SAND2015-4553C

Sandia National Laboratories

DIGITAL IMAGE CORRELATION DIC – CHALLENGE MEETING

SOCIETY FOR EXPERIMENTAL MECHANICS
JUNE 8TH, 2014

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www.dic-challenge.org

DIC CHALLENGE CHARTER

The DIC Challenge seeks to:

- Provide sample images for code verification and development.
- Benchmarked results for the sample images – published and peer-reviewed.
- A forum for the discussion and improvement of DIC.

The official charter is available at the website:
www.dic-challenge.org

CHALLENGE BOARD MEMBERS

- Phillip Reu – Chairman (US – FFT Shifting)
- Wei-Chung Wang (Asia)
- Hugh Bruck (US)
- Sam Daly (US)
- Ramon Rodriguez-Vera (Latin/South America)
- Evelyne Toussaint (EU – Analysis)
- Bertrand Wattrisse (EU – MATLAB Shifting)
- Florian Bugarin (EU – TexGen)

Inactive

THE DIC CHALLENGE IS IMPORTANT BECAUSE IT IS AN INDEPENDENT ORGANIZATION

- No ties to any commercial or university codes
- Open and free to participate
- Code developers will run their own code ensuring “optimum” parameter selection
- Validated image sets will be available tested by many groups for testing software
  - Simpler image shifting results are important!
- Benchmark results will be presented for all participants

CURRENT STATE OF THE CHALLENGE

- We have a set of sample 2D image sets that have been open for discussion for a long time.
- Organizing of 3D test is in process.
- Learning from the PIV-Challenge: We are moving slowly to ensure that all (most) participants agree that the images are appropriate and challenging.
- Todays goal is to finalize the image sets and submission guidelines.

GOAL: ACCEPT SAMPLE IMAGE SETS AND MOVE ON TO BLIND IMAGE SETS

- We need to ratify the sample image sets including:
  - Appropriateness
  - Generation method
- We need to accept the proposed blind sets
  - Type of images will be presented
  - Details of shift or strain will not be revealed
  - Proposed submission guidelines
  - A look at processing the results

Description	Set Name	Method‡	Contrast	Subset Size*	Noise σ (GL)	Shift (pixels)	# Images
TexGen Shift X,Y	Sample1	TexGen	Varying	Specify	1.5	X=Y=0.05	20
TexGen Shift X,Y	Sample2	TexGen	0 to 50	Specify	8	X=Y=0.05	20
FFT Shift X,Y	Sample3	FFT Shift	0 to 200	Specify	1.5	X=Y=0.1	10
FFT Step Shift	Sample3b	FFT Shift	0 to 200	User	1.5	0.05 to 0.5	5
FFT Shift x and y	Sample4	FFT Shift	0 to 50	Specify	8	X=Y=0.1	10
FFT Shift x and y	Sample5	FFT Shift	Varying	Specify	1.5	X=Y=0.1	10
Prosilica Bin	Sample6	Binning	0 to 200	21	Low	X=Y=0.1	10
Prosilica Bin	Sample7	Binning	0 to 50	Specify	High	X=Y=0.1	10
Rotation TexGen	Sample8	TexGen	0 to 100	Specify	2	Θ by 1	10
Rotation FFT	Sample9	FFT	0 to 100	Specify	2	Θ by 1	10
Strain Gradient	Sample10	TexGen	0 to 200	User	2	Sinusoid	10
Strain Gradient	Sample11	TexGen	60 to 130	User	2	Sinusoid	10
Strain Gradient	Sample11b	FFT	0 to 200	User	1.5	Tri. .01 to 1	6
Ex1 – Plate Hole	Sample12	Exper.	Good	User	Low	N/A	12
Ex2 – Weld	Sample13	Exper.	Poor	User	Low	N/A	52
Varying Strain	Sample14	FFT	0 to 200	User	5	N/A	4
Varying Strain	Sample15	TexGen	80 to 180	User	2	N/A	9
Rigid Motion	Sample16	Exper.	0 to 254	User	0.26	≈ 0.1	11
Interpolant Check	Sample17	Exper.	0 to 255	User	?	N/A	6

SYNTHETIC IMAGE CREATION IS DIFFICULT

- TexGen – A synthetic image generator
  - Orteu, J.-J., et al. (2006). A speckle texture image generator, SPIE.
- Fourier Shift Theorem (FFT)
- Ultra-high resolution image decimation (Prosilica)
  - Reu, P. (2011). "Experimental and Numerical Methods for Exact Subpixel Shifting." Experimental Mechanics **51(4): 443-452.**
- Experimental Image sets

There are possible issues with all of these methods. That is what we are here to discuss.

M. Bornert, P. D., J.-C. Dupré, C. Poilâne, L. Robert, E. Toussaint and B. Wattrisse (2012). Short remarks about synthetic image generation in the context of the assessment of sub-pixel accuracy of Digital Image Correlation. 15th International Conference on Experimental Mechanics (ICEM'15), Porto, Portugal, 22-27 Juillet 2012, Porto, Portugal, EURASEM.

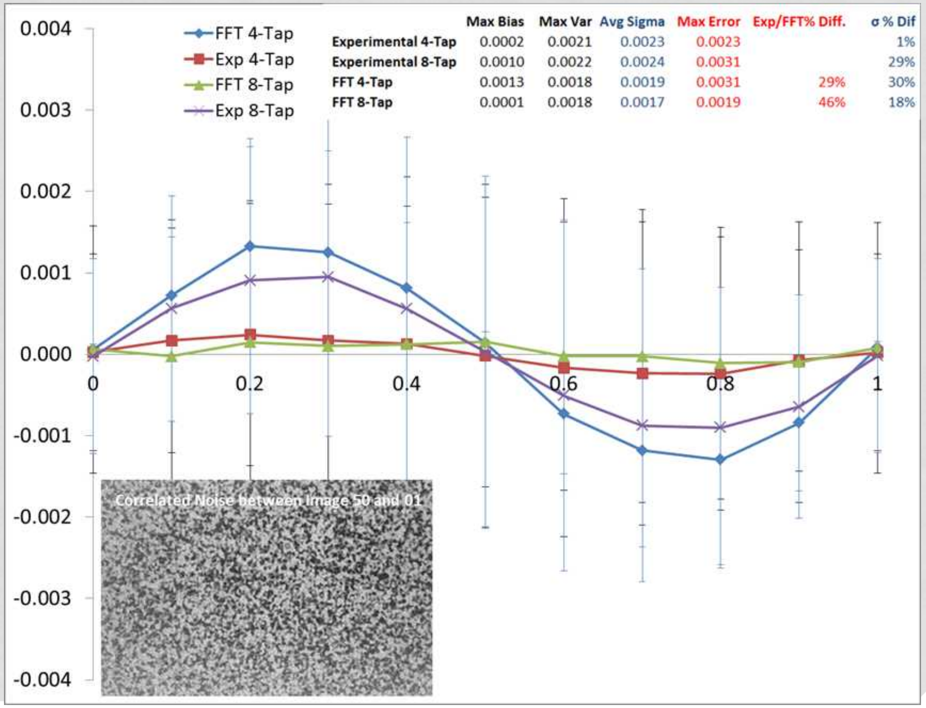
IMAGE SET DISCUSSION

- Last year we had this discussion
  - Does the image test DIC appropriately
  - Is the image appropriate: Speckle size, noise, contrast, etc.
  - All sets were deemed appropriate (if sometimes too challenging).
- This year:
  - Strain varying samples
  - How do we quantify the results for each type of image: Displacement and Strain.

SAMPLES 1 THROUGH 9 CHALLENGE THE CORRELATION AND NORMALIZATION

- Noise and contrast are varied (and sometimes very bad).
- A subset size will need to be defined (and filtering)

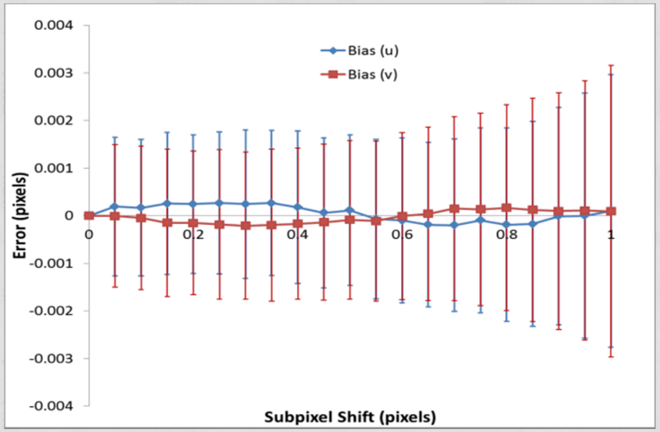
- What to do about the full-field methods?
- I think we should plot the mean displacement and the variance of *n* data points.

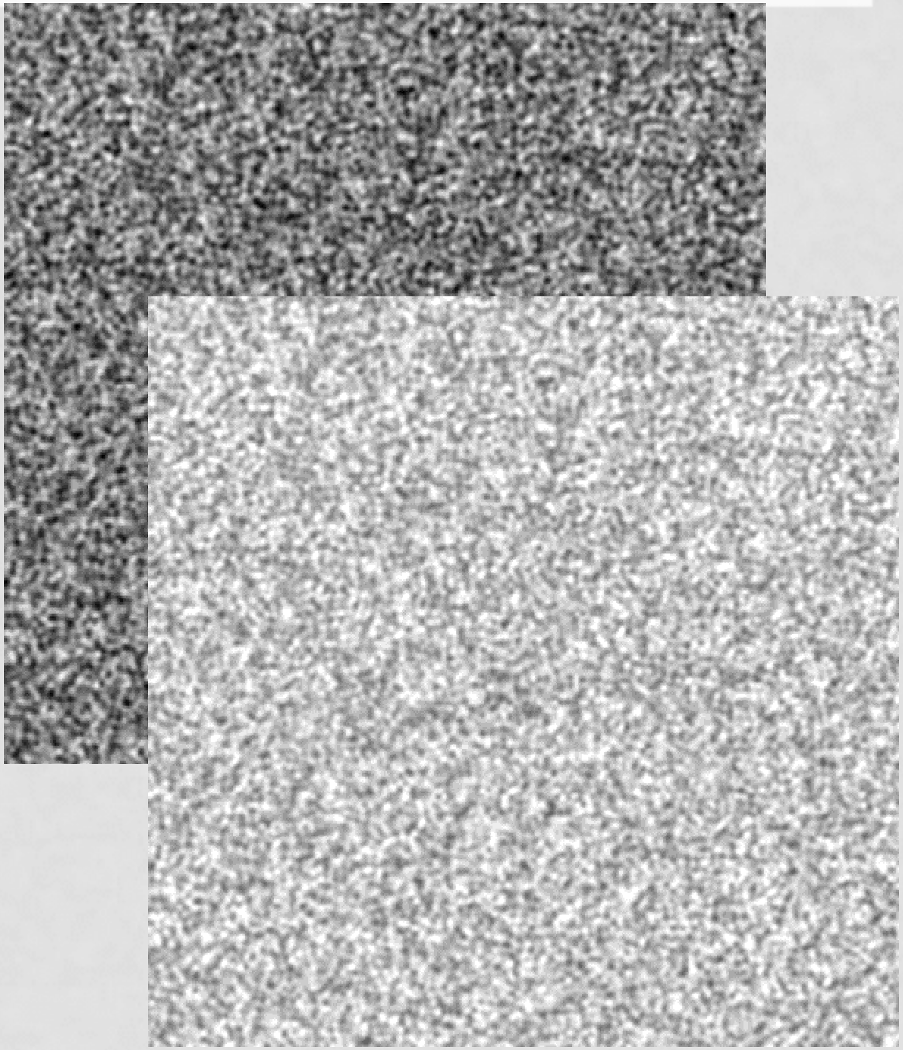


	Max Bias	Max Var	Avg Sigma	Max Error	Exp/FFT% Diff.	σ % Dif
Experimental 4-Tap	0.0002	0.0021	0.0023	0.0023		1%
Experimental 8-Tap	0.0010	0.0022	0.0024	0.0031		29%
FFT 4-Tap	0.0013	0.0018	0.0019	0.0031	29%	30%
FFT 8-Tap	0.0001	0.0018	0.0017	0.0019	46%	18%

SAMPLE 1 – TEXGEN WITH VARYING CONTRAST.

