STRAIN FIELD ANALYSIS OF CANCELLOUS BONE UNDER COMPRESSION BY IMAGE CORRELATION

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ABSTRACT: Experimental mechanical analysis of cancellous bone has been performed to capture the global strain field of specimens under compression. One major objective is to assess the test procedure and obtain the cancellous bone mechanical properties. Now a day, several techniques are available for the experimental measurement of the field displacement. Among them, the Cross-Correlation is one of most simple's techniques and can be applied to several studies cases. Based on the correlation of random speckle pattern between two images, the spatial displacement fields can be accessed. A simple digital camera or video recorder can be used without special light to capture the surface intensity pattern in each instant. If several images are taken during a test loading, the displacement field can be fallowed and subsequently the strain can be obtain by the spatial differentiation. Because of random surface pattern, the image can be divided in small areas, each of them pattern independent. By cross-correlating each of one between the two images, the relative displacement is obtained.

The Cross-Correlation is a very effective technique for small displacement with low distortion factor. The normalize cross-correlation is used in this work, because is immunity to the change light conditions. The ~~These~~ algorithm was implemented on Matlab ® platform [1,2,3]. The normalise cross-correlation between two images of intensity *f*(x,y) and f^{*}(x,y) can be sated as:

$$C(u,v)=\frac{\int_{\Delta A^*}\left[f(x,y)-\bar{f}_{u,v}\right]\left[f^*(x-u,y-v)-\bar{f}^*{}_{u,v}\right]dA}{\int_{\Delta A}\left[f(x,y)-\bar{f}_{u,v}\right]^2 dA\int_{\Delta A^*}\left[f^*(x-u,y-v)-\bar{f}^*{}_{u,v}\right]^2 dA} \tag{1}$$

The values of displacement *u*, *v* are computed by maximizing the equation (1) for each the subset of the image. Several changes were made on the proposed algorithm [1], so the execution time could be reduced. The smooth and continues displacement field were obtained by least-squares spline approximation of measure displacements [4]. The strain fields can be computed by spatial differentiation of continues displacement field. A differentiation/smoothing technique [5], noise immunity, was used to estimate the strain fields of two orthogonal directions during the deformation a specimen bone. Figure 1, presents the displacement and the strain fields obtained from the digital image recording during of loading the specimen bone.

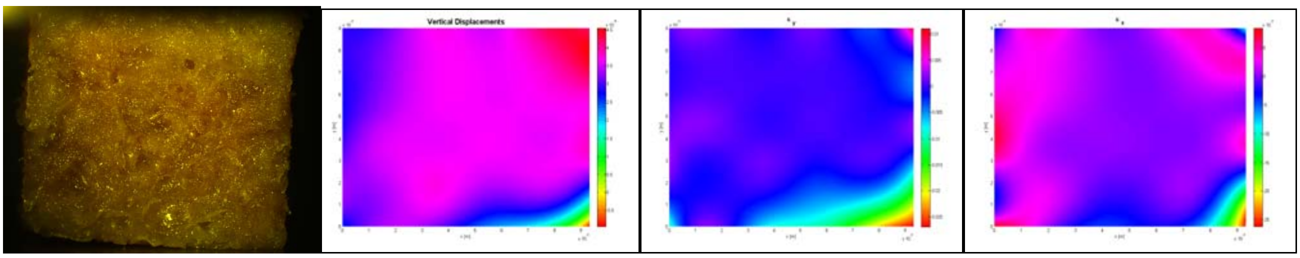

Figure 1- Displacement and strain fields of specimen bone (19456 points resolution).

[1] Lewis, J. P., "Fast Normalized Cross-Correlation," Industrial Light & Magic, http://www.idiom.com/~zilla/Papers/nvisionInterface/nip.html
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Introduction: Experimental mechanical analysis of a fresh cancellous bone has been performed to capture the global strain field of specimens under compression. One major objective is to assess the test procedure and obtain the cancellous bone mechanical properties from the displacements and strain deformation measurements. Based on the digital image correlation (DIC) of random texture pattern between two consecutive images, the spatial displacement fields can be accessed. A simple digital video recorder can used without special light to capture the surface intensity texture in each instant. Several images are taken during the test loading, the displacement field can be followed and subsequently the strain can be obtain by the spatial differentiation.

