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ACCURATE, EFFICIENT 2D STRAIN MAPPING WITH ROBUST DETECTION OF STRAIN LOCALIZATION

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Summary

DDE (Direct Deformation Estimation) and SIMPLE (Strain Interference with Measures of Probable Local Elevation) are two simple **Digital Image Correlation** algorithms that combine image analysis techniques with mechanical engineering principles to provide accurate, efficient, quantitative strain estimation and crack prediction for a variety of biomechanical and structural engineering applications.

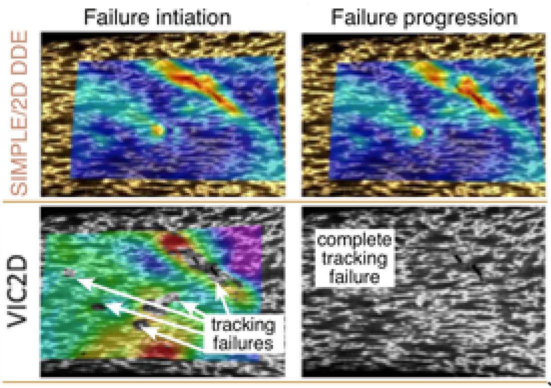
As a piece of plastic wrap is stretched, the DDE and SIMPLE algorithms identify the location (in red) where it is weakening and eventually breaks.

Background

Tracking deformation and strain is challenging during fracture, when strains are elevated in a localized region, and for large strains experienced in organs, tissues, and cells. Tracking elevated strains from time-resolved imaging and microscopy is a pressing need for the next generation of diagnostic, mechanobiological and civil engineering tools.

Technology Description

2D Direct Deformation Estimation (2D-DDE) is an optical deformation estimation technique that overcomes these challenges to fill this need. Compared to the commercially available VIC-2D, 2D-DDE improves accuracy of local strain estimates when deformation fields are non-linear and is more computationally efficient. 2D-DDE estimates deformation gradient fields directly from warping parameters derived during image registration and therefore does not require strain estimation following image registration. Additionally, a new technique, SIMPLE, determines where strain fields over various domain sizes have high gradients. This gradient detection is a robust detector of strain localization, and verifies the reliability of estimates of elevated strain. SIMPLE is also able to continue tracking throughout fracture and failure.



Strain near a material tear is visualized by SIMPLE/2D DDE and VIC-2D. As the tear progresses, SIMPLE/2D DDE successfully tracks the strain concentrations near the developing tear (upper left panel). In contrast, VIC-2D fails to track strain in the vicinity of the tear (lower left panel). As the tear progresses, SIMPLE/2D DDE continues to track strain concentrations near and around the tear (upper right panel). In contrast, VIC-2D fails to track strain anywhere in the sample after the tear becomes large (lower right panel).

Stage of Research

The inventors have validated the algorithms by analyzing four different model systems: PDMS scaffold, collagen scaffold, plastic wrap and embryonic wound healing. DDE provided strain analysis that was 10x more accurate and precise than Least Square Fit methods (sensitivity sufficient to differences in strain as small as 0.001). SIMPLE detected strain concentrations on the order of 0.005, long before they were evident using XCOR.

Applications

- **Digital Image Correlation and Strain Estimation Software** with end-user applications such as:
  - medical imaging – analyzing human tissue mechanics related to injury and stress (particularly suitable for low resolution/noisy images such as MRI)
  - civil engineering/structural health monitoring
  - automotive and aerospace

Key Advantages

- **More accurate –** critical for quantifying large strains
  - improves accuracy of strain estimation by 10% when strain fields are non-linear compared to the commercially available VIC-2D
  - distinguishes noise from the true regions of large strains
  - avoids the inaccuracies associated with displacement mapping artefacts
  - insensitive to movement and rotation of a specimen
- **Computationally efficient -** improves efficiency by up to 30% by removing deformation estimation following image registration
- **Robust crack prediction –** adding the new measure, SIMPLE, can robustly identify regions of strain localization which can be tracked during material failure.

Publications

- Boyle, J. J., Kume, M., Wyczalkowski, M. A., Taber, L. A., Pless, R. B., Xia, Y., ... & Thomopoulos, S. (2014). Simple and accurate methods for quantifying deformation, disruption, and development in biological tissues. *Journal of the Royal Society Interface*, 11(100), 20140685.

- New technology may identify tiny strains in body tissues before injuries occur, *The Source* Aug. 26, 2014

Patents

- System and method for quantifying deformation, disruption, and development in a sample (U.S. Patent No. 10,072,924)