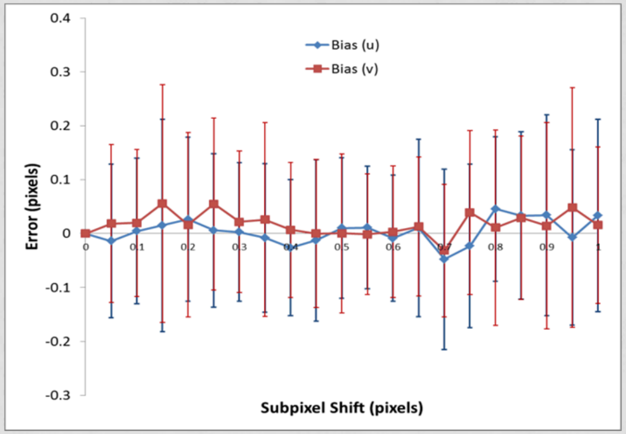
- Challenges grey level normalization.
- Ratio of contrast to noise varies
- Note there were issues reading thes in to some codes.

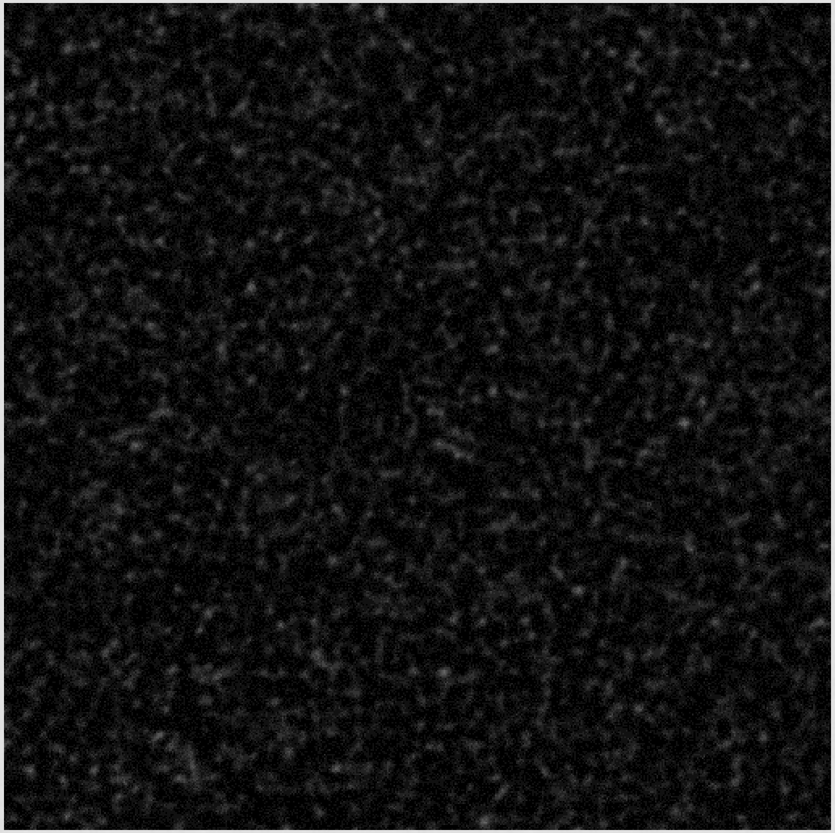




SAMPLE 2 – TEXGEN LOW CONTRAST HIGH NOISE

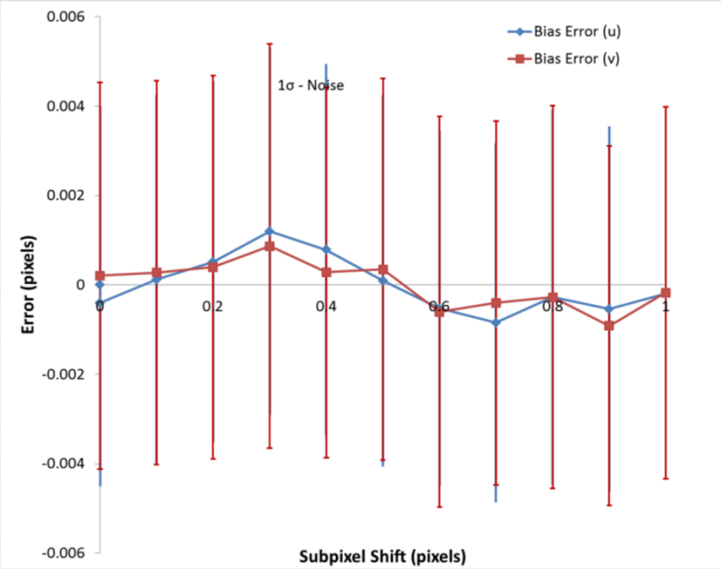
- Challenges interpolation response to noise
- Image filtering errors
- Correlation robustness
- Realistic (but very bad) images

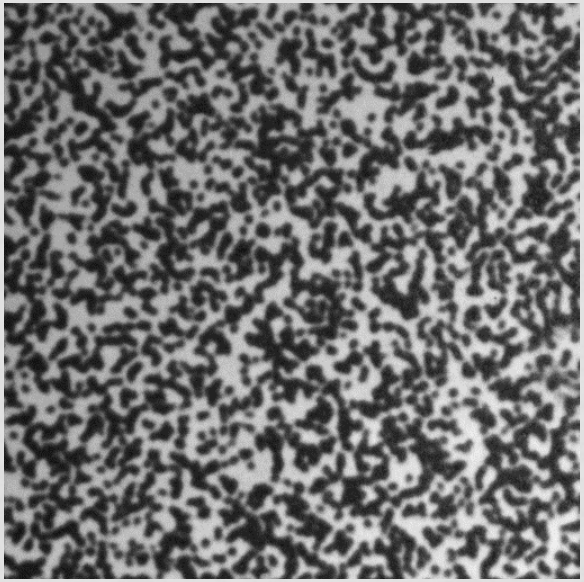




SAMPLE 3 – FFT GENERATED "GOOD" IMAGES

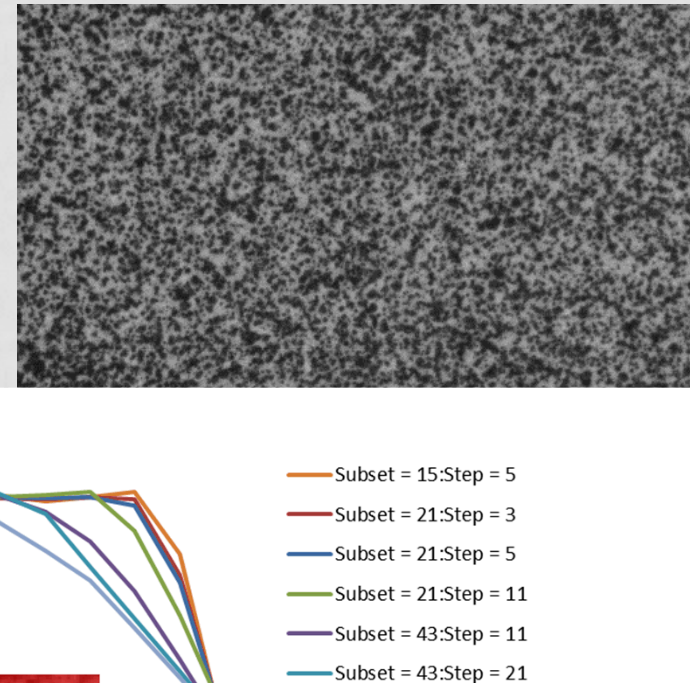
- Illustrates results from a good high-contrast and low-noise image
- Uses a different image generation method

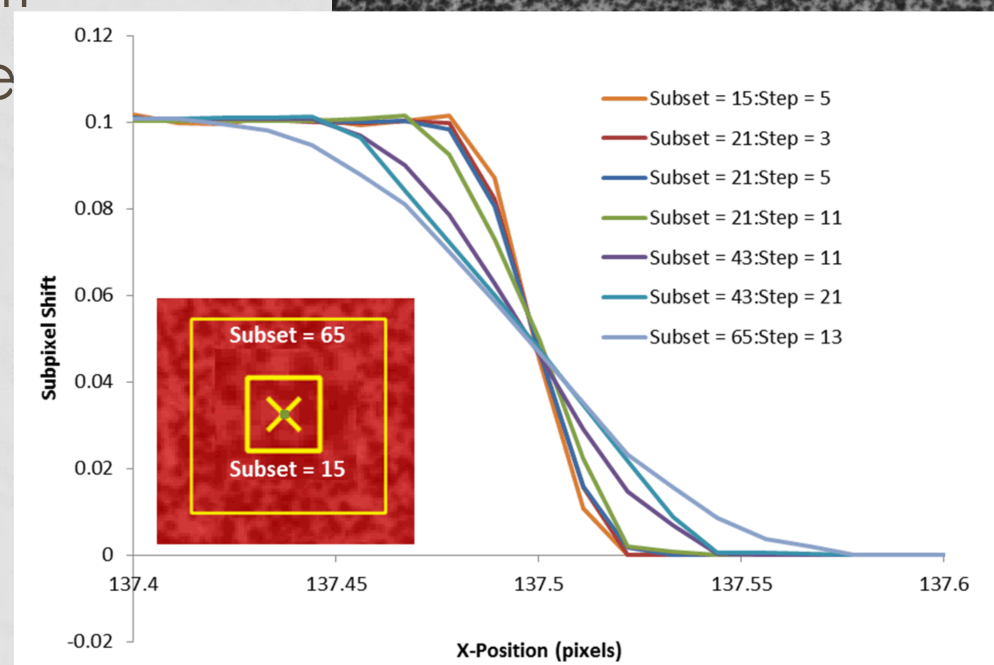




SAMPLE 3B – FFT GENERATED "CRACK"

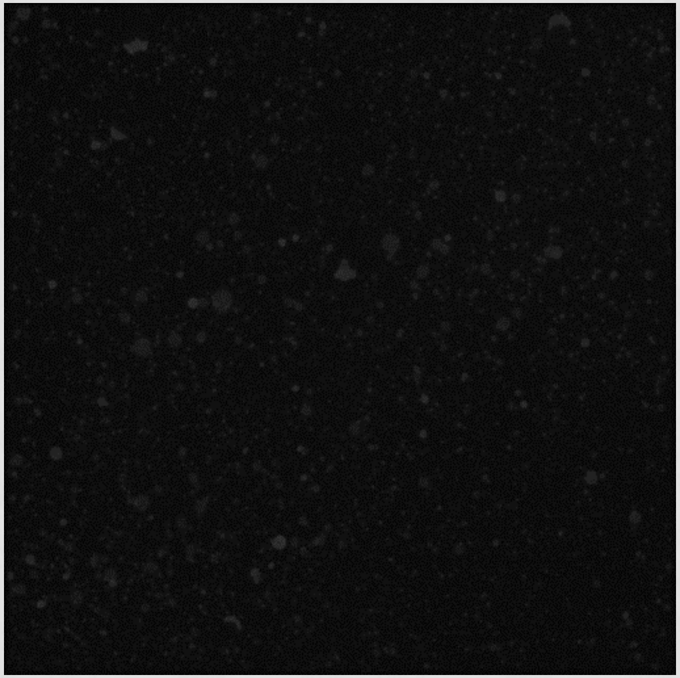
- Uses a real speckle image synthetically shifted
- A step shift in the middle challenges the spatial resolution in displacement
- Possible ringing issues due non-bandlimited signal