Principle: The normalized zero order Digital Image Correlation was implemented on Matlab® platform and the bicubic spline interpolation was used to access the full-field displacements with sub-pixel accuracy resolution. The values of displacement u, v were computed using a discrete fast Fourier algorithm and by maximizing the equation :

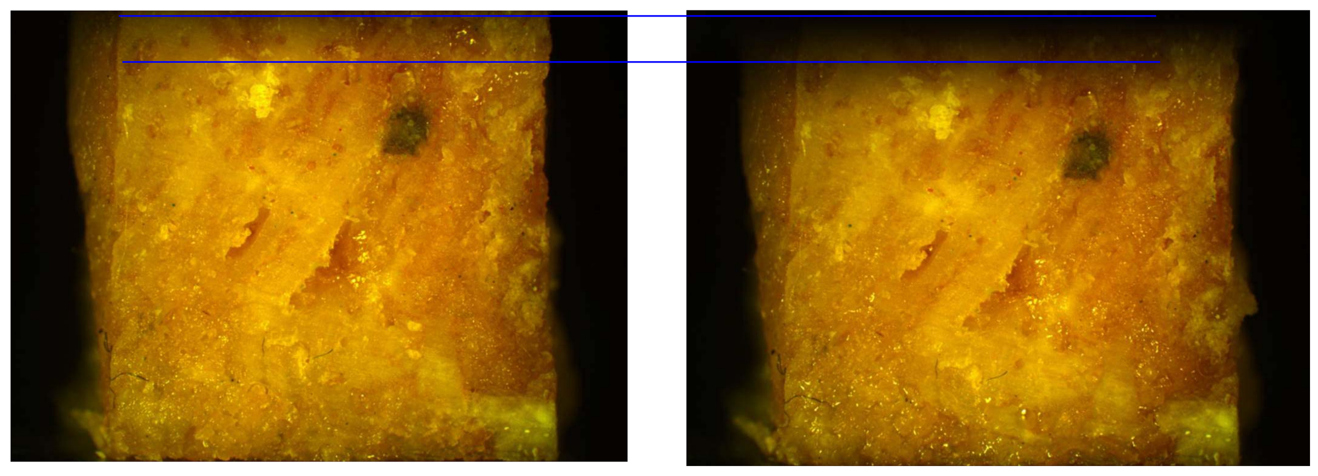
$$C(u,v)=\frac{\int_{\Delta A^*}\left[f(x,y)-\bar{f}_{u,v}\right]\left[f^*(x-u,y-v)-\bar{f}^*_{u,v}\right]dA}{\int_{\Delta A}\left[f(x,y)-\bar{f}_{u,v}\right]^2 dA\int_{\Delta A^*}\left[f^*(x-u,y-v)-\bar{f}^*_{u,v}\right]^2 dA}$$

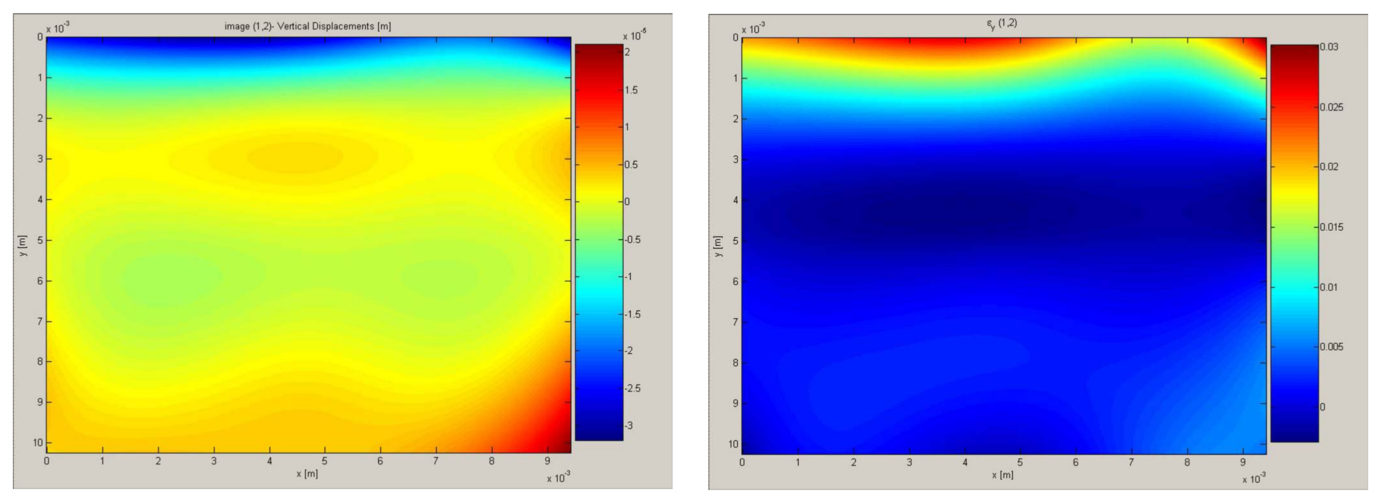
The strain fields were obtained by numerical convolution of displacements using the one dimension derivative Gaussian function:

