Directional DIC
with automated feature selection

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Janko Slavič, and Ed Habtour
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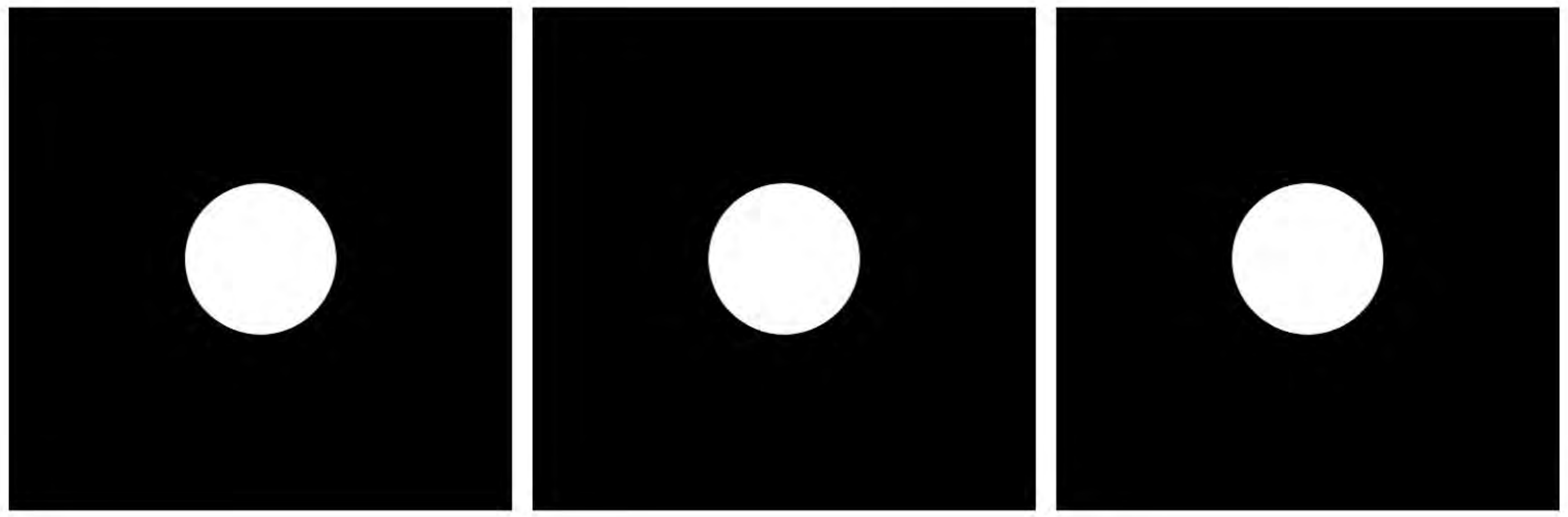
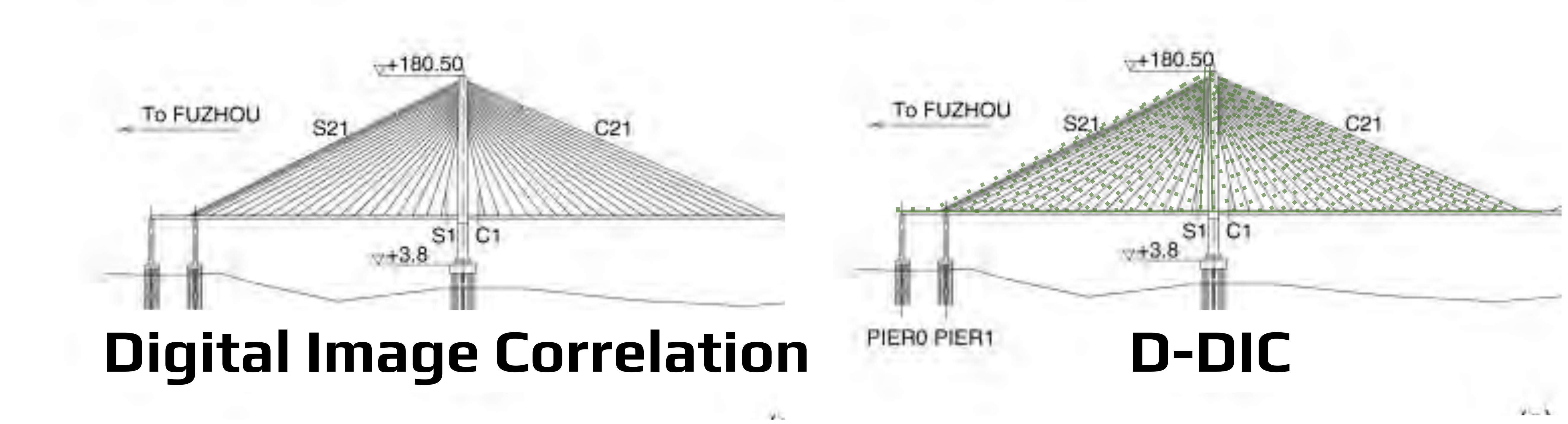
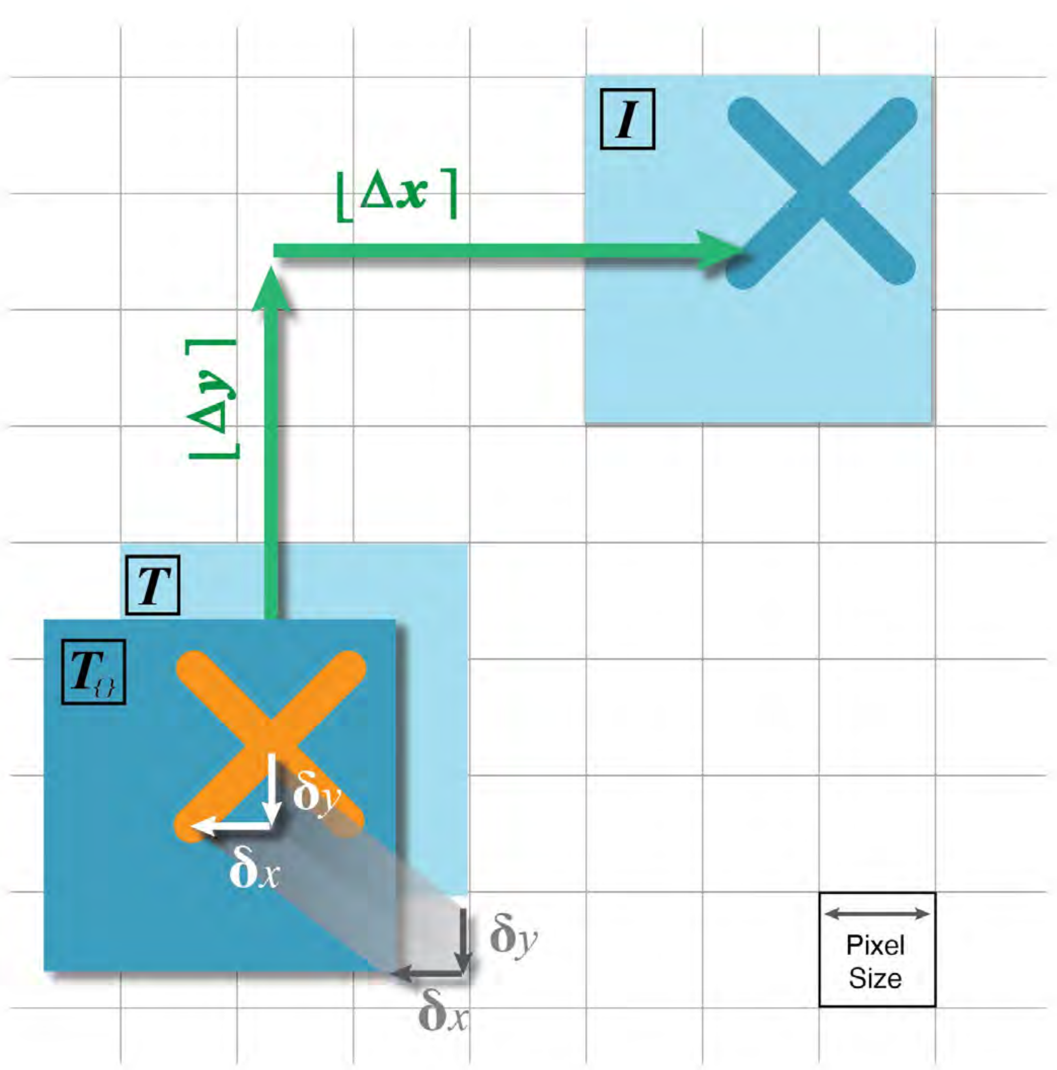
The aperture problem



