A Robust In-Situ Warp-Correction Algorithm for VISAR Streak Camera Data at the National Ignition Facility

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The Velocity Interferometer System for Any Reflector (VISAR) is the primary diagnostic at the National Ignition Facility (NIF) for measuring the timing of shocks induced into an ignition capsule. The VISAR system utilizes three streak cameras which are inherently nonlinear and require warp corrections to remove these nonlinear effects. A detailed calibration procedure is applied to the camera correction analysis in production; however, the camera nonlinearities drift over time affecting the performance of this method. To correct these small nonlinear drifts, we develop an in-situ warp-correction algorithm which utilizes the method of thin-plate splines to model the cameras' distortions.

Introduction

The National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory is a 192-beam pulsed laser system for high energy density physics experiments. Sophisticated diagnostics have been designed around six key performance metrics to achieve ignition. VISAR is the primary diagnostic for measuring shock timing and utilizes three streak cameras. Streak cameras are inherently nonlinearly and require warp corrections to remove these nonlinear effects. A detailed calibration procedure has been developed with National Security Technologies (NSTec) and applied to the camera correction analysis in production to remove these nonlinearities. However, the camera nonlinearities drift overtime due to sweep rate jitter and slow thermal drift, negatively impacting the performance of this method. We develop a robust in-situ warp-correction algorithm using thin-plate splines (TPS) to model the streak camera nonlinearities (see figure 1).

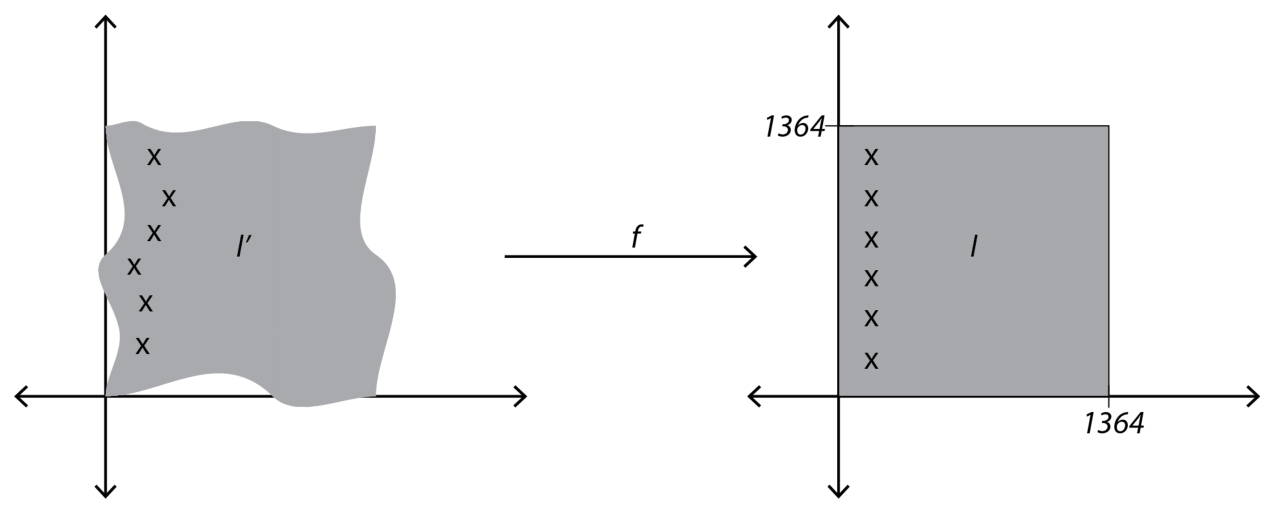

Figure 1 – Illustration of a TPS warp correction.

Thin-Plate Splines

Thin-plate splines is a vector valued function $(x,y) \mapsto (f_x(x,y), f_y(x,y))$ mapping each landmark point to its homolog so that the component surfaces f_x and f_y are least bent in the sense that the quadratic functional

$$I(f) = \int_{\mathbb{R}^2} \left((\partial_{xx} f)^2 + 2\left(\partial_{xy} f\right)^2 + \left(\partial_{yy} f\right)^2 \right) dx dy$$

is minimized over all such interpolating functions f_x and f_y. The component surfaces are of the form

$$f_x(x,y) = \underbrace{a_1 + a_2 x + a_3 y}_{\text{affine part}} + \underbrace{\sum_{k=1}^{n} w_k U\left(\|(x'_k, y'_k) - (x,y)\|\right)}_{\text{fully nonlinear part}}$$

where $U(r) = r^2 \log r$, and similarly for f_y. Figures 2 and 3 show a TPS example where the points (1,1), (4,1), (1,4) are identically mapped and (4,4) ↦ (5,4).