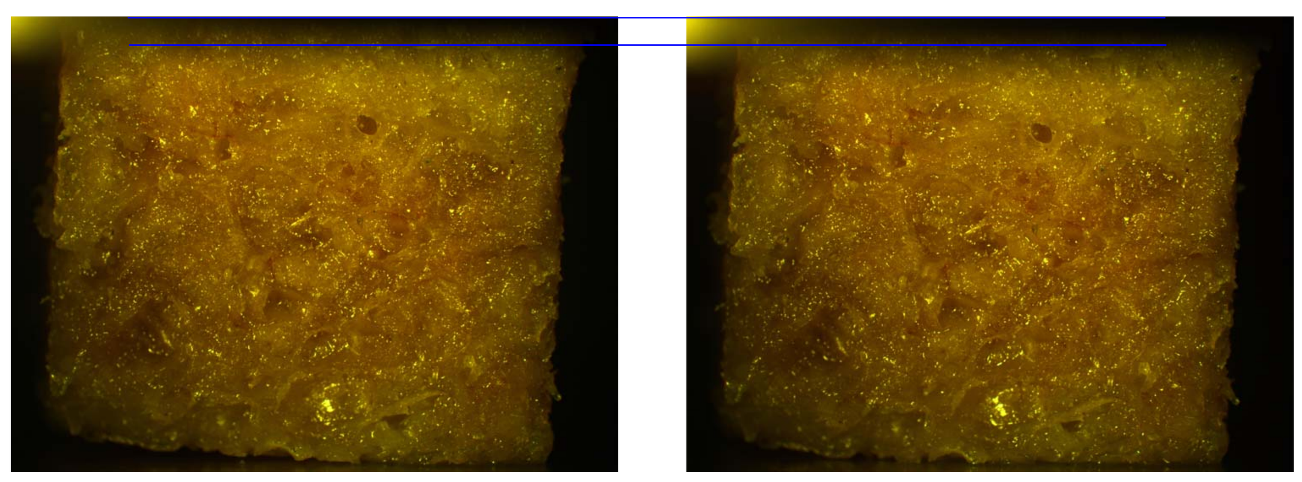
$$\frac{\partial}{\partial x}(u,v)=\left(\frac{1}{\sqrt{2\pi}}\right)\left(\frac{x}{\sqrt{2\pi}}\right)(u,v)$$

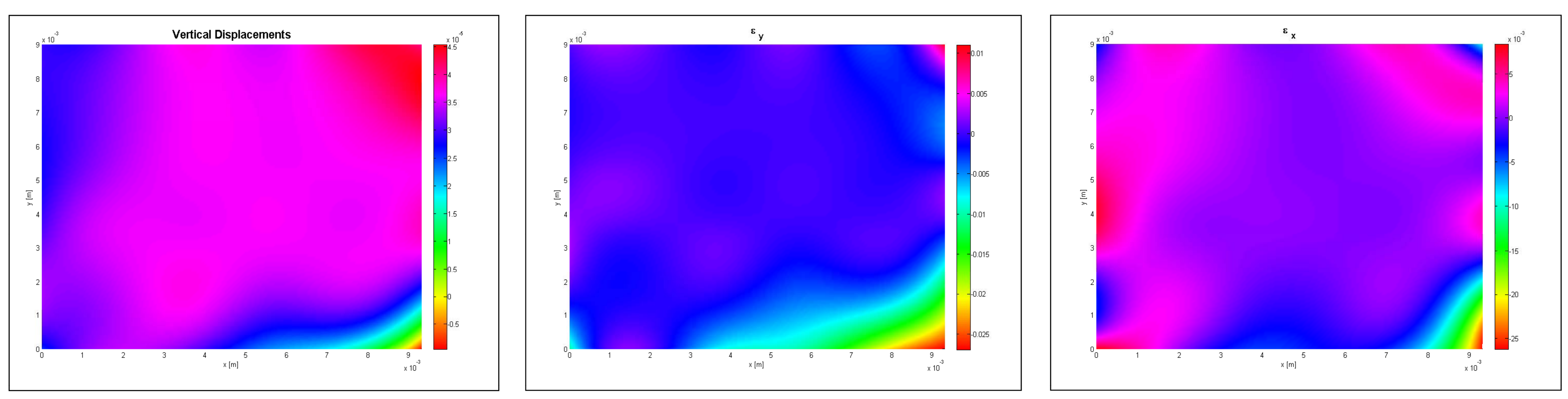
Experimental Set-up: The cubic fresh cancellous bone specimens (10 x 10 x 10 mm), obtained from three human femoral heads, were tested on an universal mechanical testing machine (INSTRON 1125). A high resolution camera Dolphin was used to acquired the images.

Some Results:









Conclusions: The results show the effectiveness of the implemented DIC technique for displacement and strain measurements on a fresh cancellous bone under compression. The displacements values were in accordance with those indicated by the testing machine. The quality of the results were similar to the ones found in the literature. The non-uniform deformation results can be explained by the trabecular irregular structure of the specimens. On the other hand the continuous flow of marrow out of the specimens, due to the compression, produced unrealistic displacements in some subsets. This problem was overcome by taking the displacements average around of each subset.

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