Introduction to SUN-DIC

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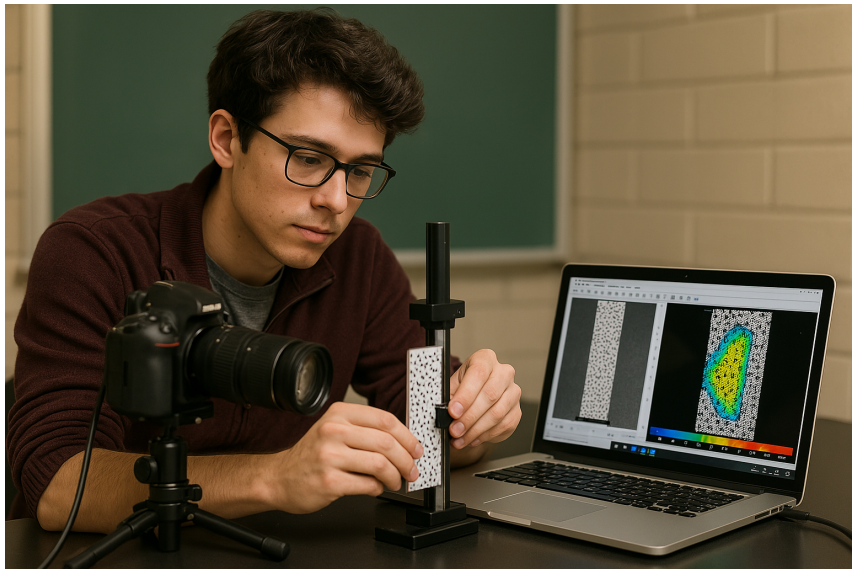
What is Digital Image Correlation (DIC)

A non-contact, length scale independent, optical tool to determine full field shape and surface displacements



What is Needed to Perform DIC?

- **Hardware**
  - Specimen with speckle pattern
  - Load frame (or some way to apply load to the specimen)
  - Calibration plate (not always needed)
  - Camera
  - Lights
  - Computer
- **Software**
  - Algorithm for tracking changes in the speckle pattern

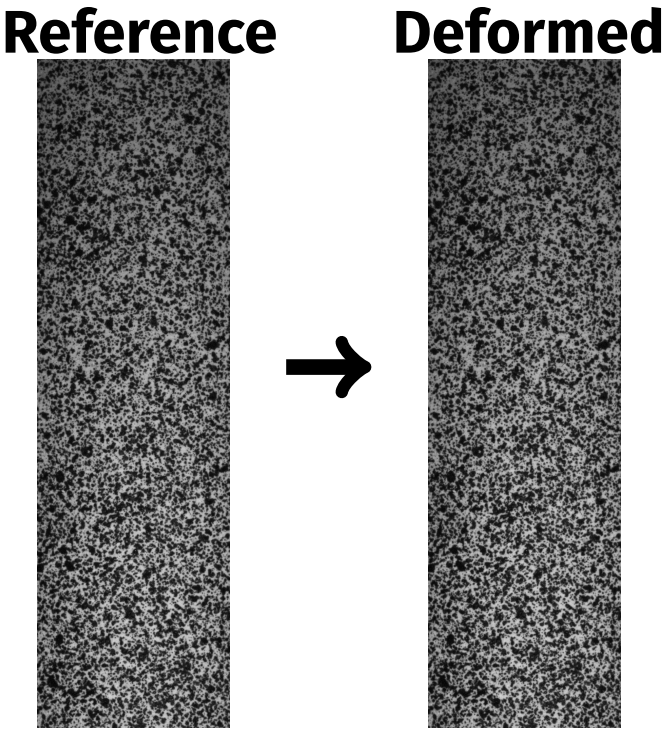
SUN-DIC

- This presentation will concentrate on the software side of DIC
- Specifically SUN-DIC - a freely available, fully open source DIC software system developed in Python

https://github.com/gventer/SUN-DIC

How are Changes in the Speckle Pattern Tracked?

- Need at least two images - a reference and a deformed image
- Define a region of interest (ROI)
- Divide the ROI into subsets
- Track the displacement of each subset center point between the images
- Sub-pixel accuracy, typically in the range of 0.01 - 0.1 pixels

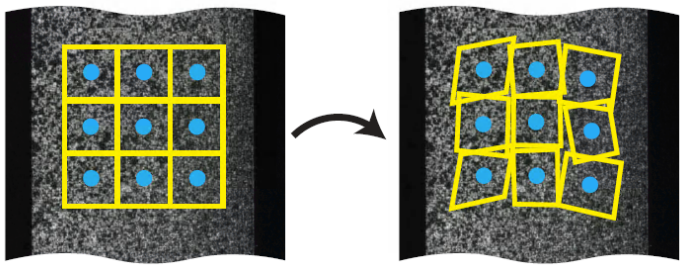


(Images from Reu et al. 2018)