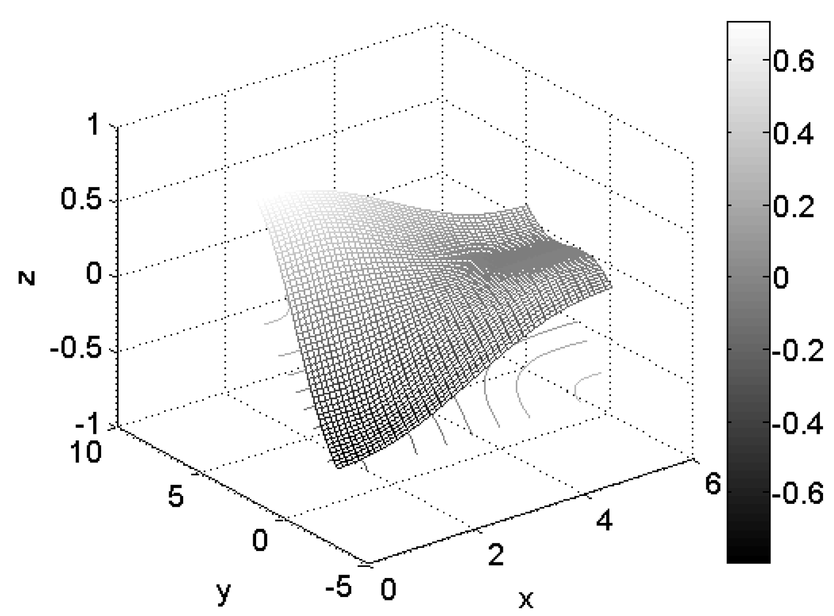

Figure 2 – Fully Nonlinear f_x

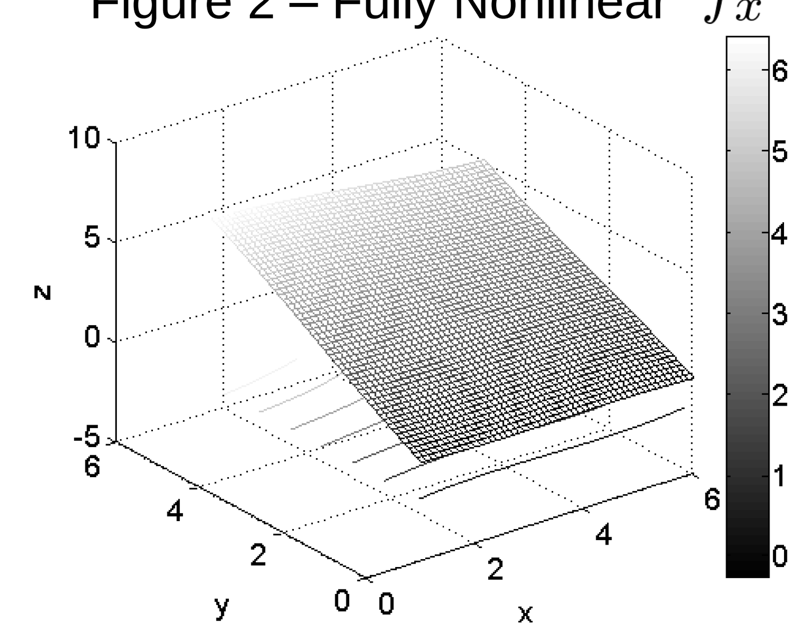

Figure 3 – Full f_x

In-Situ Warp-Correction Algorithm

- A multi-comb injection system generates a 2D grid of comb pulses. A 2D peak detection algorithm in production reports the (x'_{ij}, y'_{ij}) positions of each detected comb pulse (See figure 4).
- The algorithm is made robust by accounting for *missing* and *invalid comb pulses*. *Valid comb pulses* are used as *landmark points* to generate the TPS warp-correction map.
- Corrected *homolog* comb pulses are constructed by first choosing the comb pulse closest to the center of the image called the *reference point*.
- The rest of the homolog comb pulses are constructed using an algorithm that applies the comb period, the average *x*-coordinate position, the fiber-bundle delay of the current comb, and the center reference point.
- Boundary landmark and homolog points are calculated to prevent the TPS warp-correction from resizing the image.
- Construct the TPS mapping with $\{(x'_{ij}, y'_{ij}), \partial I'\} \longmapsto \{(x_{ij}, y_{ij}), \partial I\}$, and apply the warp correction to I' to obtain the corrected image I.

