A Force-Sensitive Microrobot and Stereoscope for Characterising Skin Mechanics

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Background

Structurally-based constitutive models of skin mechanics are increasingly being applied to medical and cosmetic applications.

Accurate estimation of parameters requires careful experimental control and data collection that quantifies both deformations and structure.

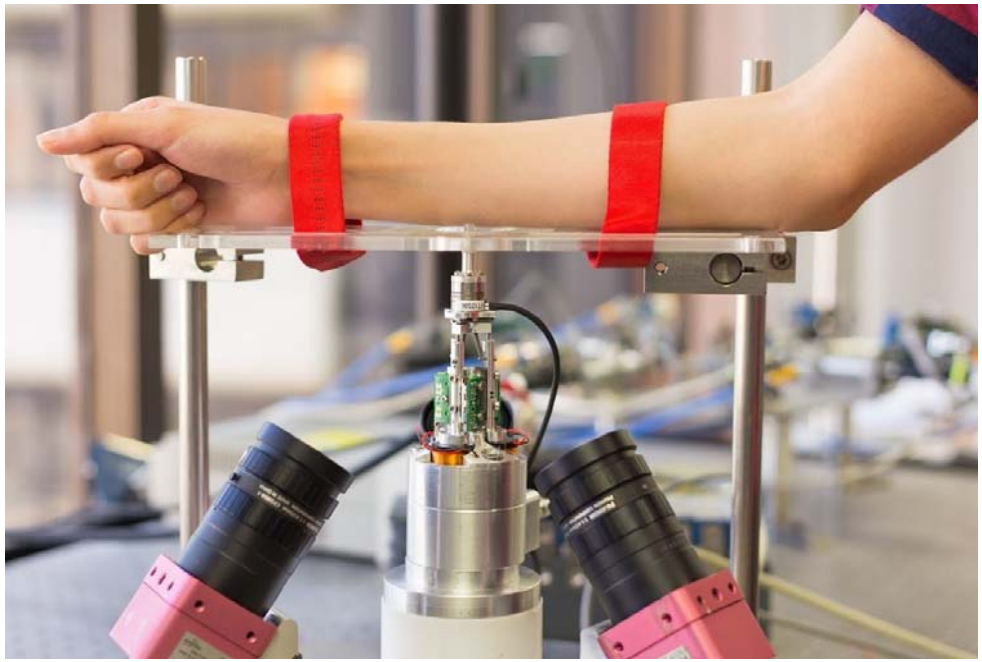
Typical experiment protocols impose deformations using extensiometers, suction, torsion, or indentation devices[1]. Such approaches cannot measure the response of skin in 3D.

We present the combination of a multi-directional, six axis force-torque-sensitive microrobot and stereoscope to capture stress, strain and surface deformation, which will be interpreted using a finite element model.

The ability of these devices to deform and measure a surface needs to be validated using a well-understood soft material.

Method

- Sylgard 527 silicone gel soft tissue phantom.
- Surface deformation tracking: phase-based cross-correlation tracking of an airbrushed speckle pattern
- Independent tracking points: array of 500 μm to 600 μm diameter fluorescent polyethylene microspheres.
- Deformation profile: 3mm normal indentation, imaged at 100 μm intervals.

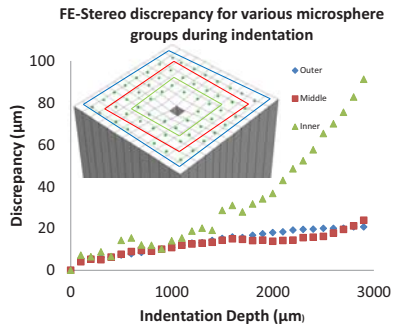


The combined stereoscope and microscope performing an indentation test on in vivo skin

- Validation step: speckle-tracked material points fit to FE mesh at each imaging step, manually reconstructed microsphere positions embedded in the initial undeformed mesh.
- FE mesh preserves material location of embedded microsphere positions, producing predictions of where the microspheres have moved.
- Model-based predictions of microsphere locations were then compared with those of the stereo-reconstructions at each deformation interval.

Summary

Spheres closer to the indenter contributed the most error, which is in part due to more deformation in this region, and failure of the mesh to adequately match the stereo data.



Improvements may be made by increasing the number of cameras around the indenter, and by increasing the degrees of freedom in the mesh.

This validation suggests that a finite element representation of surface geometry can be used, in concert with the microrobot, towards an improved characterisation of 3D skin mechanics.

References

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