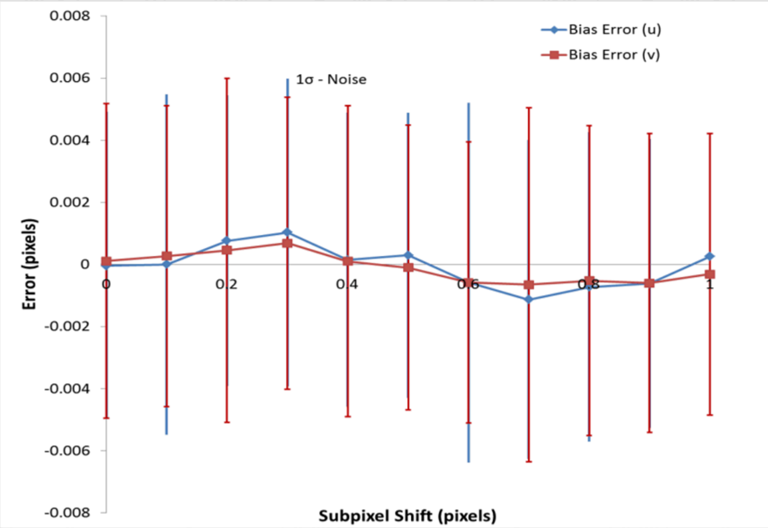
SAMPLE 4 – FFT LOW CONTRAST HIGH NOISE

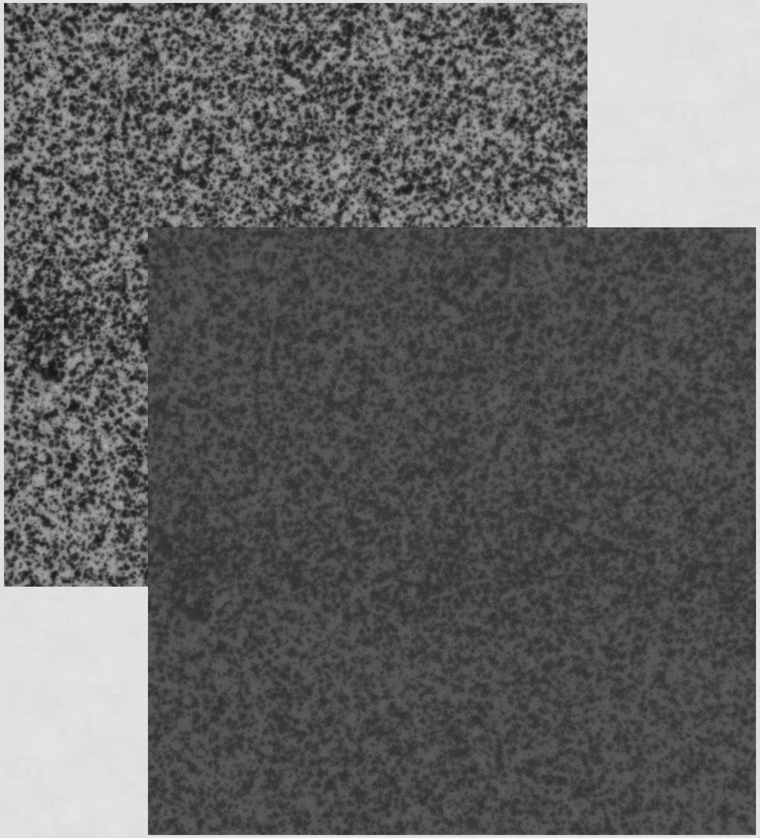
- Uses a real speckle image synthetically shifted
- Low-contrast and high-noise challenges the DIC algorithms
- Comparable to TexGen method, but using a different image generation technique.



SAMPLE 5 – FFT VARYING CONTRAST

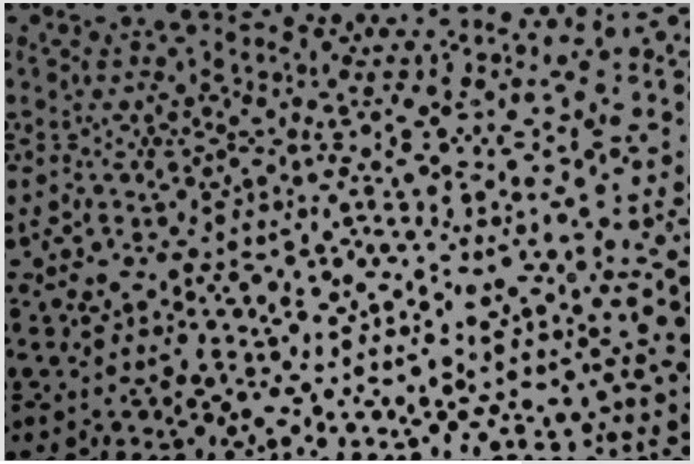
- Uses a real speckle image synthetically shifted
- Challenges normalization
- Comparable to TexGen method, but using a different image generation technique.

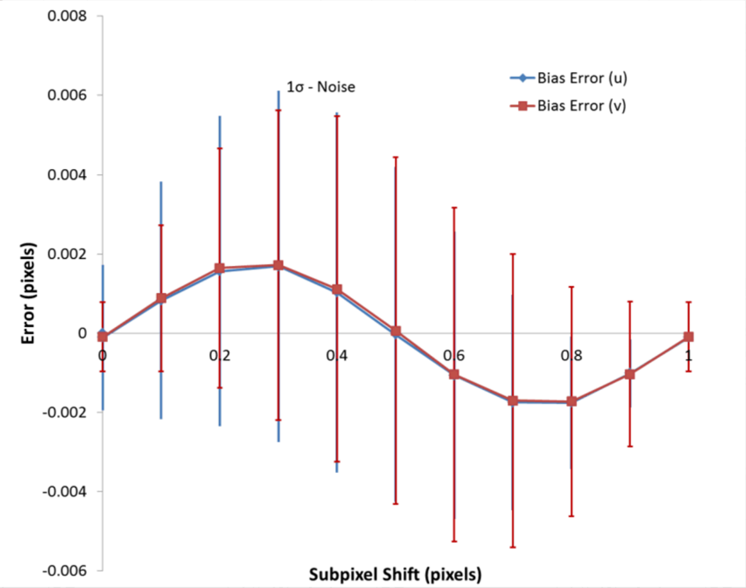




SAMPLE 6 – NUMERICAL BINNING OF EXP. IMAGE

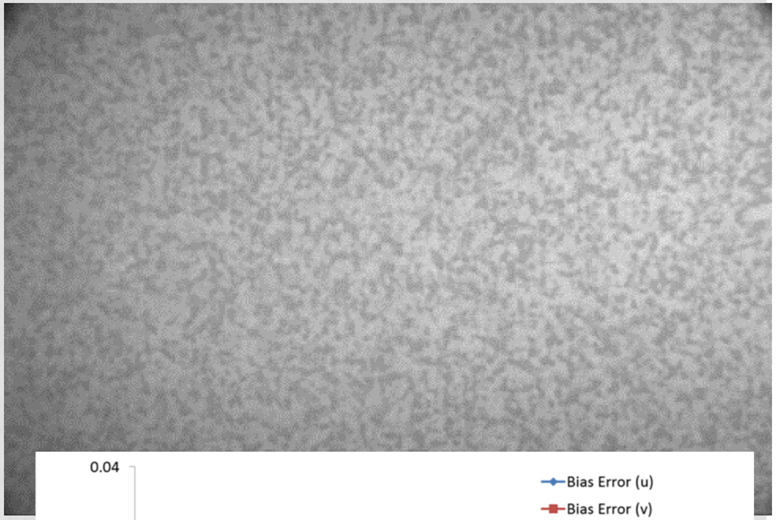
- Uses a real experimental speckle image shifted via binning
- Captures all the "real" imaging train issues?
- A third method comparable to the TexGen and FFT method

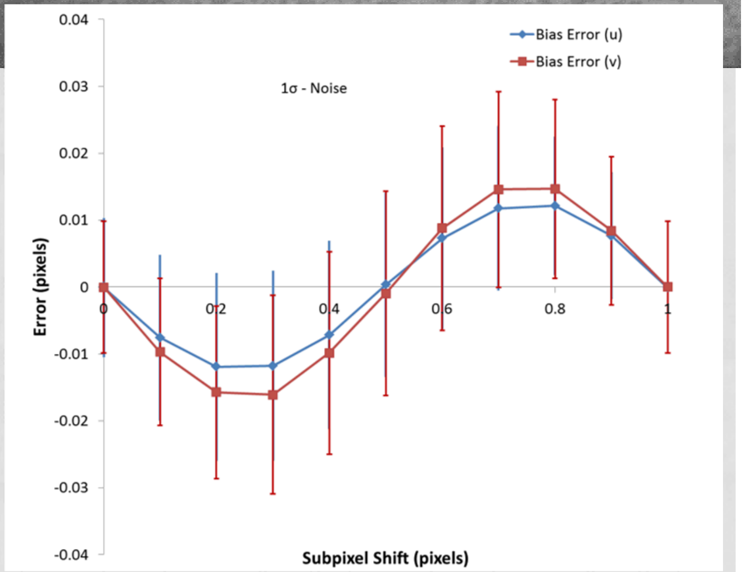




SAMPLE 7 – NUMERICAL BINNING OF EXP. IMAGE

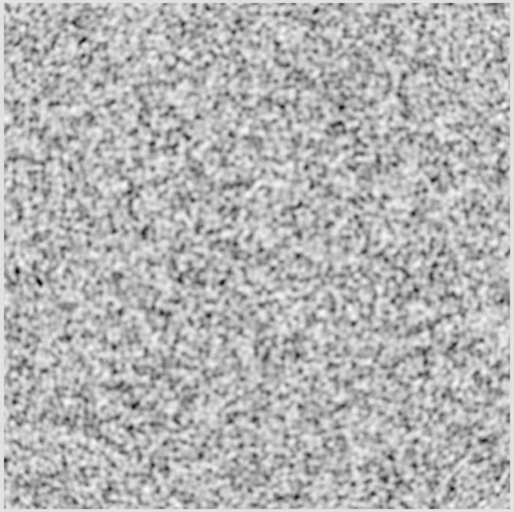
- Uses a real experimental speckle image shifted via binning
- Captures all the "real" imaging train issues? Noise and contrast not added numerically!
- A third method comparable to the TexGen and FFT method





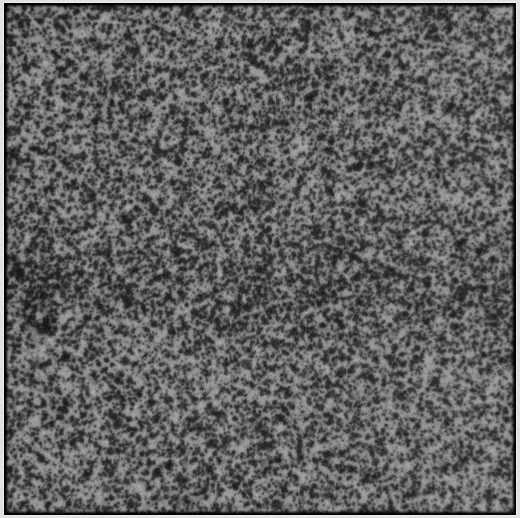
SAMPLE 8 – TEXGEN ROTATED IMAGE

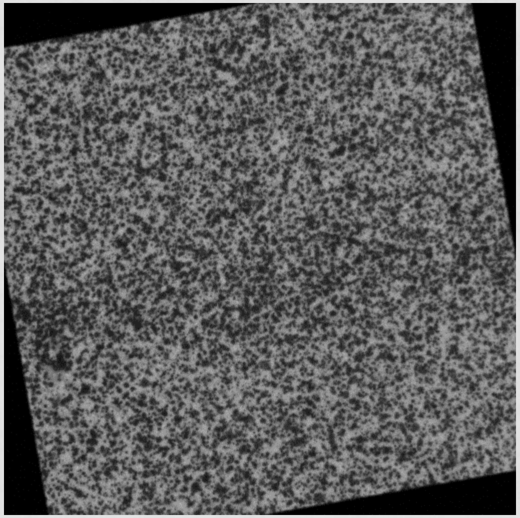
- High-contrast and low-noise image.
- Tests the subset shape function.



SAMPLE 9 – FFT ROTATED IMAGE

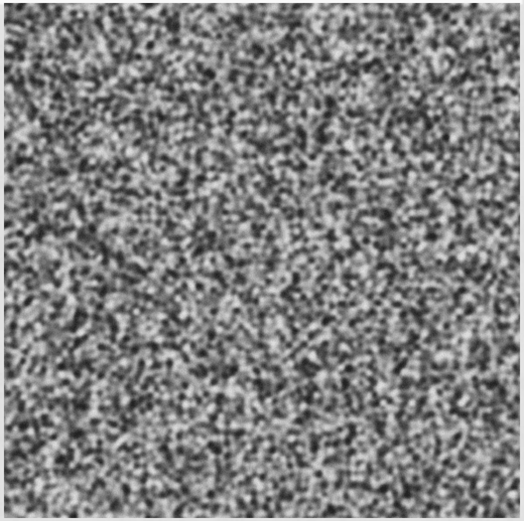
- High-contrast and low-noise image.
- Real image synthetically shifted.
- Tests the subset shape function.
- A different image generation method for comparison.