Local vs Global DIC Algorithms

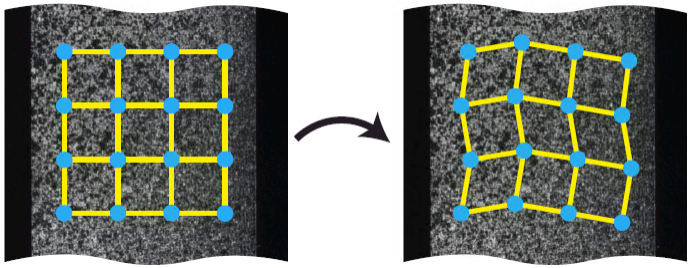
Local DIC

- Subsets tracked independently
- Older but most used technology



Global DIC

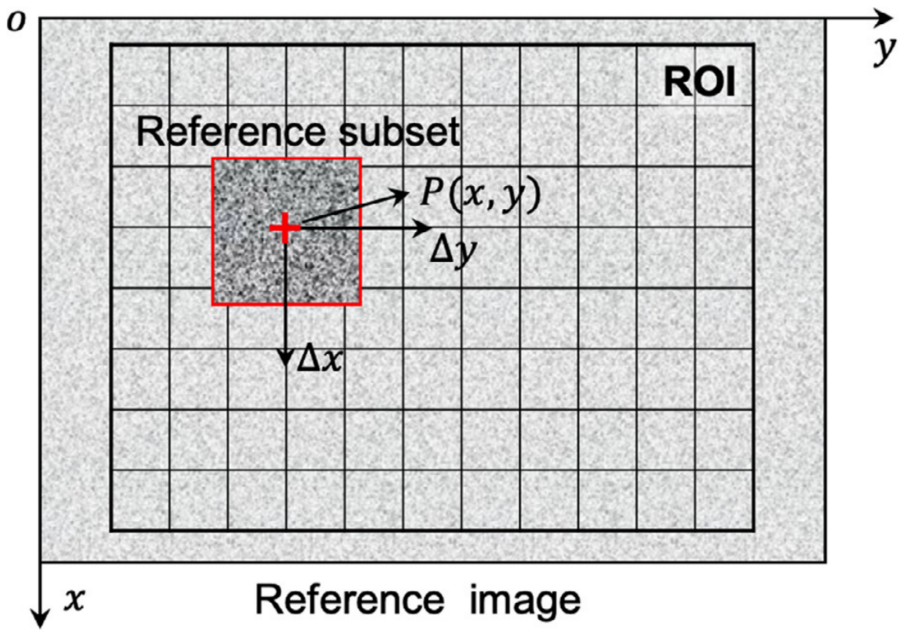
- Subsets tracked all at once
- Compatibility enforced

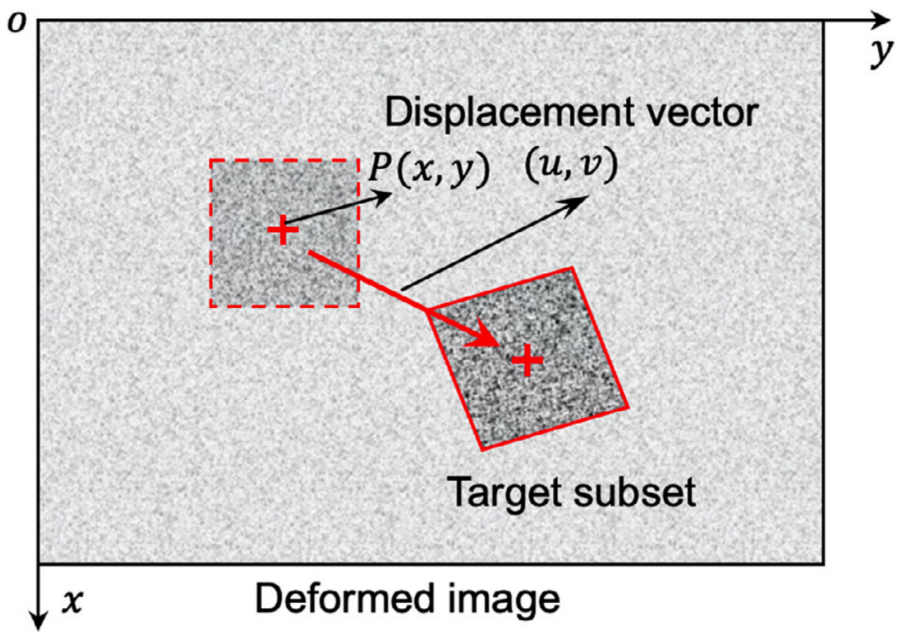


(Images from Yang 2025)

SUN-DIC is a local DIC algorithm

How are Changes in the Speckle Pattern Tracked?