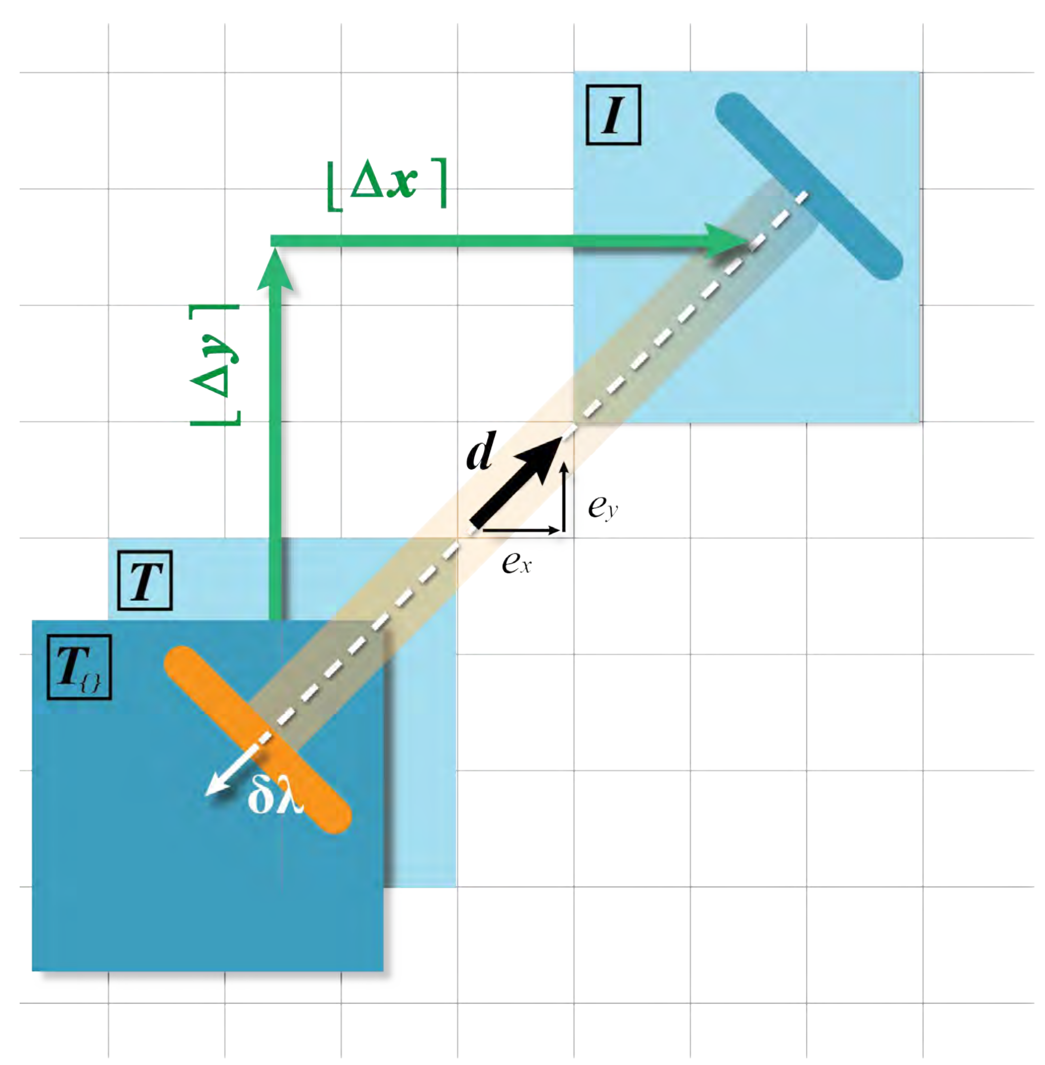
Enable more tracking locations



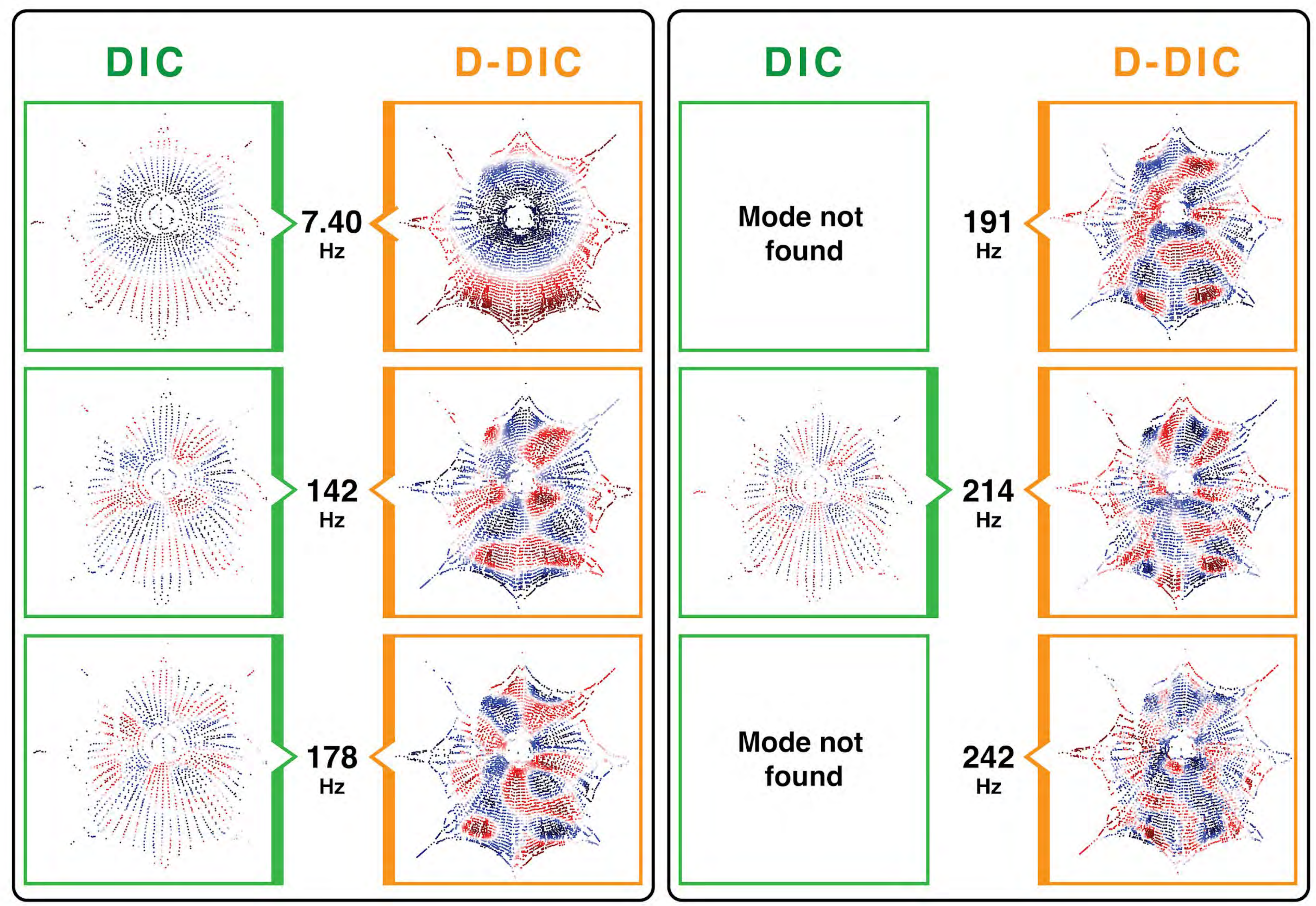
Conventional DIC



Directional DIC



Less noise, more stable poles, and more fitted mode shapes



Directional DIC (D-DIC)
with automated feature selection

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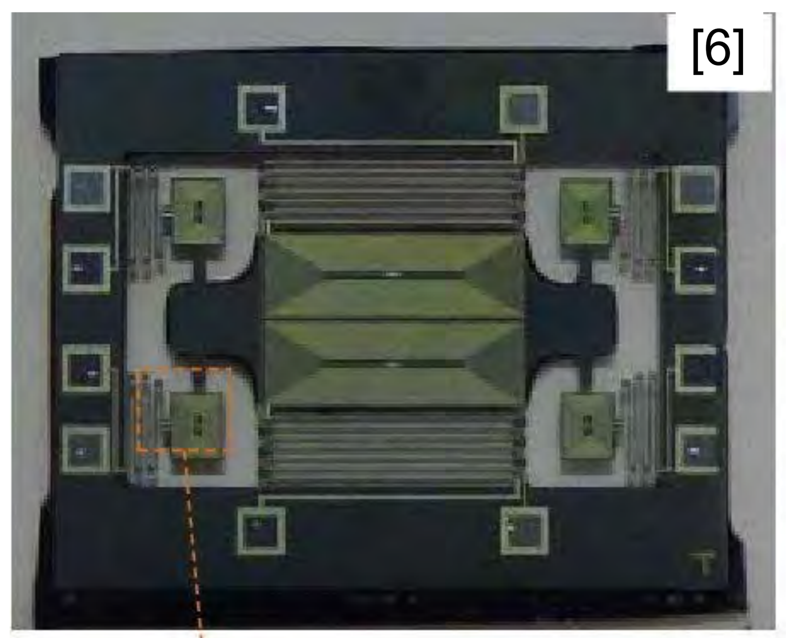
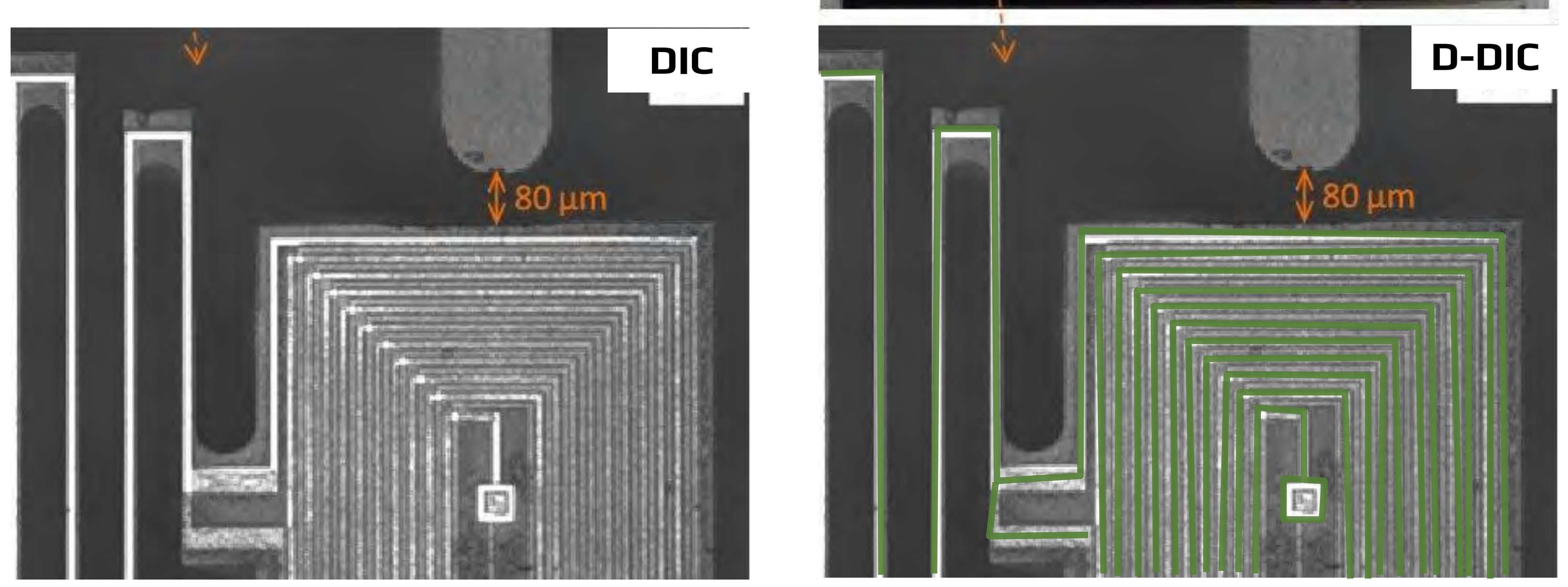
INTRODUCTION

Displacement measurements on high-speed videos with **Digital Image Correlation** are found to be an attractive non-contact, full-field method for measuring displacements of structural components exposed to dynamic loads [1,2,3]. For reliable displacement identification, DIC is applied to subsets of pixels with a well-defined gradient in orthogonal directions. If a sufficient gradient in one of the directions is missing, the motion in this direction cannot be observed, a phenomenon called the aperture problem [4]. **Directional DIC overcomes the aperture problem by using a pre-defined displacement direction**. This is possible as vibration shapes are locally directional in structural vibration. Automatic feature selection is well-known in computer vision and is used to find appropriate features [5]. **This is the first time Automatic feature selection is used for measurement estimation, and this paper introduces the first parameter for automatic feature selection for a uni-directional image alignment technique**