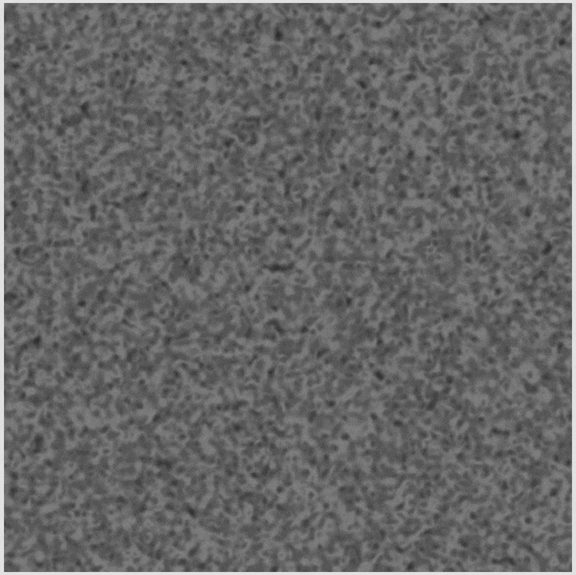


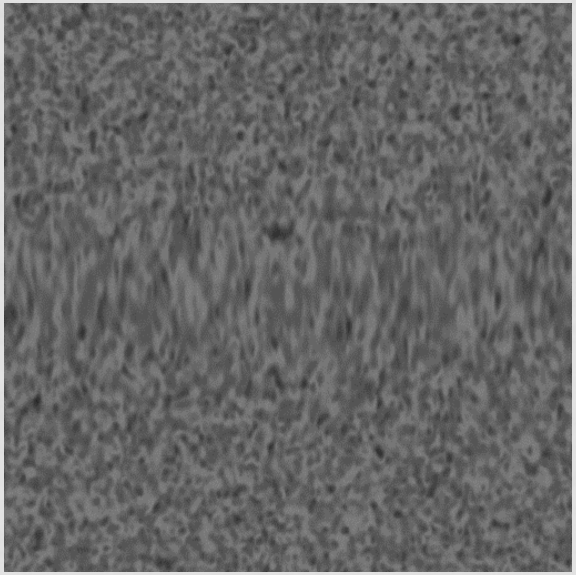


SAMPLE 10 & 11 – TEXGEN STRAIN SAMPLES

- One good and one poor image.
- Strain gradients seem too low.
- How do we quantify spatial resolution?

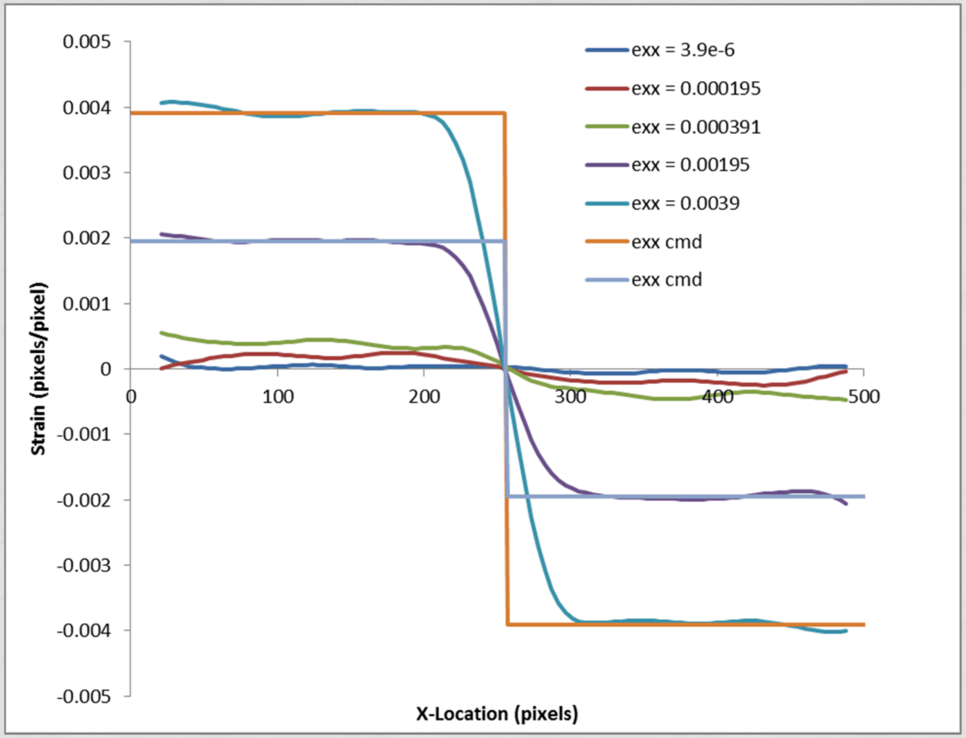


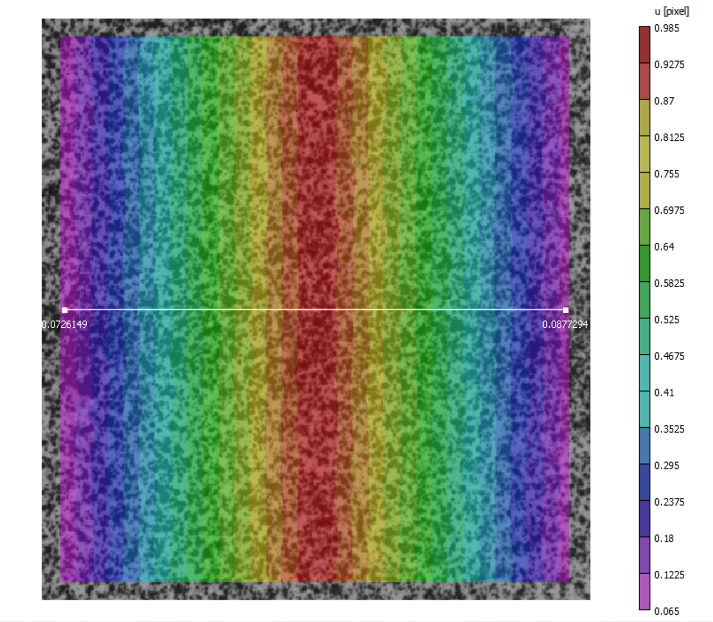




SAMPLE 11B – FFT TRIANGLE DISPLACEMENT

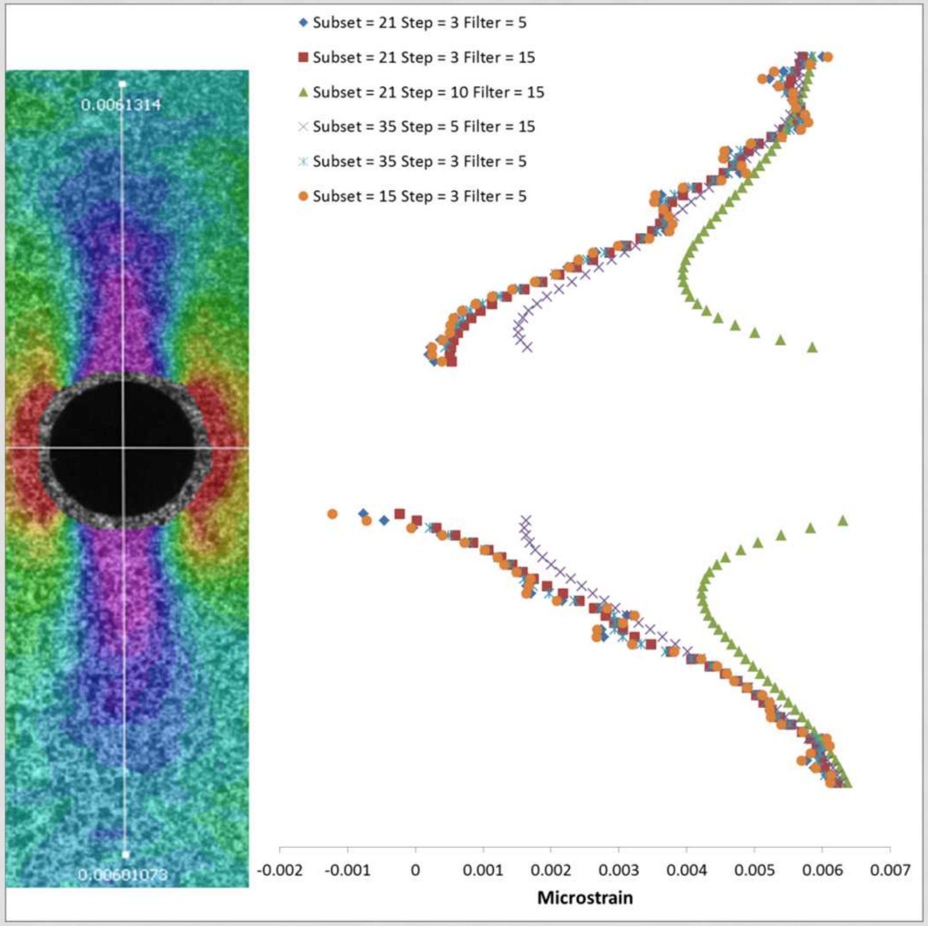
- FFT expansion with linear interpolation to find grey level at displaced location.



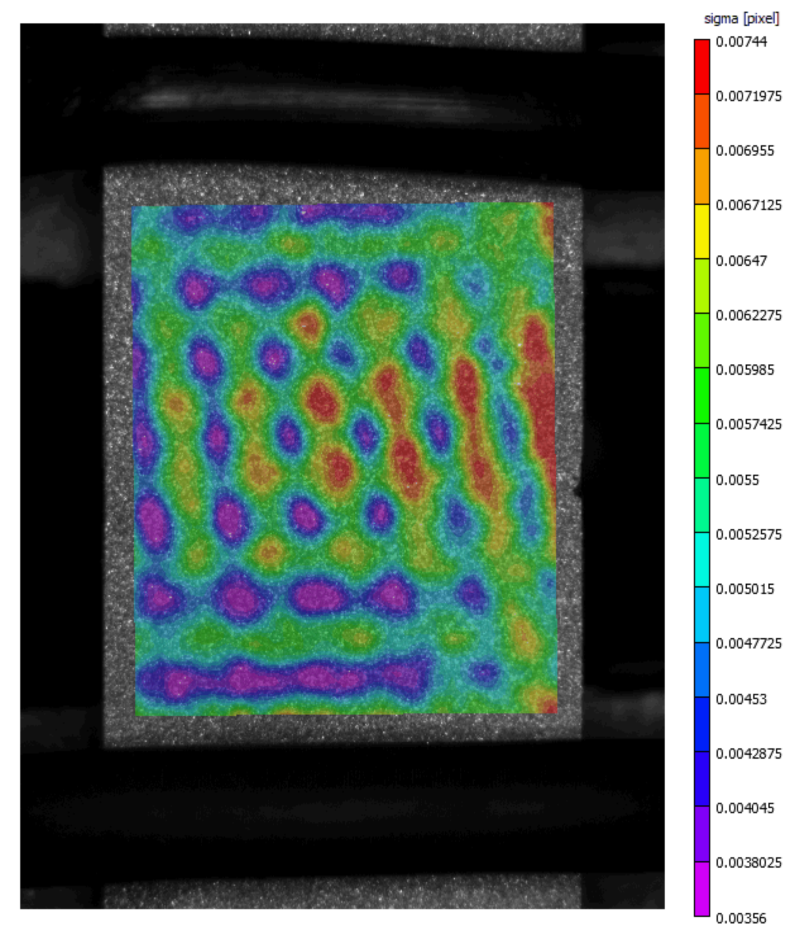


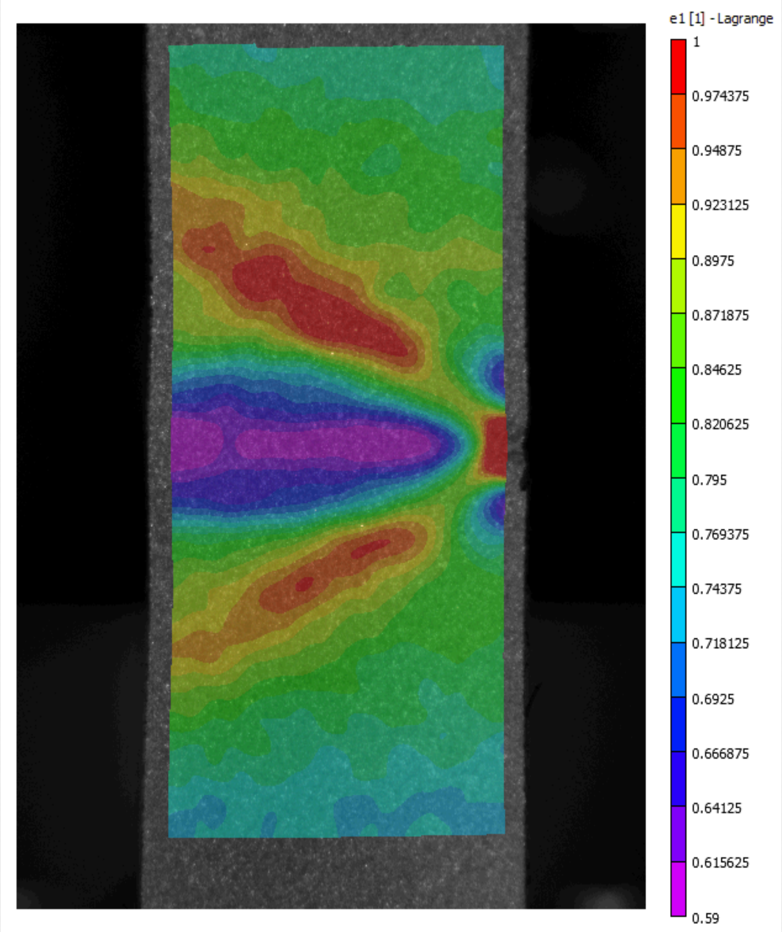
SAMPLE 12 AND 13 – EXPERIMENTAL DATA

- Line cut comparison?
- Max strain location?
- Point-wise comparison?
- We will use these data sets for the challenge. Only the processing is in question.