(Images from Chen and Jungstedt 2022)

Tracking Subsets

- Assume shape functions to represent deformation of a subset
- Example linear (or affine) shape functions

$$\boldsymbol{W}(x, y, \boldsymbol{p}) = \begin{Bmatrix} x' \\ y' \end{Bmatrix} = \begin{bmatrix} 1 + u_x & u_y & u \\ v_x & 1 + v_y & v \end{bmatrix} \begin{Bmatrix} x \\ y \\ 1 \end{Bmatrix}$$

$$\boldsymbol{p} = \{u, u_x, u_y, v, v_x, v_y\}^T$$

- Solve optimization problem to find the unknown parameters $\boldsymbol{p}$
- In other words “find the deformed subset in the deformed image”

The DIC Optimization Problem

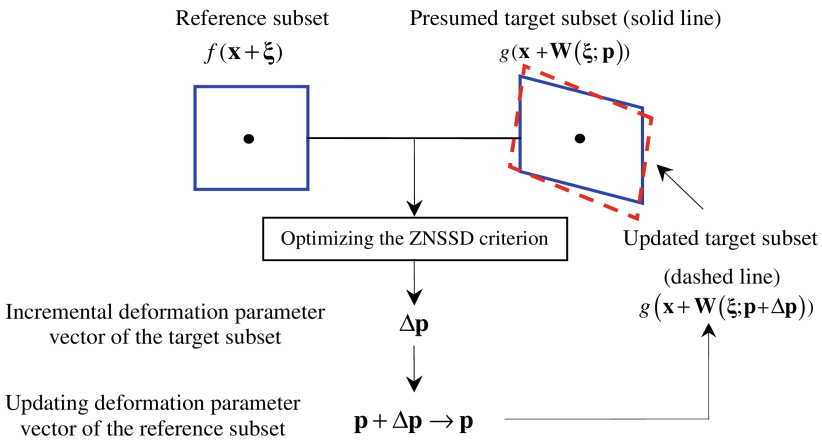
- **Design variables** - the parameters from our shape functions
- **Objective function** - a correlation function (there are many)

$$C_{ZNSSD} = \sum \left(\frac{f_i - \bar{f}}{\sqrt{\sum (f_i - \bar{f})^2}} - \frac{g_i - \bar{g}}{\sqrt{\sum (g_i - \bar{g})^2}} \right)^2$$

- **Optimization algorithm**
  - Inverse Compositional Gauss Newton (IC-GN)
  - Inverse Compositional Levenberg Marquardt (IC-LM)
- Second order algorithms - converge quickly but needs Hessian information

Optimization Algorithms

Forward Additive (FA-GN)

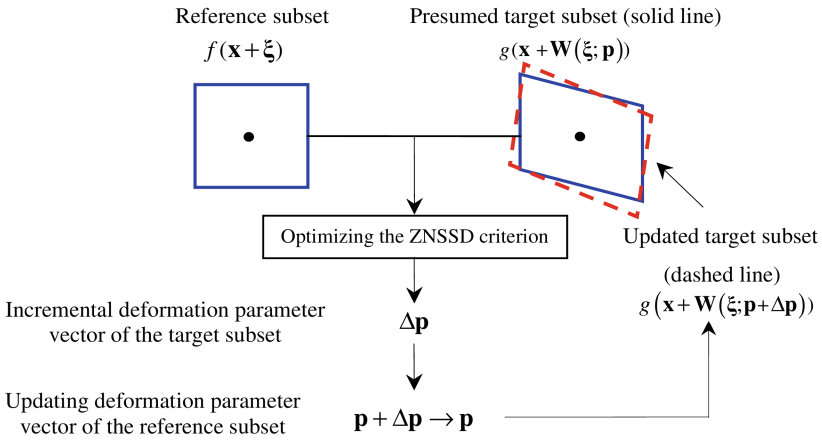


Inverse Compositional (IC-GN)