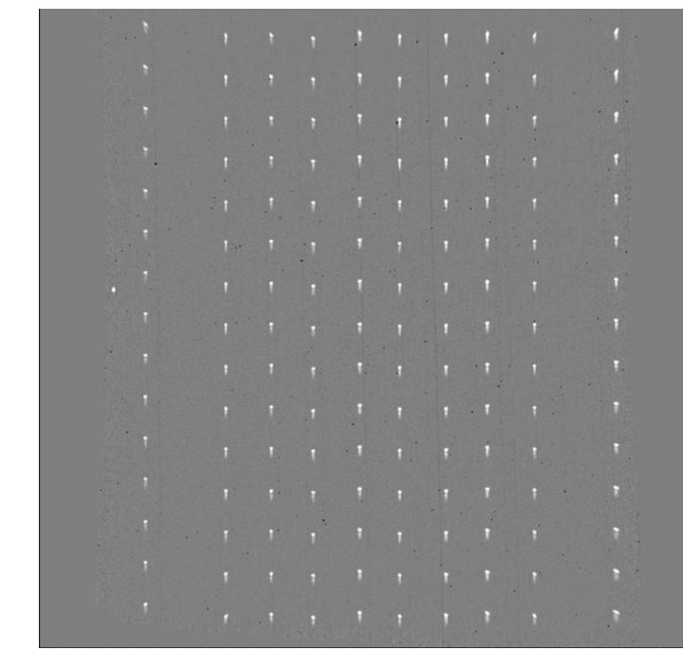

Figure 4 – Ten-comb image

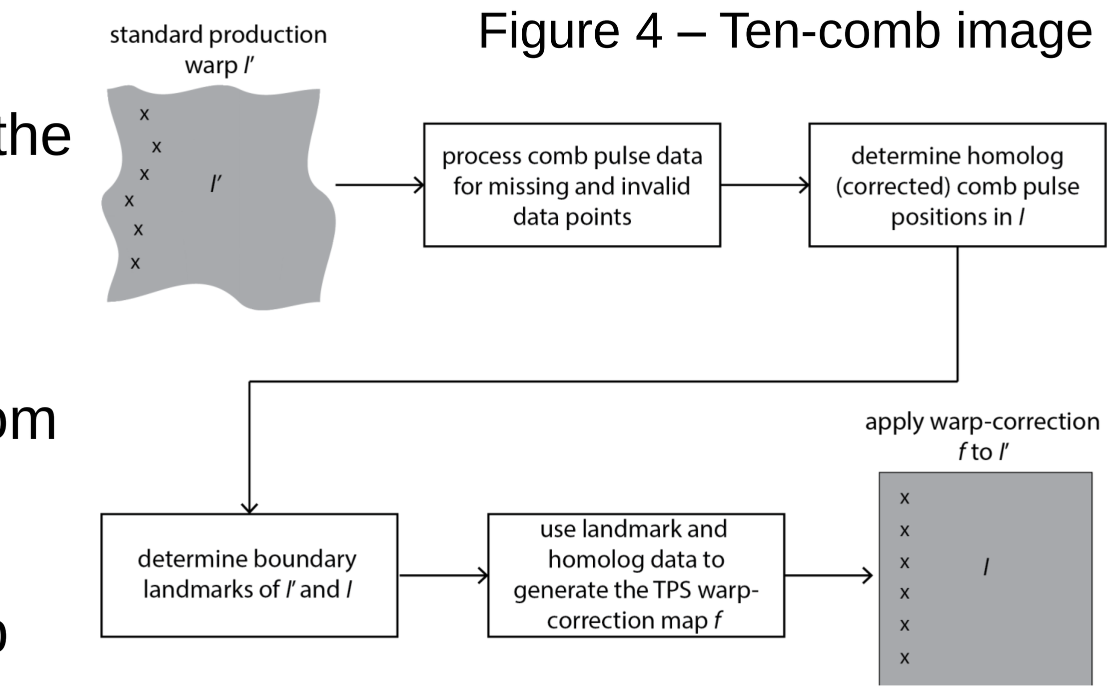

Figure 5 – TPS Warp-correction flow chart

Results and Future Work

The performance of the in-situ warp-correction algorithm is evaluated by generating a TPS warp-correction map for a 10-comb image, and then applying that map to another 10-comb image obtained during the same shot sequence. Figure 5 shows the