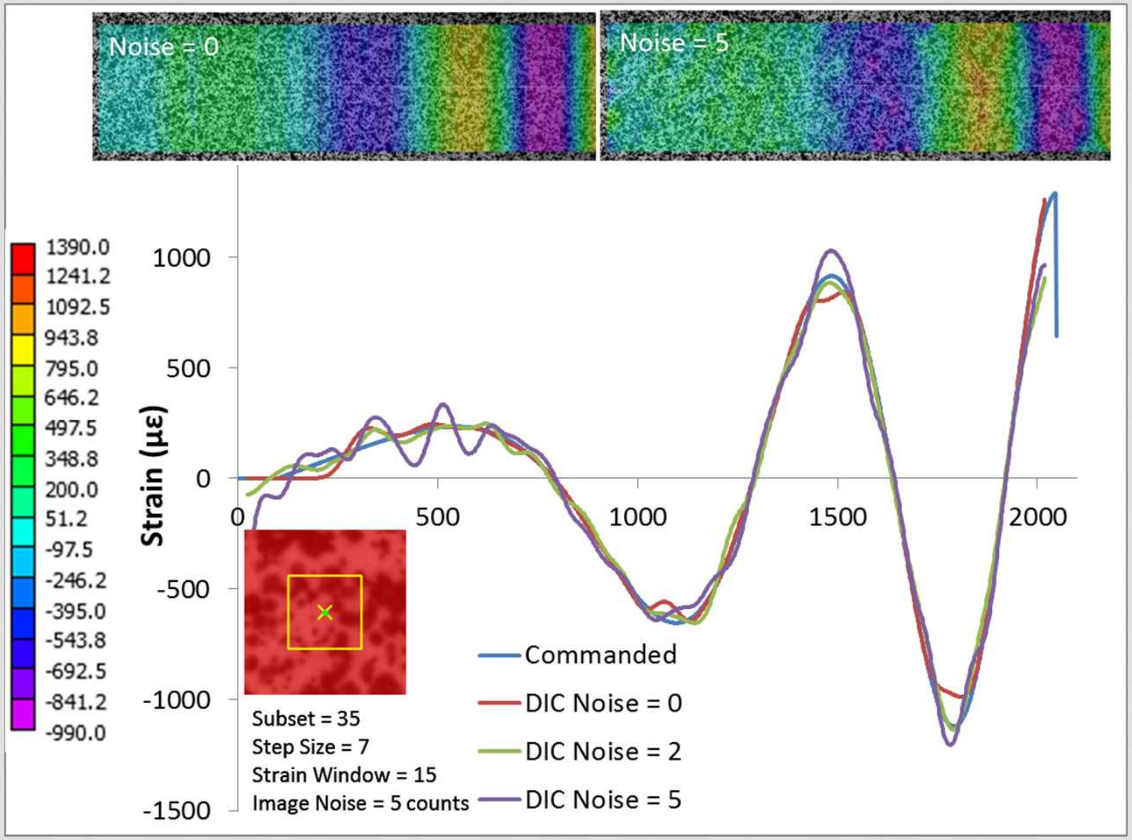
SAMPLE 13 – CHALLENGING EXPERIMENTAL IMAGES (ALIASED)





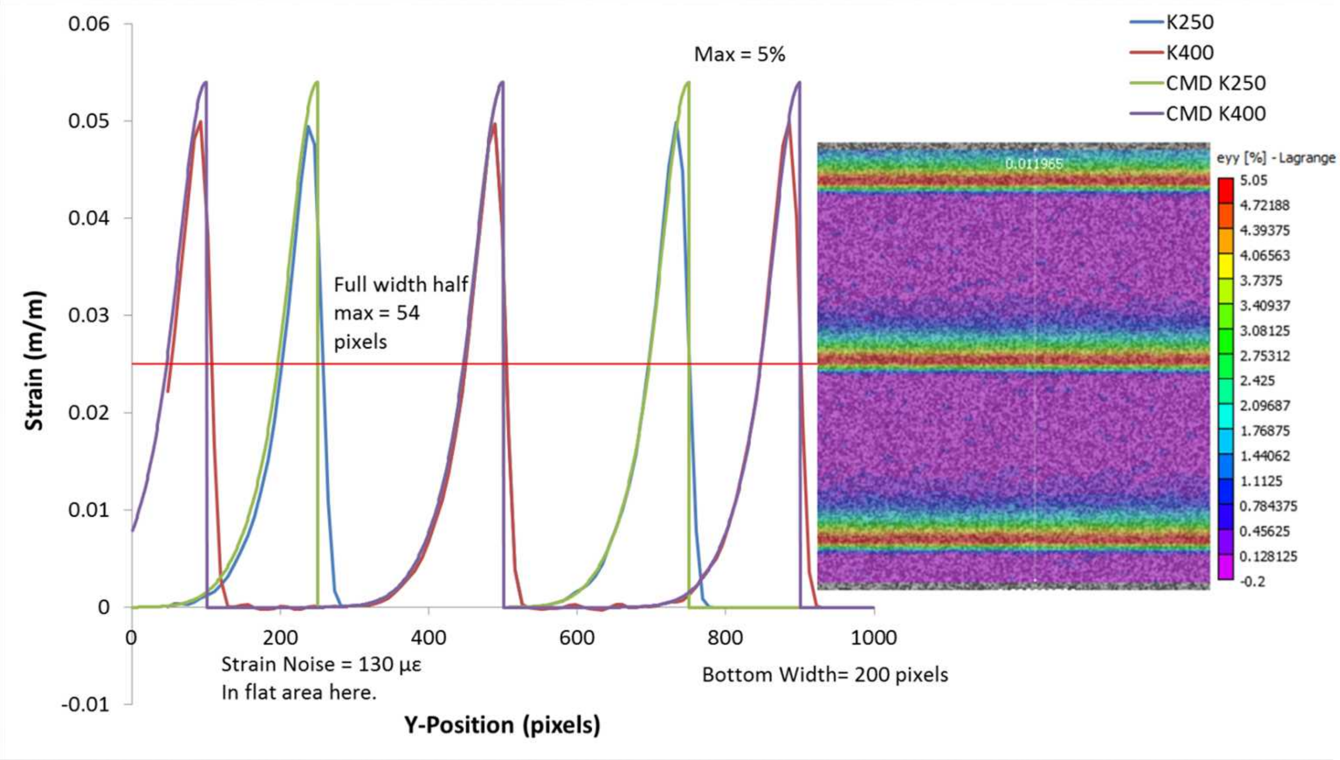
SAMPLE 14 – FFT SPATIALLY VARYING STRAIN

- Point-wise comparison
- Zero strain part will reveal noise floor
- Peak strains and higher frequencies will test spatial filtering.
- Exact displacement field available upon request.



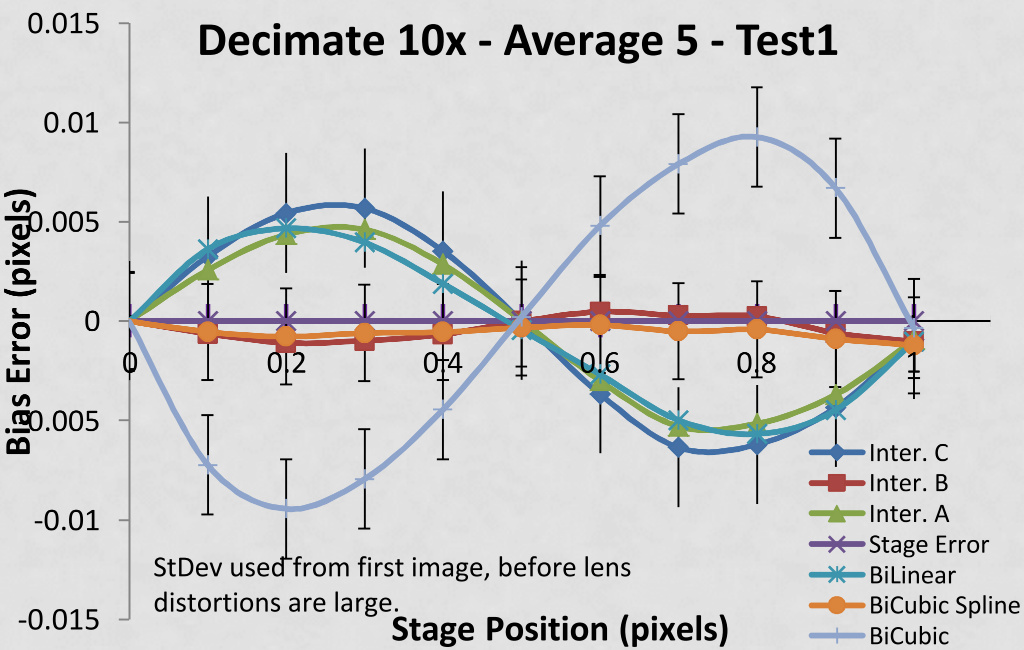
SAMPLE 15 – TEXGEN SPATIALLY VARYING STRAIN

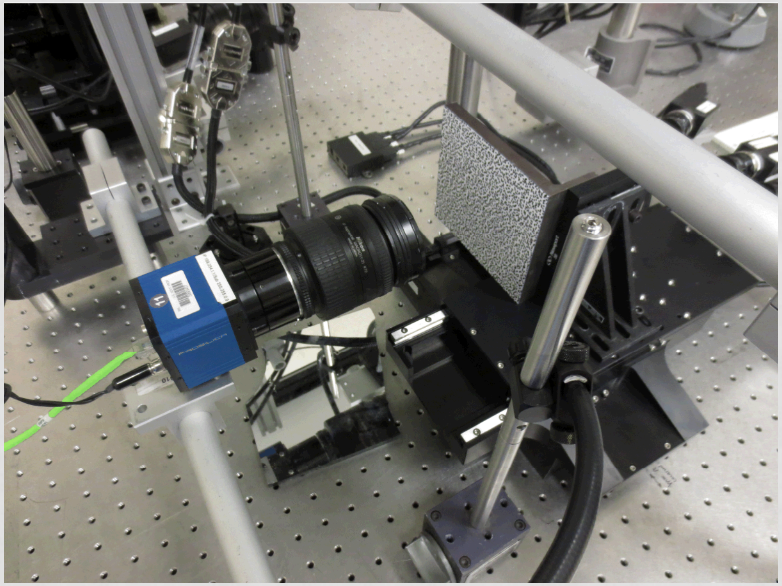
- Point-wise comparison
- Zero strain part will reveal noise floor
- Peak strains and higher frequencies will test spatial filtering.
- Exact displacement field available upon request



SAMPLE 16 – EXPERIMENTAL SUBPIXEL SHIFT

- Experimentally shifted "exactly"
- Stage error is negligible
- Camera noise is very low





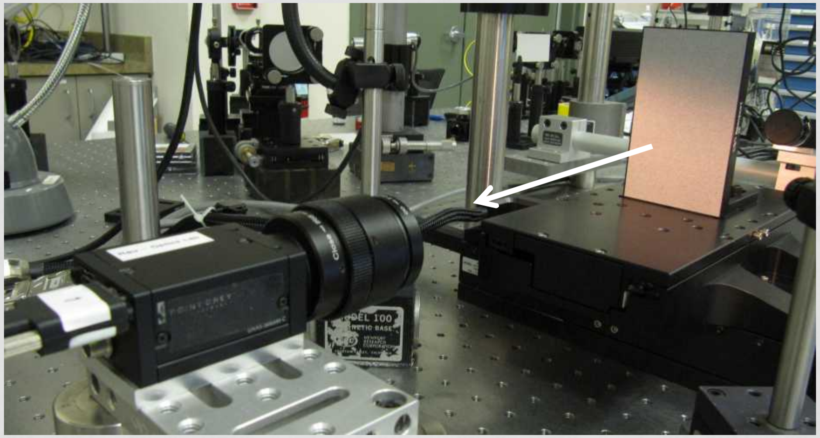
Stage Specifications		
Absolute Position	0.000 8	(pixels)
Position Error	0.000 004	(pixels)
StDev	0.000 02	(pixels)