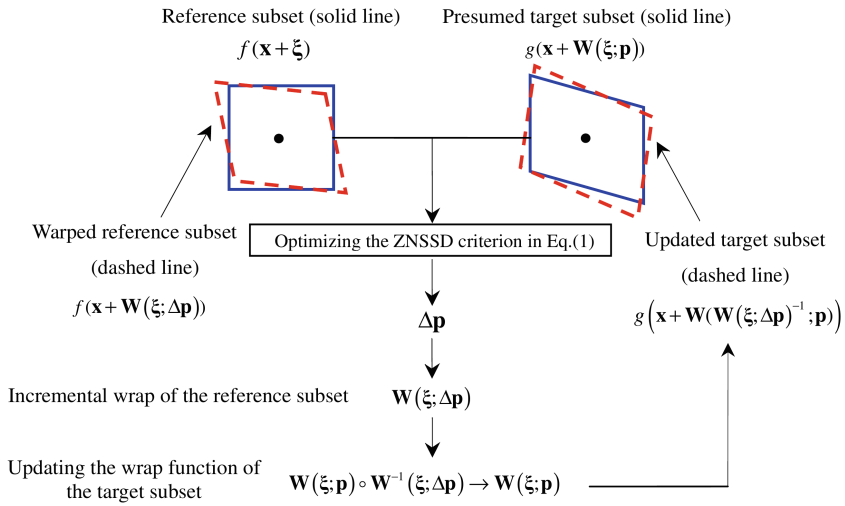
(Images from Pan, Li, and Tong 2013)

Optimization Algorithms

Forward Additive (FA-GN)



Inverse Compositional (IC-GN)



(Images from Pan, Li, and Tong 2013)

SUN-DIC Key Features

- Fully open source DIC algorithm developed in Python
- Available on github and easy installation using pip
- Currently a planar (2D) only algorithm - *watch this space*
- Parallel computing on multiple cores
- Both affine (linear) and quadratic shape functions are available
- Both absolute or relative tracking between multiple images
- Easy to use GUI

SUN-DIC Implementation

- Correlation criterion is C_{ZNSSD}
- Both IC-GN and IC-LM optimization algorithms available
- Intelligent **starting strategy** to reduce error propagation during optimization
- **Automatic detection** of irregular ROI (eg plate with a hole) based on average subset intensity

Key Principles of SUN-DIC

- API based (with a GUI available)
- Post-processing and utilities separate from main algorithm

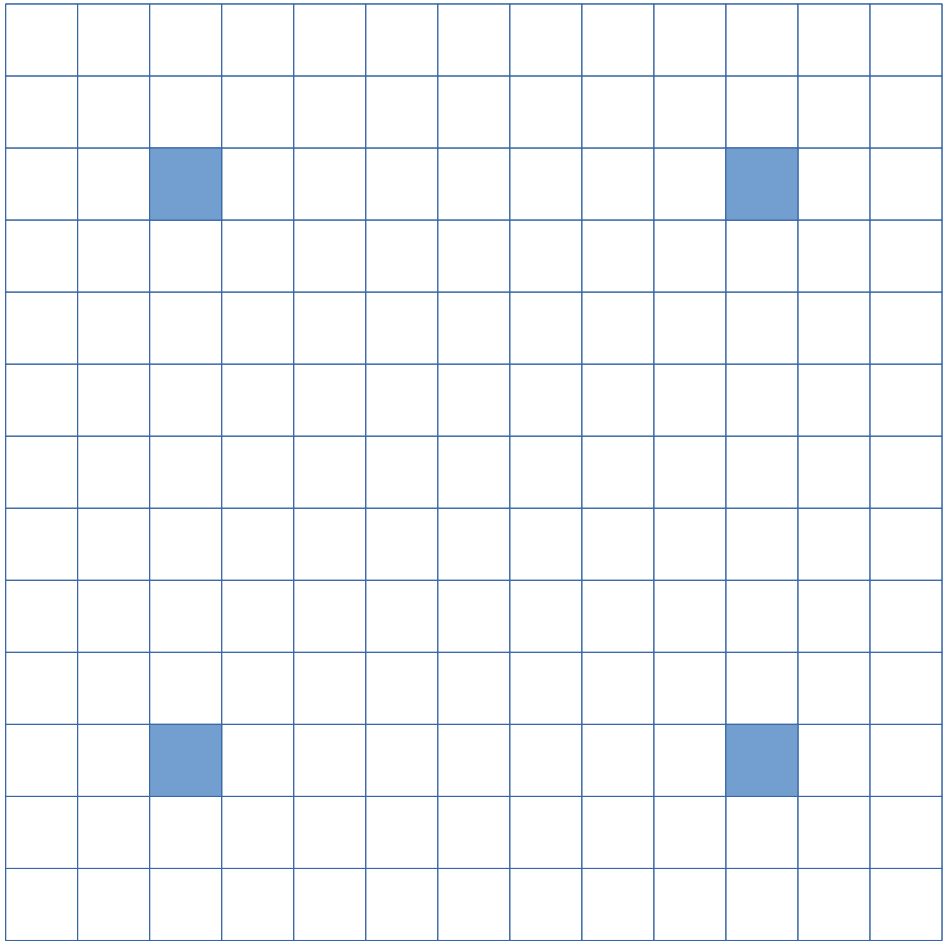
SUN-DIC Starting Strategy

- **Step 1 - Initialization**
  - Use $n \times n$ Gauss Quadrature (GQ) points to identify initial subsets
  - Use AKAZE feature detection for each GQ subset to determine initial $\boldsymbol{p}$ values
  - Calculate and store the C_{ZNSSD} value for each GQ subset
  - Select the GQ subset with the smallest C_{ZNSSD} value and continue to the next step