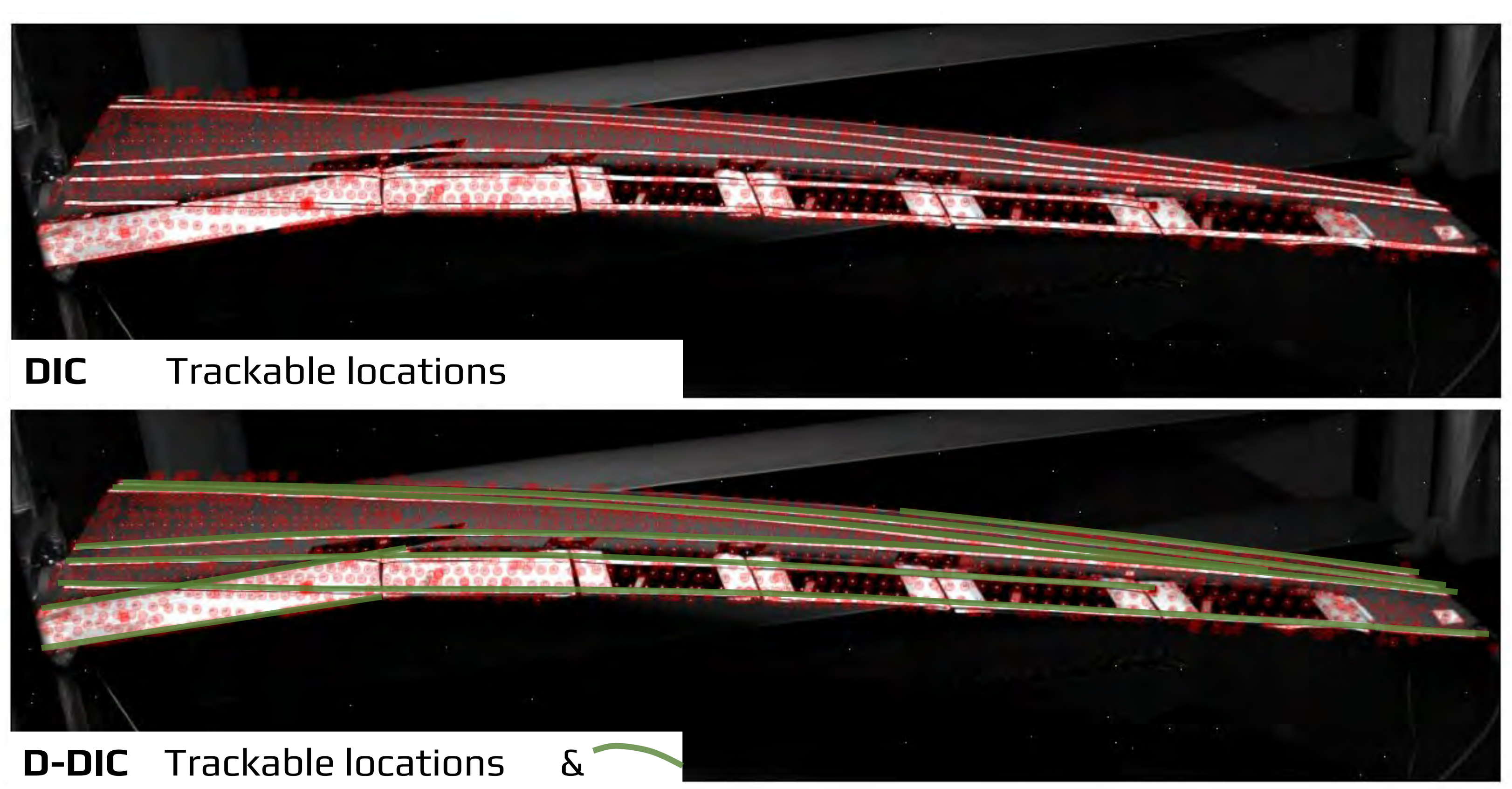
MOTIVATION

Adding speckle patterns to flexible lightweight structures is impractical and affects the dynamics of the system. D-DIC enables full-field displacement measurements on MEMS devices at significantly more locations. Here, appropriate feature locations are marked for conventional DIC compared to D-DIC for an In-Plane MEMS Electromagnetic energy harvesting device [6]. **Many more trackable locations can be selected for D-DIC.**





Adding a speckle pattern to a wing foil is discouraged as it alters the aerodynamic properties of the structure [7]. To measure the dynamics with conventional DIC of a wing of A&A's Active Aeroelastic Structures lab temporary reflective markers had to painstakingly be added to create trackable spots. **For D-DIC reflective strips could be added quickly instead**.