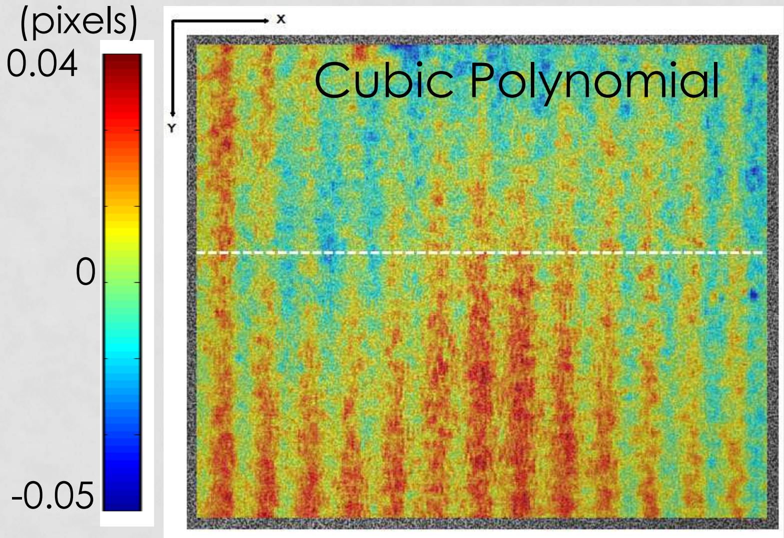
Prosilica 14-MPixel (binned x10 & Avg. 5)

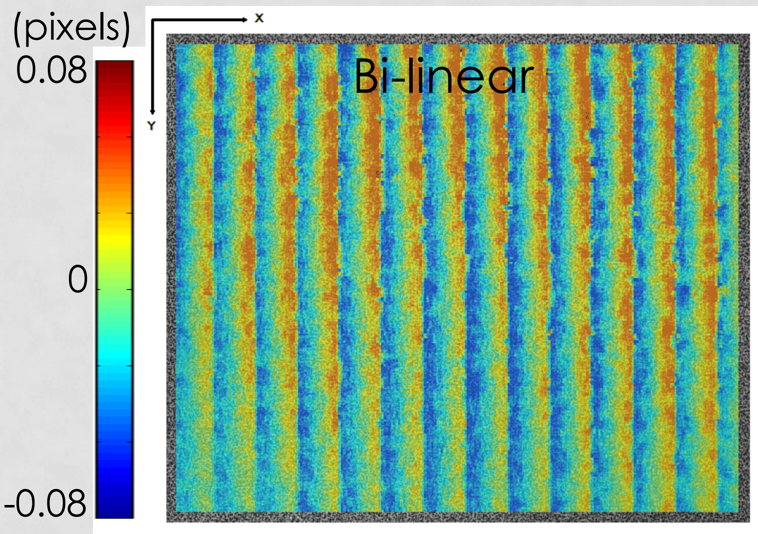
- 335 µm/pixel or 335 000 nm/pixel
- Pixel noise ≈ 0.26 counts (1σ) 0.1%
- Stage specifications for this FOV

SAMPLE 17 – INTERPOLANT ERROR CHECKING

- Idea from Pascal Lava
- Simple experimental setup.
- Tests noise and interpolant simultaneously
- Comparison between various interpolants are easier.





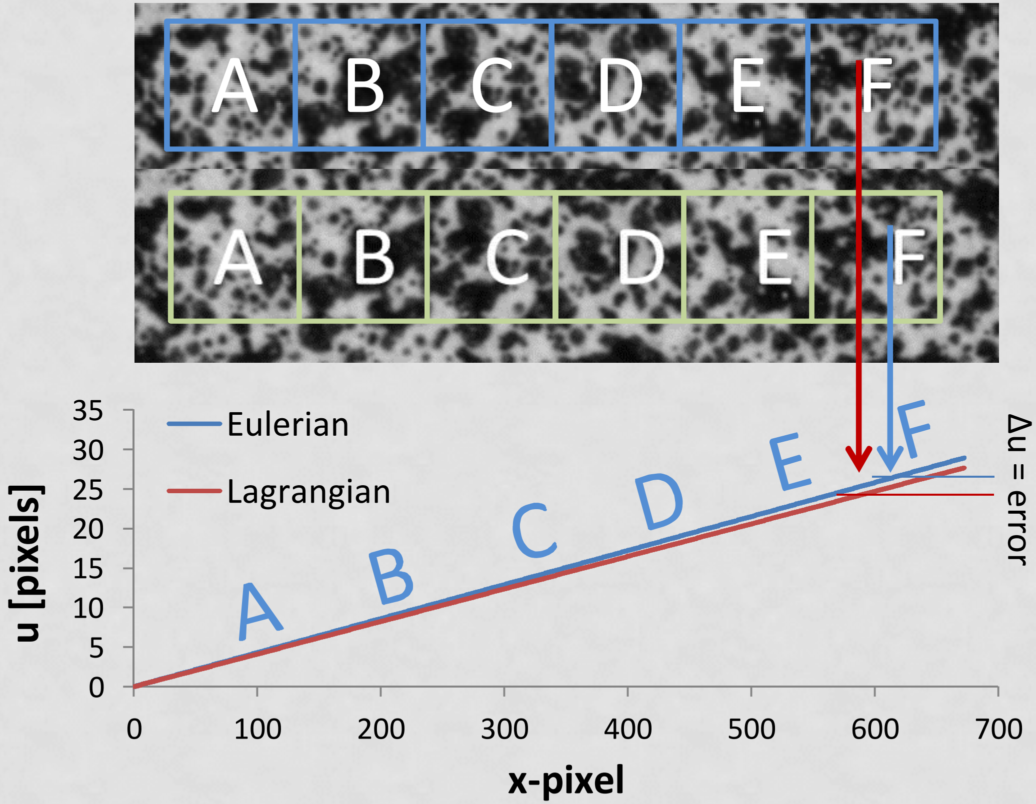


SAMPLE IMAGE ANALYSIS

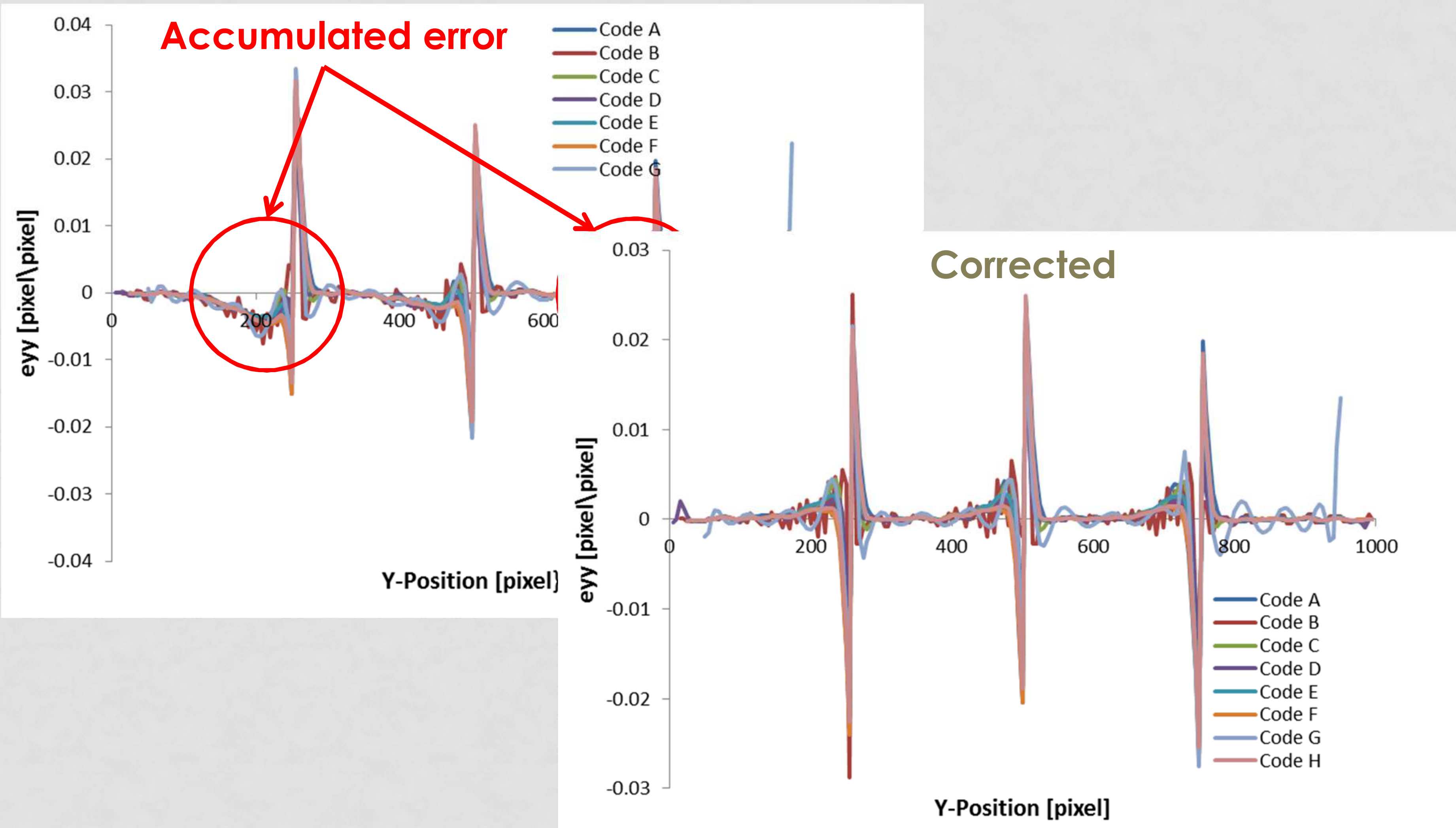
- Names are protected at this point. This is not the intention during the Blind image sets.
- Sample 14 and Sample 15 were completely analyzed.
- An Eulerian versus Lagrangian displacement (and strain) field error was discovered and corrected.
  - Both TexGen and FFT Shifting results were affected.

EULER VS LAGRANGE

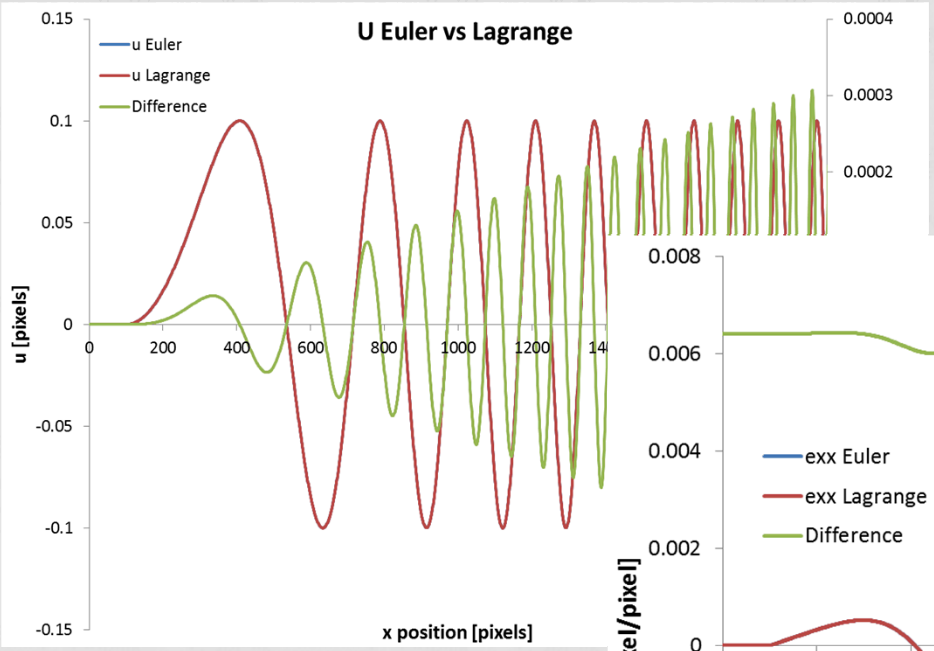
- In simulations, the speckle flows under the pixels. This is Eulerian!
- The pixels remained fixed as the speckles flow underneath. DIC gives the displacement at these fixed pixel locations.
- The difference between the displacement at the shifted speckle (simulation) and the fixed pixel defines the error.
- Correction via interpolation using: $x_{Lag} = (x_{Eul} - u)$