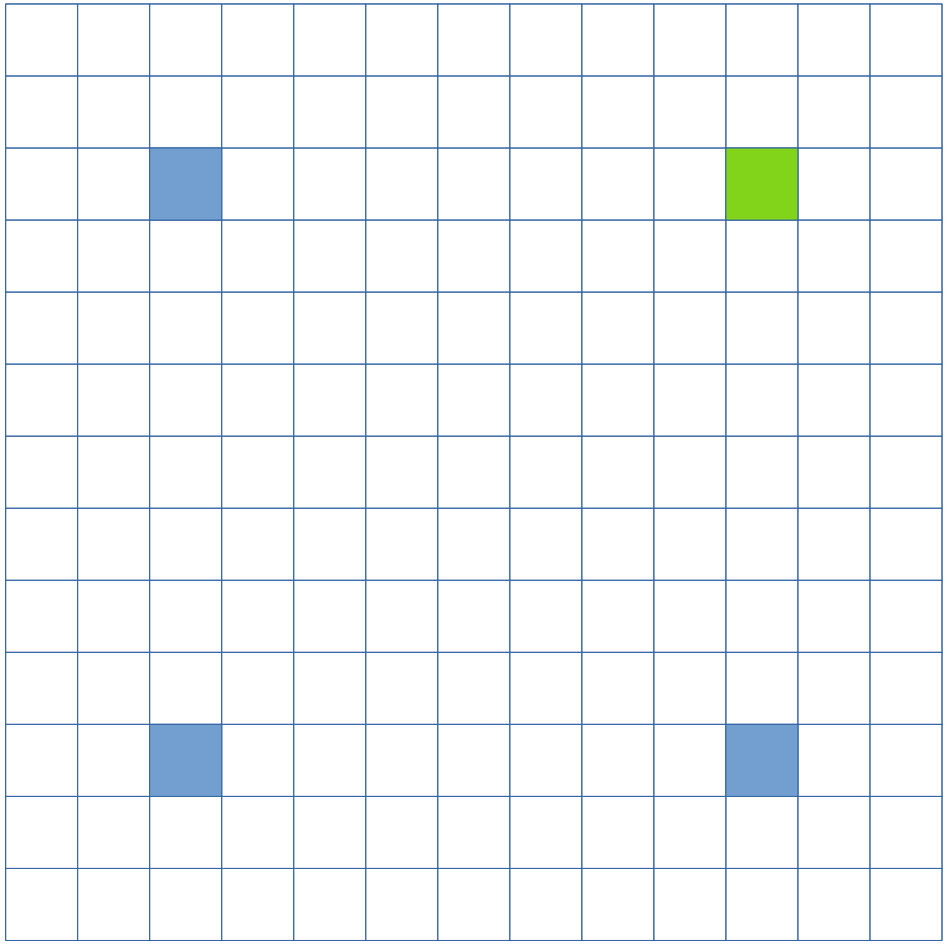
SUN-DIC Starting Strategy

- **Step 2 - Iteration**
  - Optimize the current best subset to find the final $\boldsymbol{p}$ values
  - Use the current $\boldsymbol{p}$ values as starting point for the optimization
  - Apply these optimized $\boldsymbol{p}$ values to the neighboring subsets that has not been optimized yet
  - Calculate and store the C_{ZNSSD} value for each neighboring subset
  - If a subset already has a C_{ZNSSD} value only update if the new value is smaller
  - Select the subset with the smallest C_{ZNSSD} value
  - Repeat step 2 until all subsets has been analyzed