METHODS

The goal of DIC is to align a template image $T(x,y)$ and an input image $I(x,y)$ [8]:

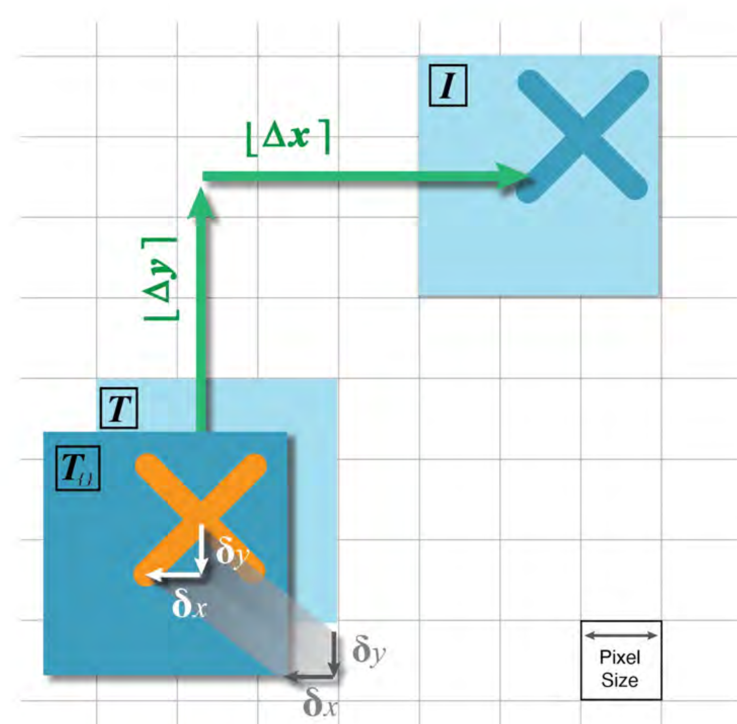
$$\min_{\Delta x, \Delta y} \sum_{p} \left[T(x-\Delta x, y-\Delta y) - I(x,y)\right]^2$$

Where p are the pixels in a subset of pixels in the images. Solving for the displacements directly leaves a residual error. Therefore, the displacements are found incrementally by solving for the incremental displacements (δx), interpolating the template image ($T_{()}$), and updating the global displacements Δx until convergence.

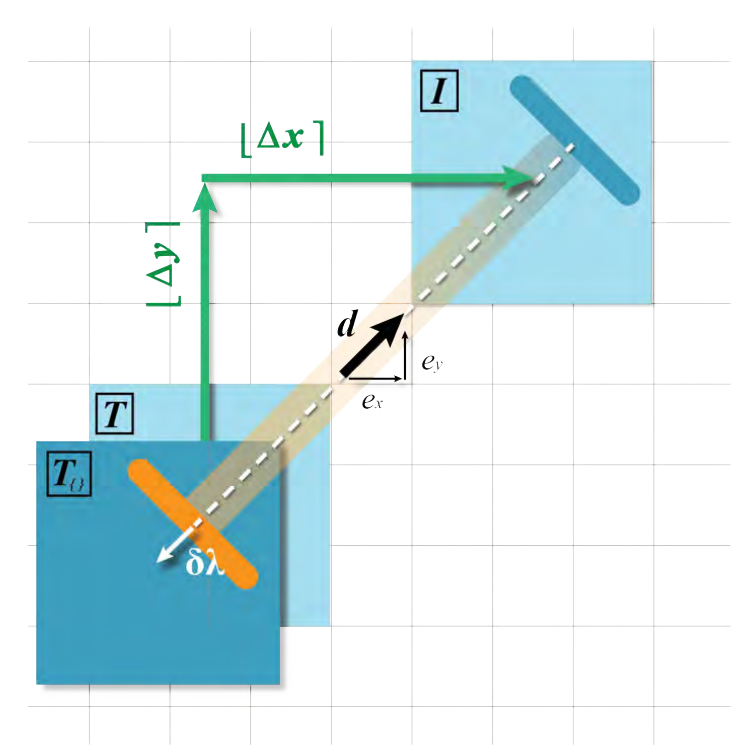
$$\min_{\delta x, \delta y} \sum_{p} \left[T(x-\Delta x-\delta x, y-\Delta y-\delta y) - I(x,y)\right]^2$$

$$\Delta x \leftarrow \Delta x + \delta x$$

Conventional DIC



Directional DIC



Directional DIC assumes the motion to be along direction $\boldsymbol{d} = [e_x, e_y]^T$, with $|\boldsymbol{d}| = 1$ and λ is the displacement in $\boldsymbol{d}$. Directional DIC incrementally solves:

$$\min_{\delta\lambda} \sum_{p} \left[T(x-\Delta x-\delta e_x\lambda, y-\Delta y-\delta e_y\lambda) - I(x,y)\right]^2$$