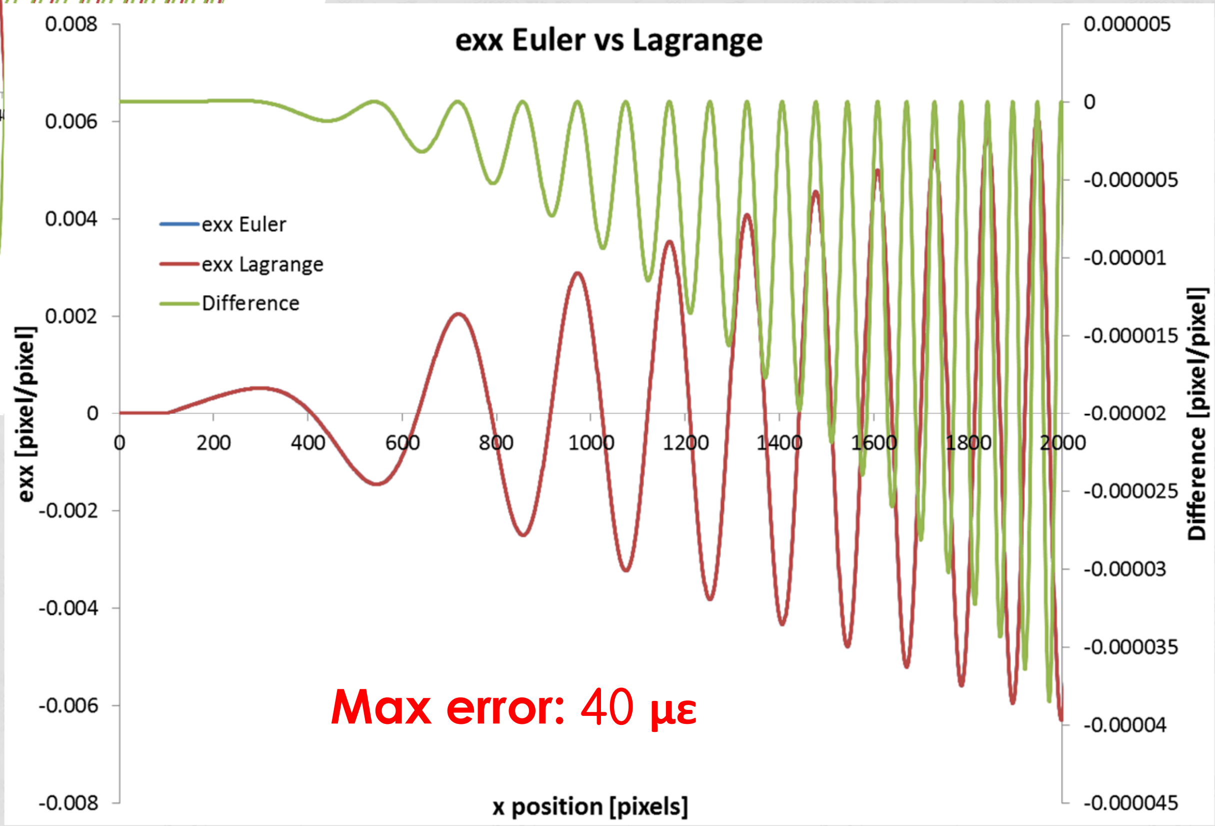
ERROR AS SEEN IN SAMPLE 15



ERROR SEEN IN SAMPLE 14



Max error: ±0.000 3 pixels



Max error: 40 με

SUMMARY OF EULER VS LAGRANGE

- The challenge "works" a rigorous peer review of the images and results found errors. Thank You!
  - How many times has this happened in a paper?
  - The images and their displacement fields are now verified!
- A special thanks to Bernd Weineke and Stephan Roux for pointing out the issues.
- I can use more help in the data analysis portions. Please volunteer if interested.

SAMPLE ANALYSIS PARTICIPANTS

- Two university codes
  - Emily Jones and Stephane Roux/Francois Hild
- All 5 commercial vendors (In random order)
  - Dantec
  - CSI
  - LaVision
  - MatchID
  - GOM
- Two global codes
  - Stephane/Francois
  - AdaptID (Lukas Wittevrongel and Pascal Lava)
- Names are redacted at this point. They will not be for the blind images.
  - Code A through Code G for rest of this presentation.
  - Only Phil knows who is who (hope he isn't hit by a bus)
- Thank you to the participants for their time and help.

SUBMISSION GUIDELINES – SPATIALLY VARYING (BLIND 3 AND BLIND 4)

Original Submission Rules!

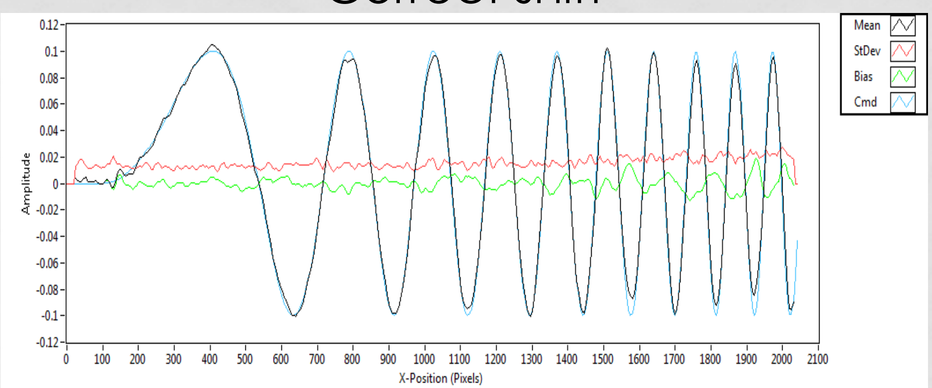
- Origin (0,0) Top – Left
- 5 pixel step size for data
  - Displacement
  - Strain in x, y, and shear (Lagrange)
  - Initial Guess? y/n
  - Correlation parameters
- Submit:
  - File Header. Shape function, Interpolation method, finite difference/Other (Supply a list - include unknown)
  - x, y, u, v, exx, eyy, exy, Subset/Element size, gauge length, Match(T,F), Correlation Score(if available)
  - y is up and x is to the right

This was only approximately followed. We will need to be more careful in the future.

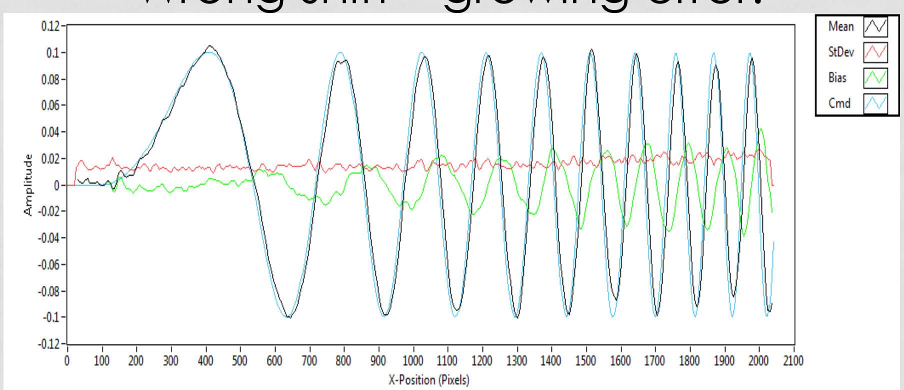
AUTOMATIC DECODING OF THE DATA FILES WAS THE FIRST STEP

- Some of the minor issues
  - Delimiter issues (fairly easily dealt with)
  - Strain units (I used various multipliers to have them make sense.
  - Positive direction of x and y.
- Major issues
  - Starting pixel number (should have been 0,0 at top left)
    - Method below may not be very diagnostic to determine issues.
  - Reported step size of 5-pixels is too large. 1 will be used in the future.

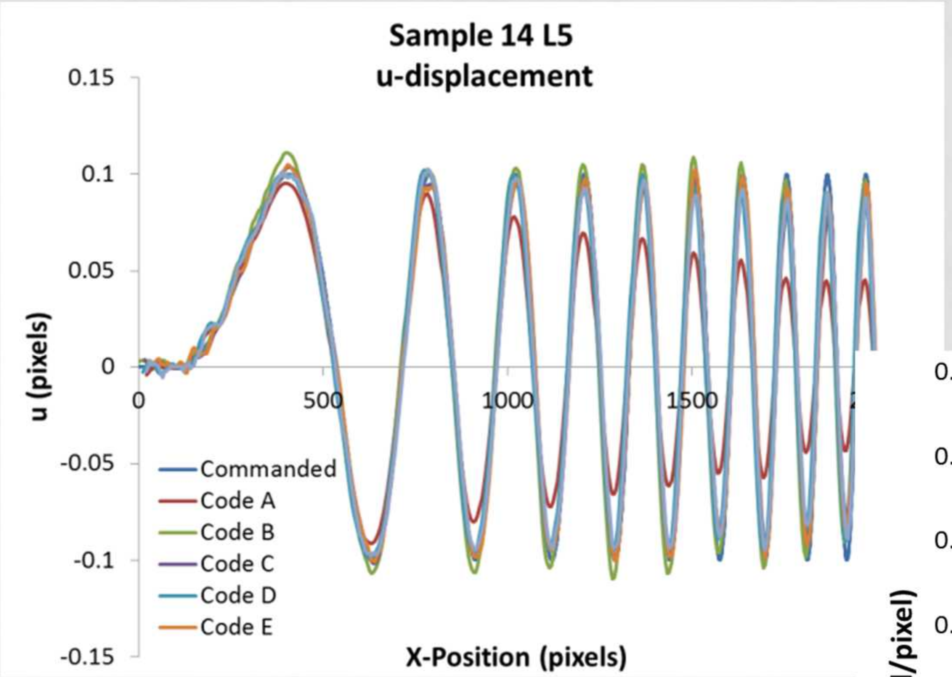
Correct shift



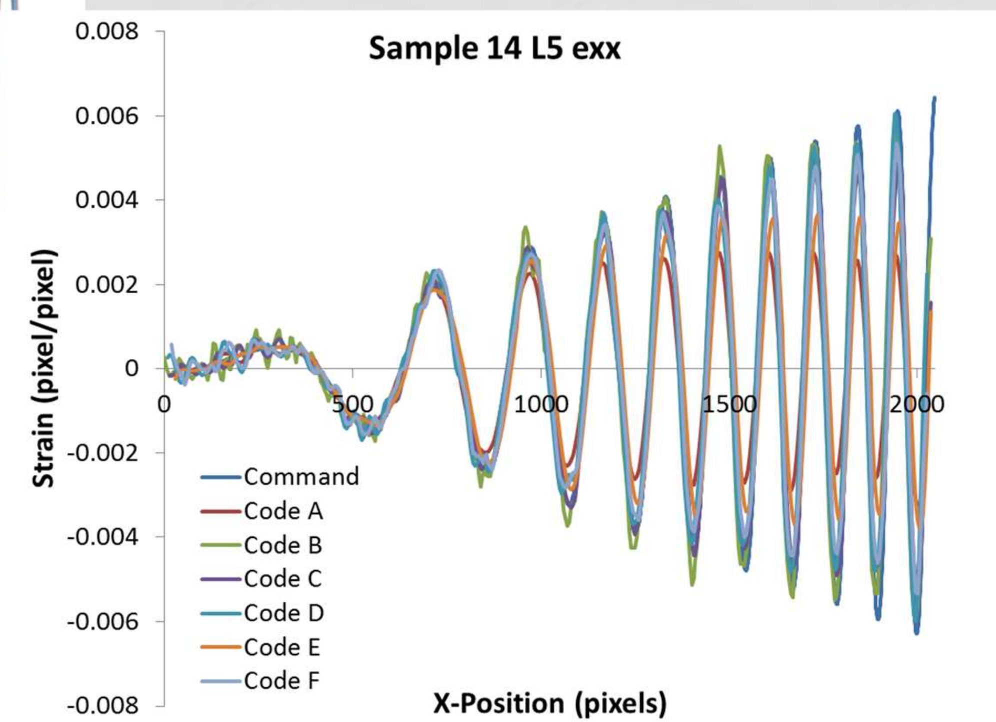
Wrong shift – growing error.