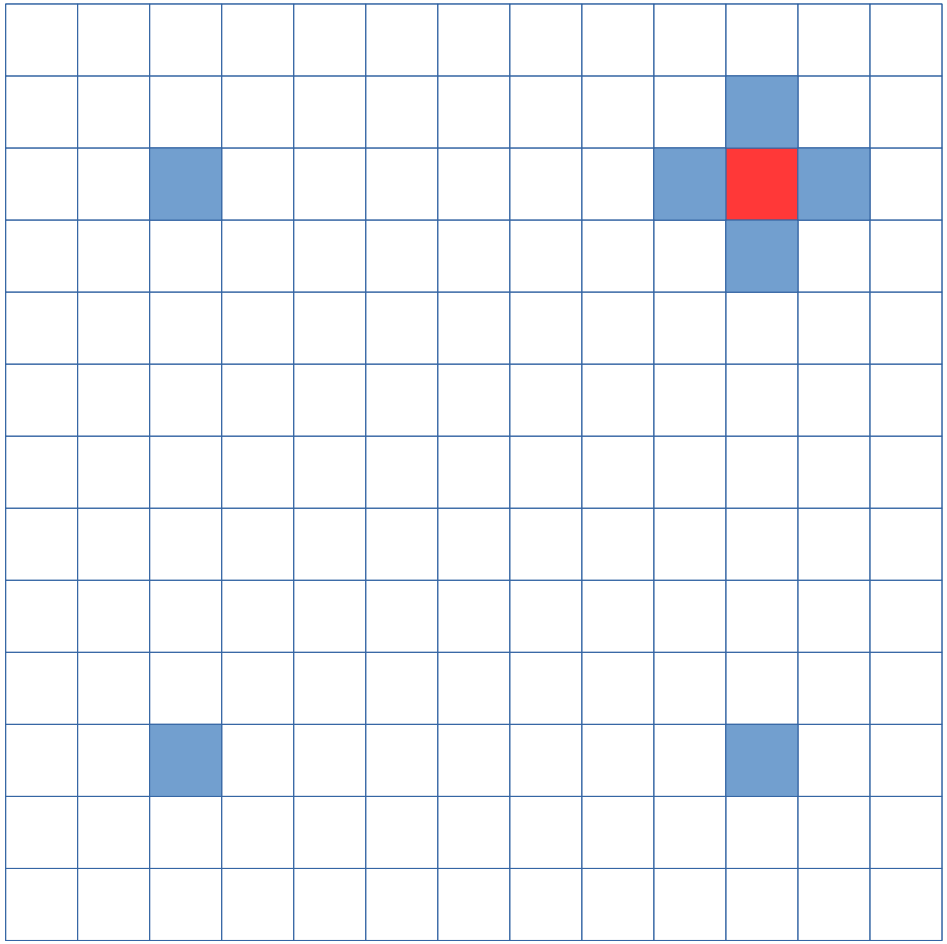
SUN-DIC Starting Strategy



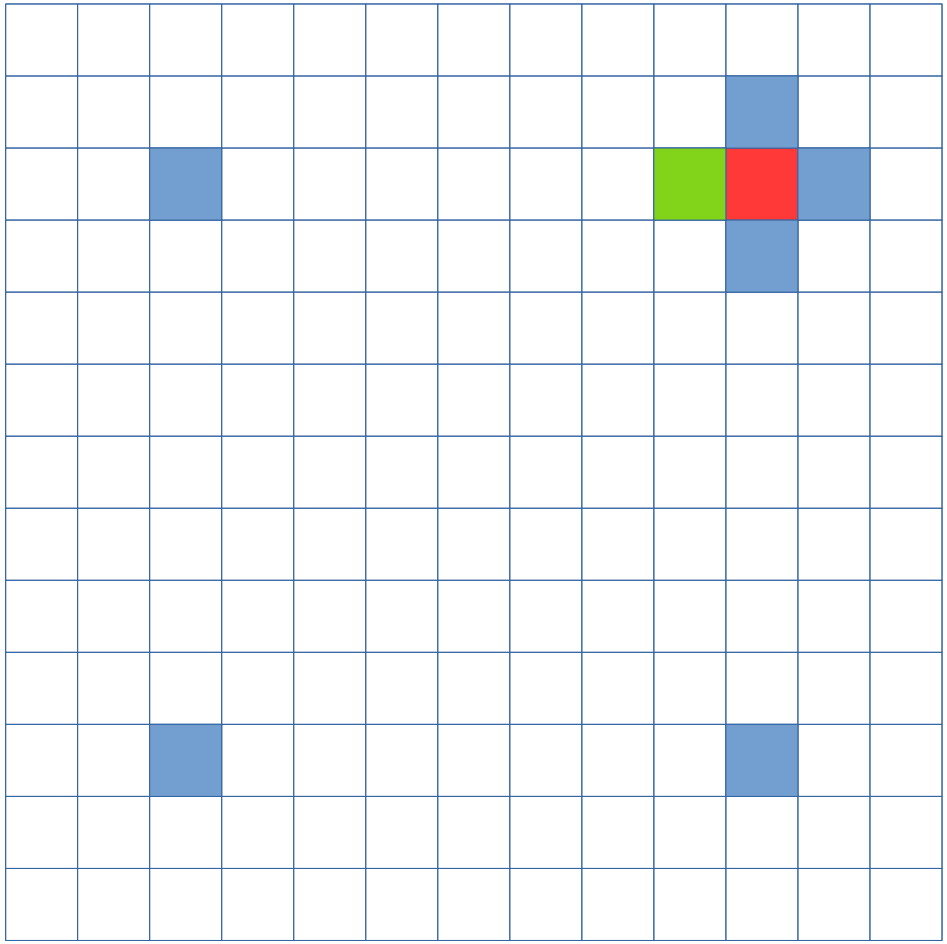
SUN-DIC Starting Strategy



SUN-DIC Starting Strategy