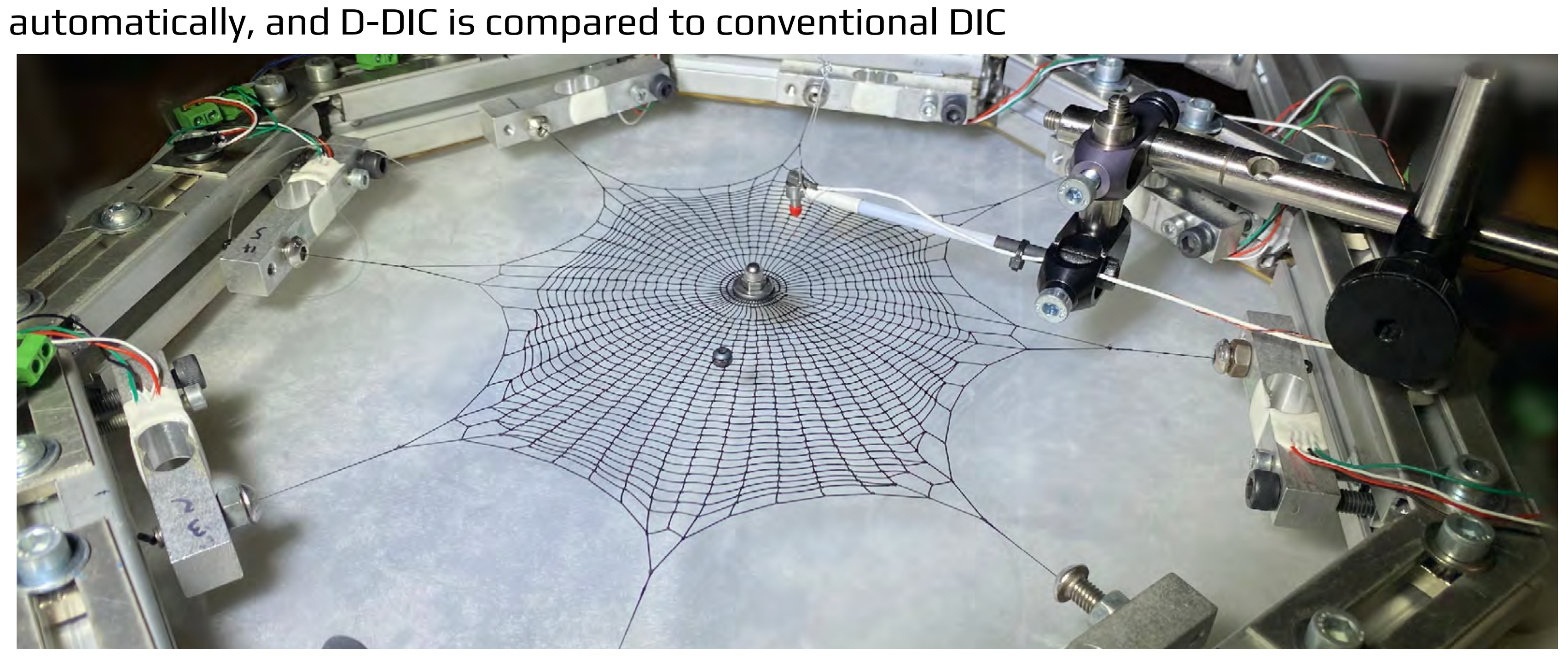
$$\Delta x \leftarrow \Delta x + \delta e_x \lambda$$

This research introduces the first parameter to be used for automatic feature selection for a uni-directional image alignment technique. The parameter is the absolute sum of the pixel intensity gradients in the direction of $\boldsymbol{d}$:

$$\lambda_{\mathrm{d}} = \sum_{p} \left| e_x \frac{\partial T}{\partial x} + e_y \frac{\partial T}{\partial y} \right|$$

