural image (left), retardance image (right).

- Tracking techniques were also applied to 3D images of sheep skin.

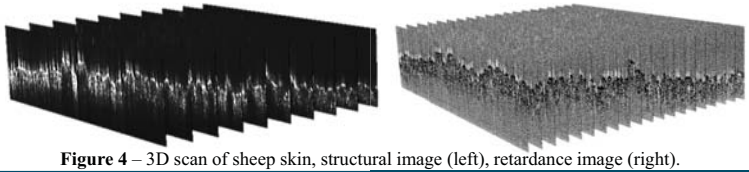

**Figure 4** – 3D scan of sheep skin, structural image (left), retardance image (right).

**References**

[1] M. Health, "Cancer : New registrations and deaths," Wellington, 2009.

[2] K. D. Huang, et al, "Optical Coherence Tomography," *Science*, vol. 254, pp. 1178–1181, 1991.

[3] D. T. K. Malcolm, P. M. F. Nielsen, P. J. Hunter, and P. G. Charette, "Strain measurement in biaxially loaded inhomogeneous, anisotropic elastic membranes.," *Biomech. Model. Mechanobiol.*, vol. 1, no. 3, pp. 197–210, Dec. 2002.

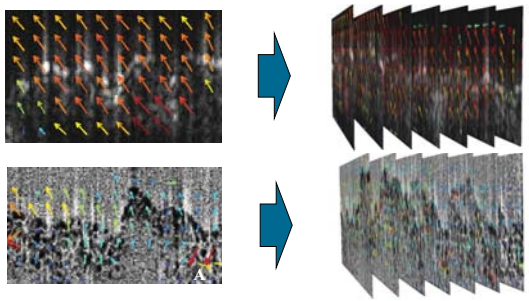

**Figure 5** – **Top**, Tracking of motion in structural images, actual displacement in X and Y is 10 ±1 µm. Measured displacement in X is 12.8 µm (RMS) and in Y is 11.4 µm (RMS). **Bottom**, Tracking of motion in retardance image. Measured displacement in X is 13.5 µm (RMS) and in Y is 16.2 µm (RMS). **A** – An example of false tracking.

Noise is the primary contributor to false tracking in the retardance images as shown in Figure 5. This method has been applied to tracking deformation:

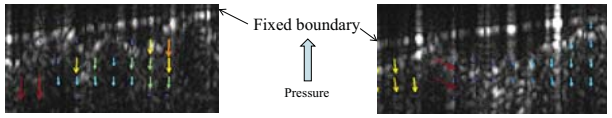


**Figure 6**– Annotated vector maps of deformations.

Qualitative assessment of the results show a displacement map consistent with pressure at a fixed boundary. As would be expected there is no motion at the boundary, with larger displacements through the tissue.

## Future Work

- Quantification of deformation within a biological tissue would allow for the non-invasive quantification of mechanical properties.
- Noise reduction would improve sensitivity of tracking algorithm.

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