SUN-DIC Starting Strategy



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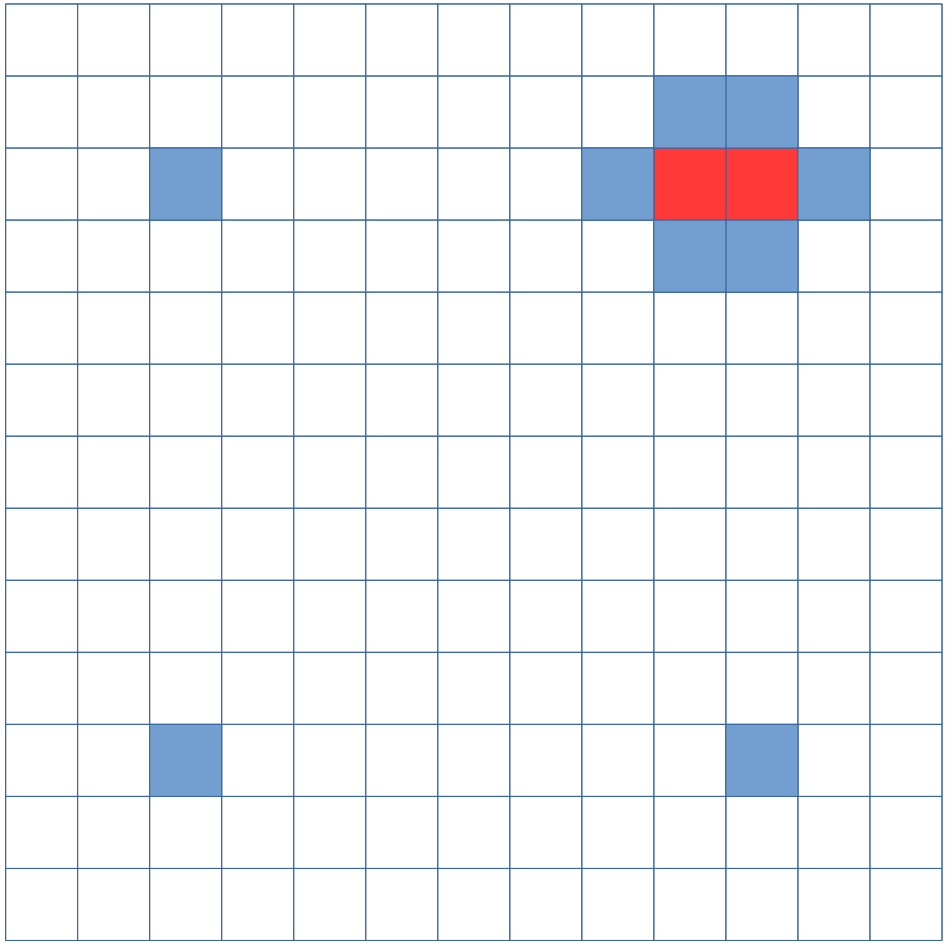
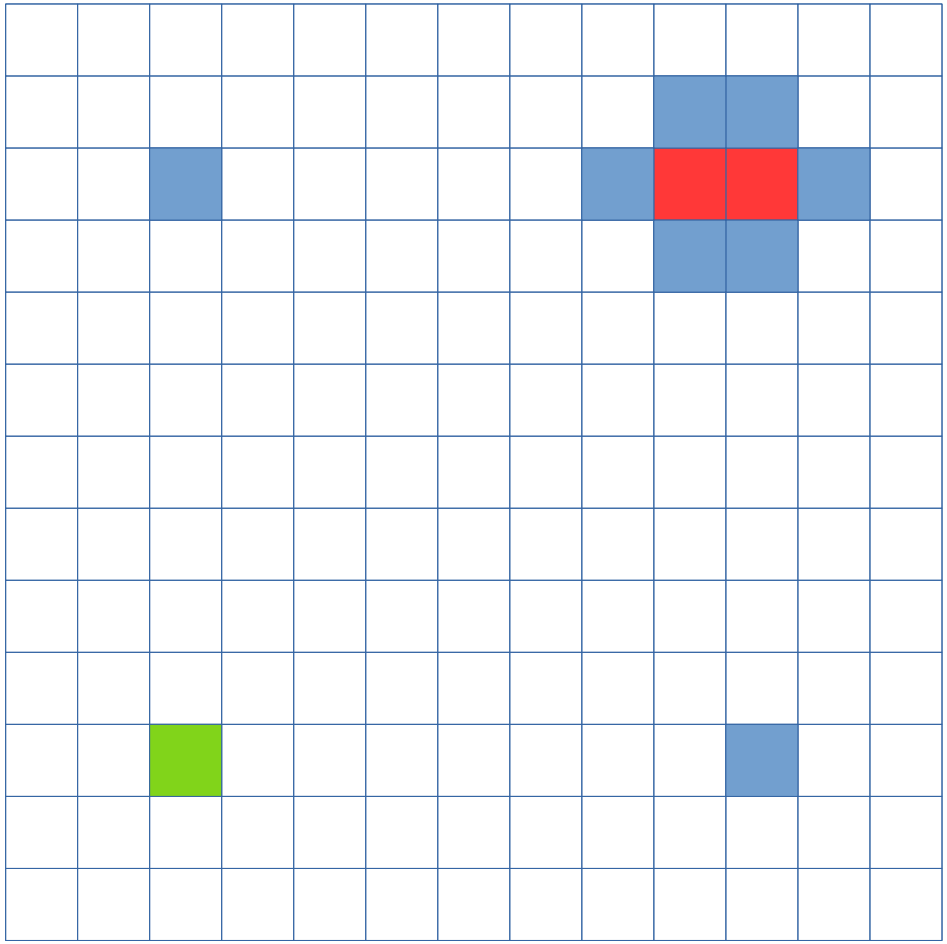