result of a warp correction in the temporal and spatial directions.

Preliminary results are promising; the algorithm improves spatial and temporal accuracy for VISAR measurements. Future work will involve gathering statistics on the algorithm's performance.

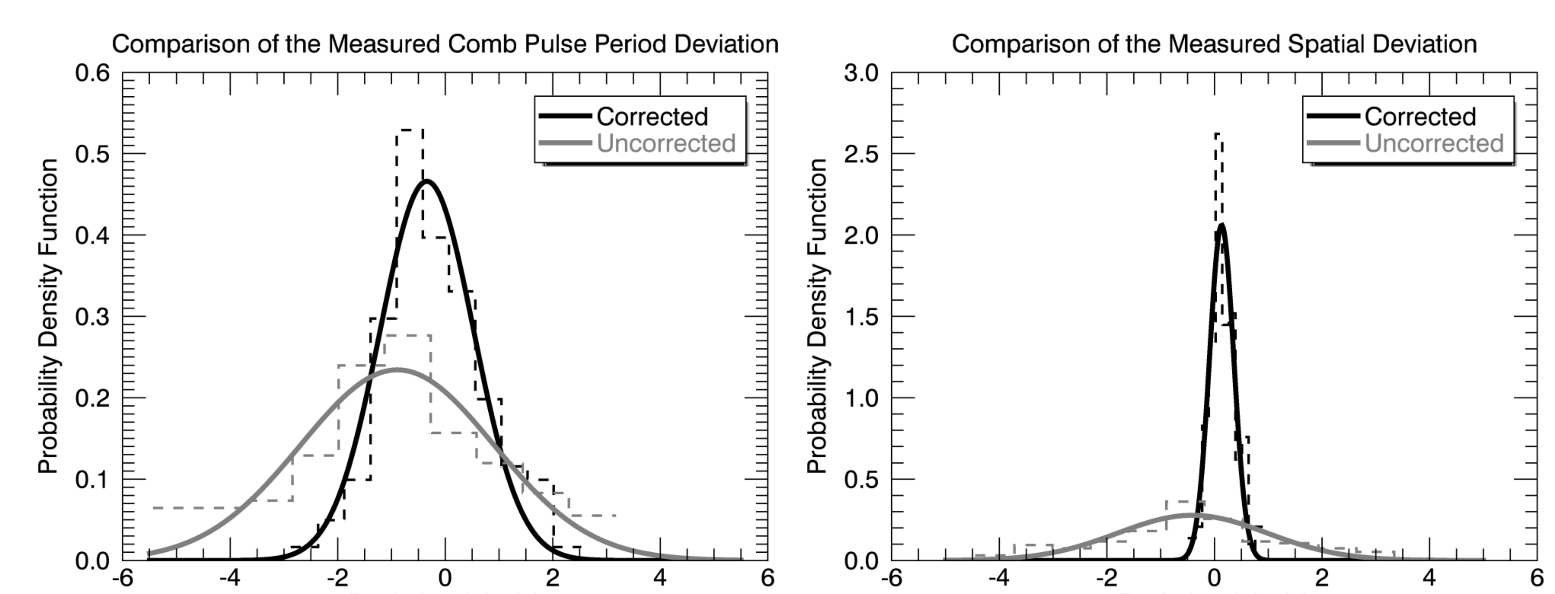

Figure 5 – Uncorrected and corrected deviations on a 10-comb image

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