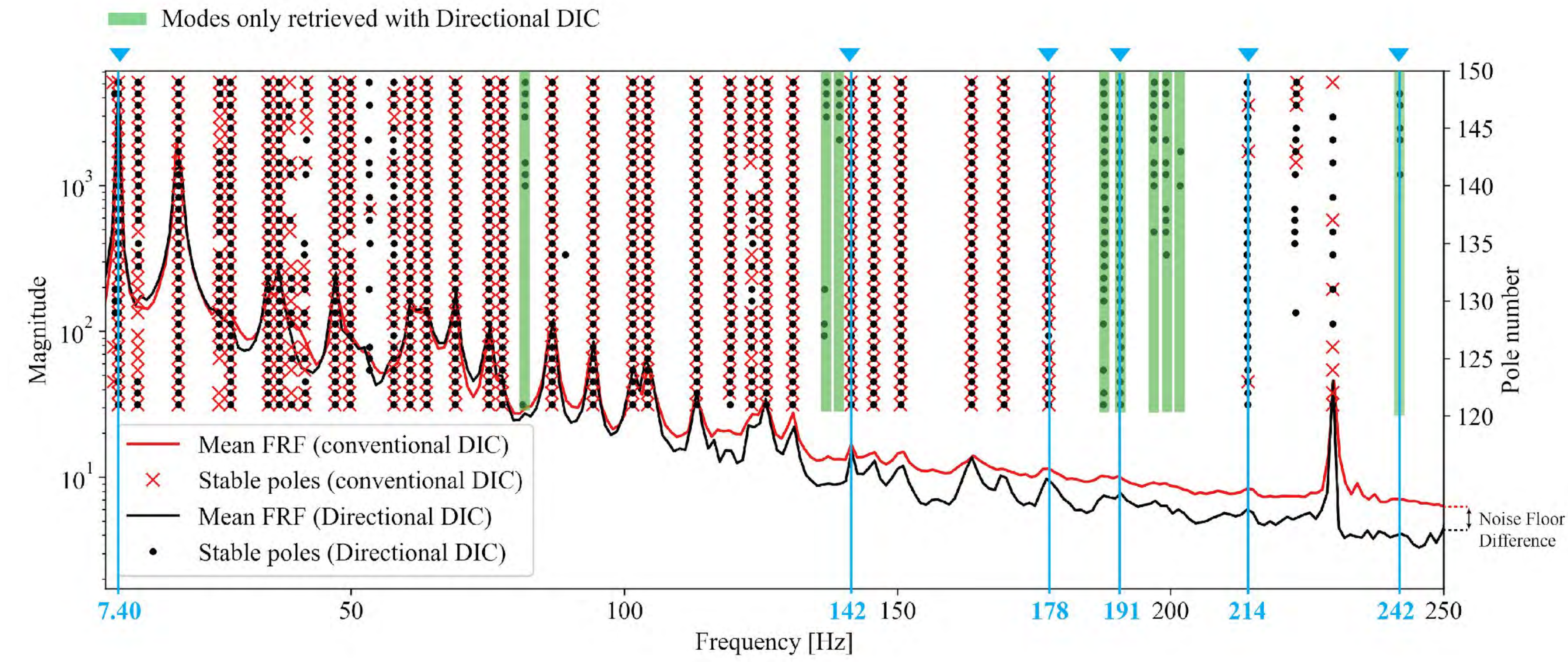
Validation

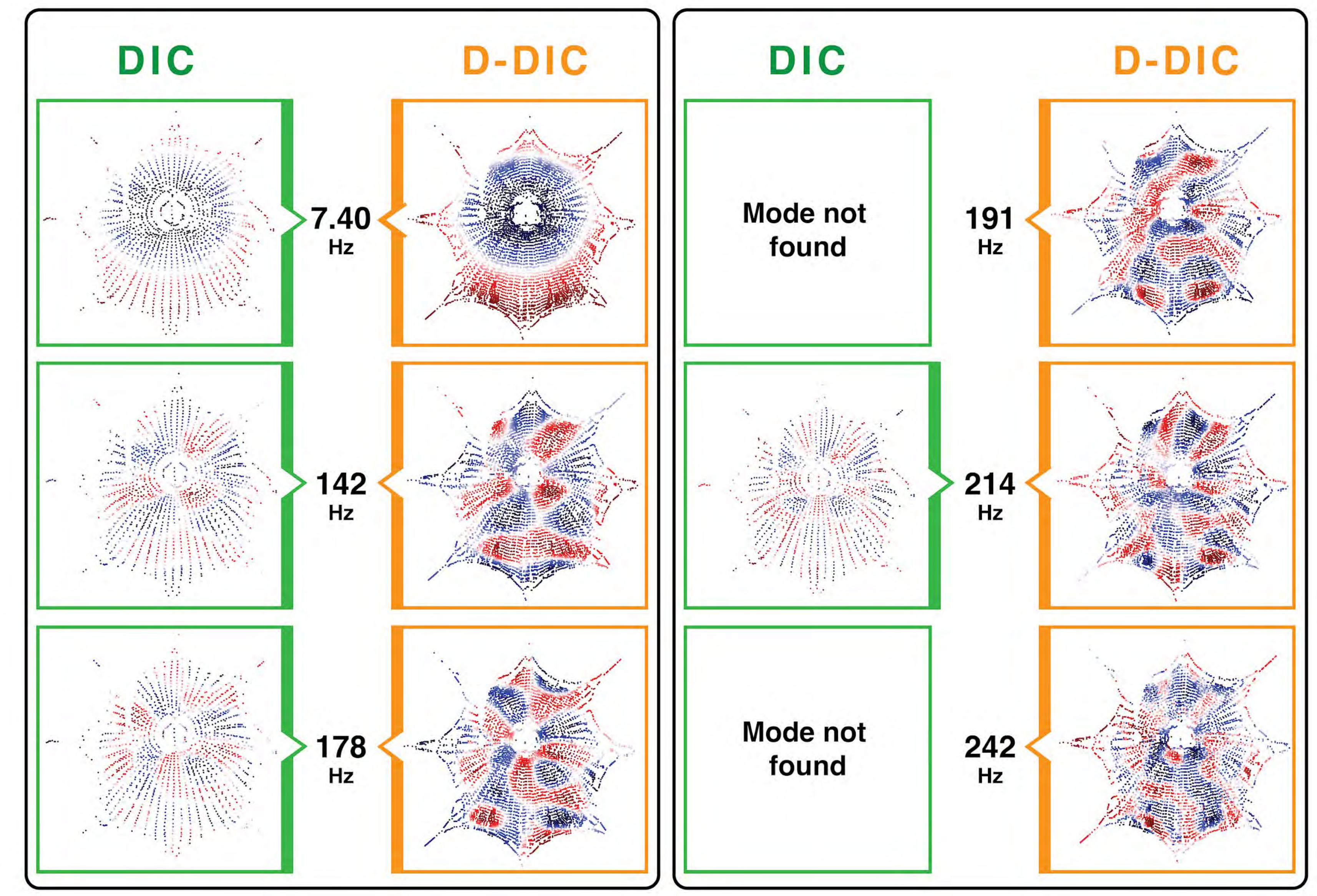
D-DIC is validated by conducting a modal test on a flexible structure that does not have a well-defined gradient in orthogonal directions. Tracking locations are selected automatically, and D-DIC is compared to conventional DIC



RESULTS

5,340 subsets could be tracked successfully with D-DIC as opposed to 1,553 in conventional DIC. The mean Frequency Response Function of the signals are set out below, in which also stable poles are set out. Vibration modes are fitted at the blue vertical lines and are highlighted in the bottom image.





CONCLUSIONS

Trackable points could be selected automatically for a unidirectional method. More than three times as many locations could be tracked with D-DIC than with DIC in the validation test. D-DIC was found to be less noisy than DIC. This allowed for retrieving more stable poles and fitting more vibration mode shapes. The fitted mode shapes are more spatially dense, making interpreting them easier. The introduced D-DIC method makes optical methods more accessible for displacement measurements on structures where no appropriate speckle pattern can be applied. This paves the way for characterizing the dynamics of cables, lightweight and flexible structures, aircraft wings, and many more.

LITERATURE

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