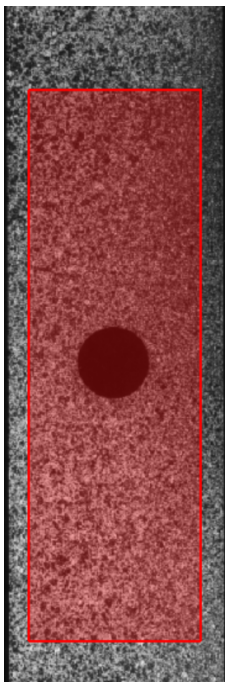
SUN-DIC Starting Strategy



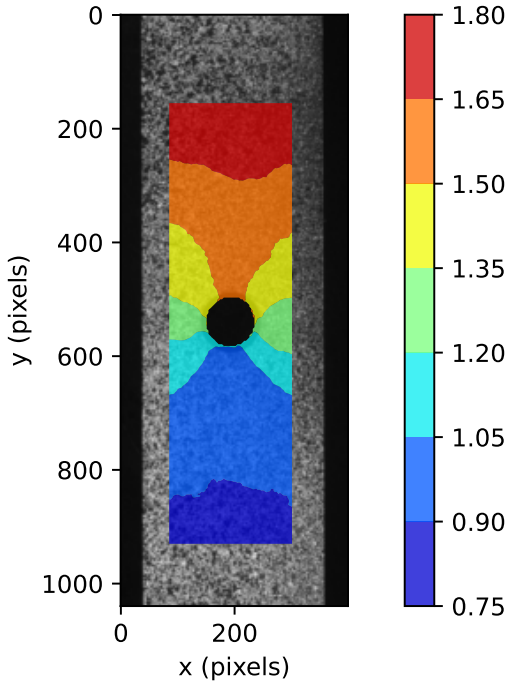
SUN-DIC Automatic Detection of Irregular ROI

- Automatically detect and ignores subsets with an average intensity value less than a specified threshold

Selection



Result



SUN-DIC API Demonstration

- Install the software in a virtual environment (eg using pip in linux)

```
python3.11 -m venv sundic
source sundic/bin/activate
pip install sun-dic
```

- Copy a working example from github

```
copy-examples
```

  - `settings.ini` - Settings file
  - `test_sundic.ipynb` - Jupyter notebook file
  - `planar_images` - Image directory
- Typical workflow:
  - Modify `settings.ini` file for your problem
  - Start with the `test_sundic.ipynb` file and modify as needed

SUN-DIC

https://github.com/gventer/SUN-DIC

References

- Chen, Bin and Erik Jungstedt (2022). "Fast and large-converge-radius inverse compositional Levenberg–Marquardt algorithm for digital image correlation: principle, validation, and open-source toolbox". In: *Optics and Lasers in Engineering* 151, p. 106930.
- Pan, Bing, Kai Li, and Wei Tong (2013). "Fast, robust and accurate digital image correlation calculation without redundant computations". In: *Experimental Mechanics* 53, pp. 1277–1289.
- Reu, Phillip L et al. (2018). "DIC challenge: developing images and guidelines for evaluating accuracy and resolution of 2D analyses". In: *Experimental Mechanics* 58, pp. 1067–1099.
- Yang, Jin (2025). *2D Finite Element Global Digital Image Correlation (FE-DIC)*. GitHub repository. Retrieved April 4, 2025. URL: https://github.com/jyang526843/2D_FE_Global_DIC.