SAMPLE 14 OVERLAY PLOTS DO NOT REVEAL MUCH…

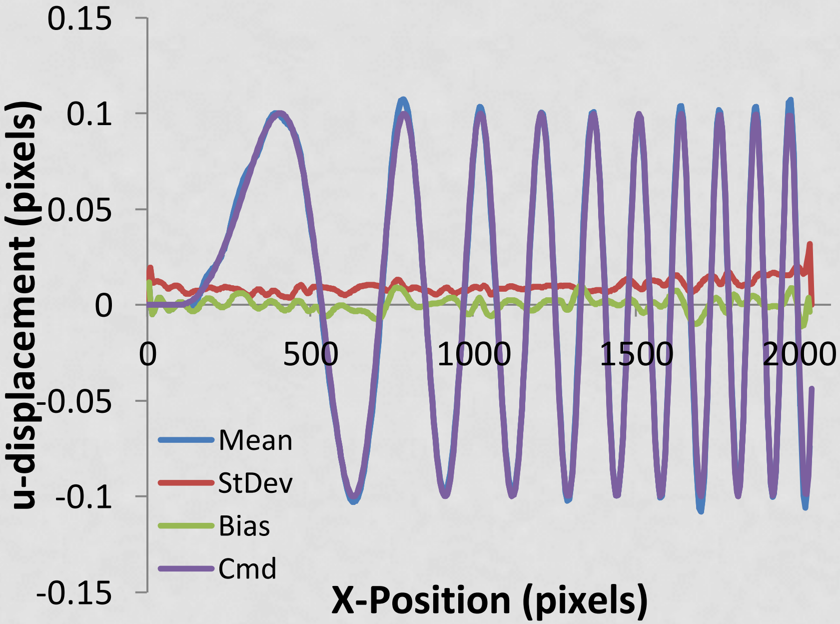


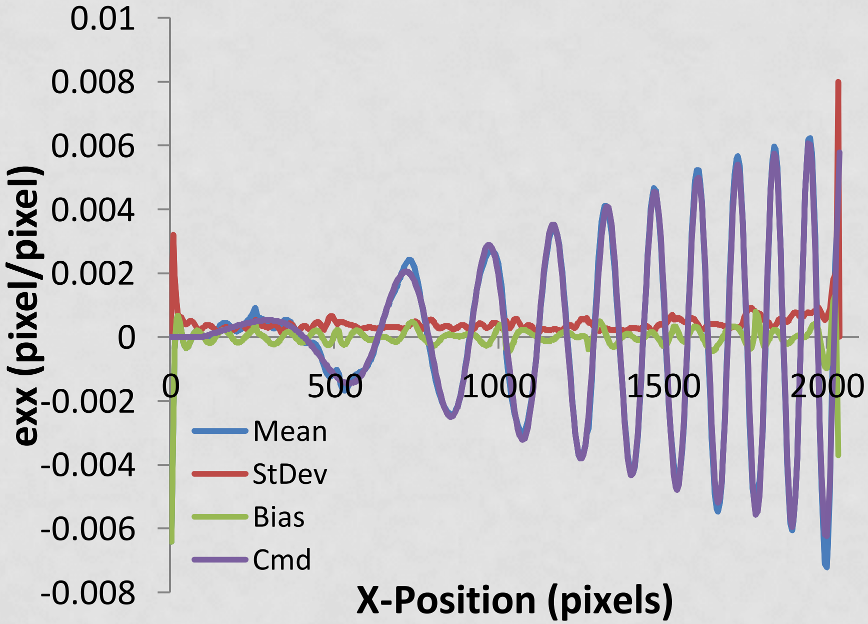
- 50 rows averaged to get curve
- Independence of the data?
- Average more/less rows?
- Does show a little heavy filtering of 1 of the codes.



- Shows a little more "noise" in some codes.
- In general, not very diagnostic with the quality codes seen thus far.

SAMPLE 14 – AVERAGE NOISE

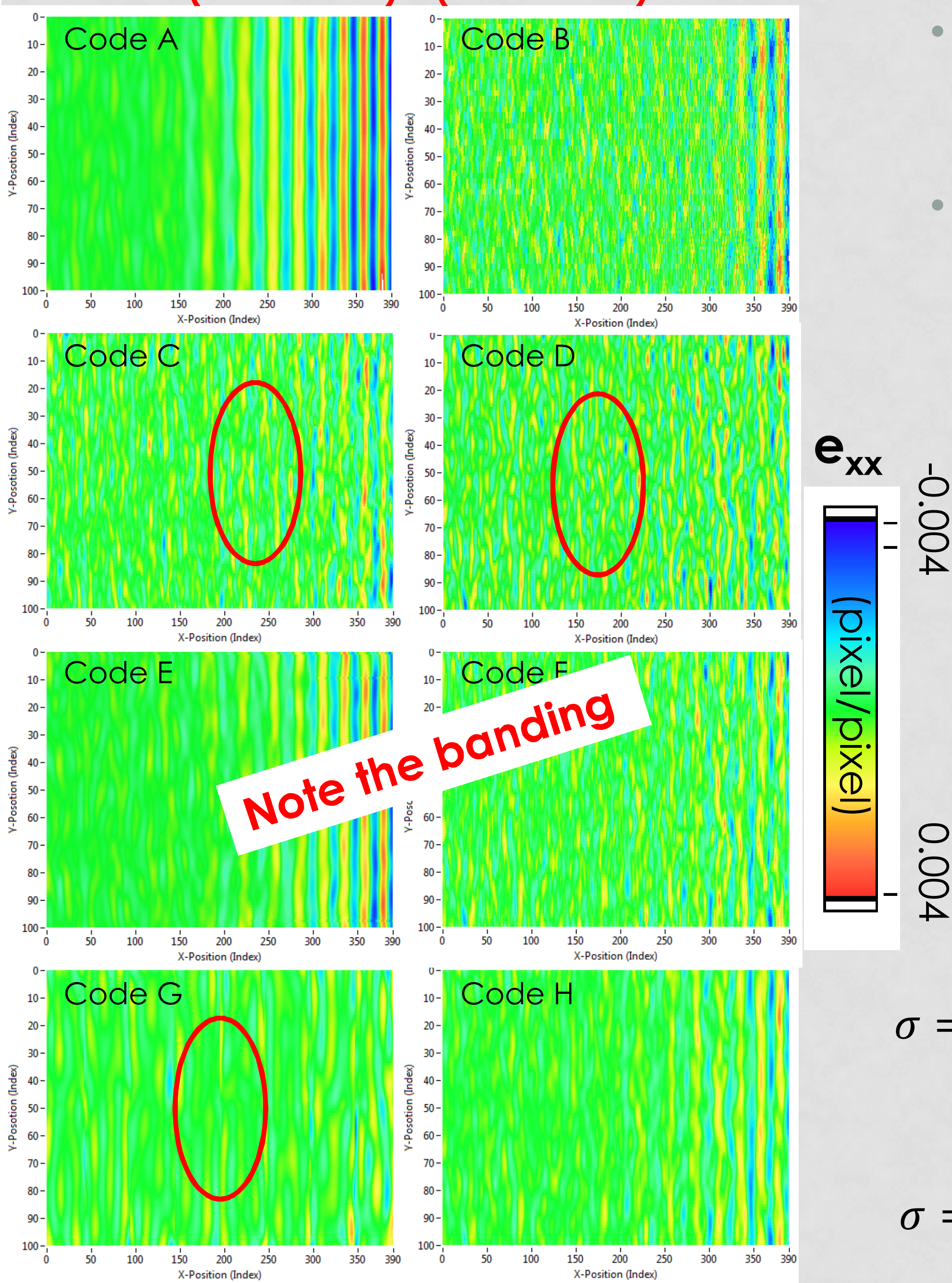




	u StDev	μe_{xx} StDev
Code A	0.005	172
Code B	0.010	676
Code C	0.010	578
Code D	0.011	686
Code E	0.015	256
Code F	0.011	542
Code G	0.010	429
Code H	0.011	341

- Standard deviation of each point from the 50 line cuts is averaged.
- Both displacement and strain.

(Command) – (DIC Results)



- Full field difference between the commanded and measured results.
- Equations below give equations used.

$$\Delta u(x,y) = u_{CMD}(x,y) - u_{DIC}(x,y)$$

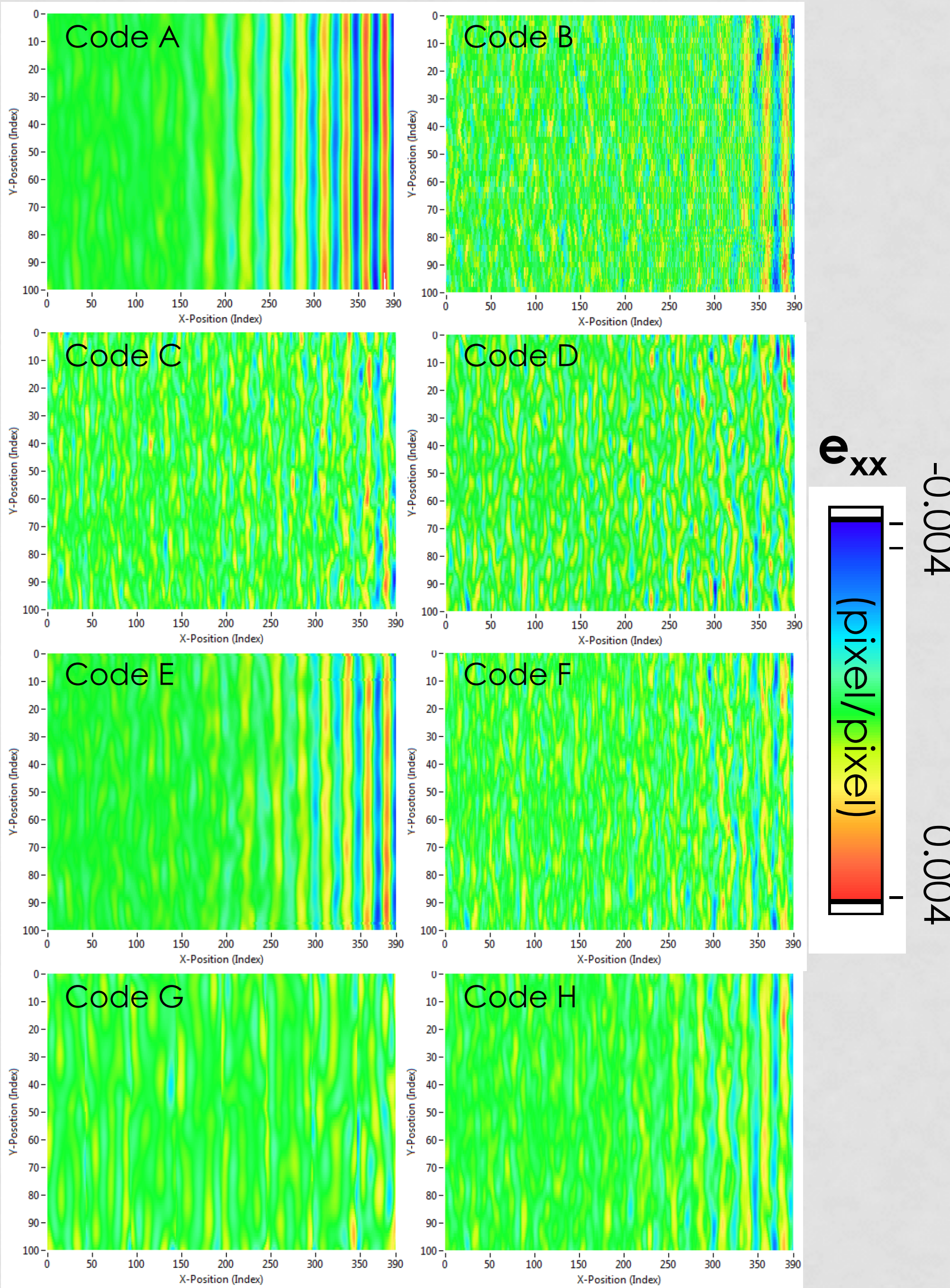
$$\Delta \varepsilon(x,y) = \varepsilon_{CMD}(x,y) - \varepsilon_{DIC}(x,y)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{x,y}[\Delta u(x,y)]^2}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{x,y}[\Delta \varepsilon(x,y)]^2}$$

$$\sigma = \sqrt{\frac{n\sum_{x,y}[\Delta u(x,y)]^2 - \left[\sum_{x,y}[\Delta u(x,y)]\right]^2}{n(n-1)}}$$

$$\sigma = \sqrt{\frac{n\sum_{x,y}[\Delta \varepsilon(x,y)]^2 - \left[\sum_{x,y}[\Delta \varepsilon(x,y)]\right]^2}{n(n-1)}}$$

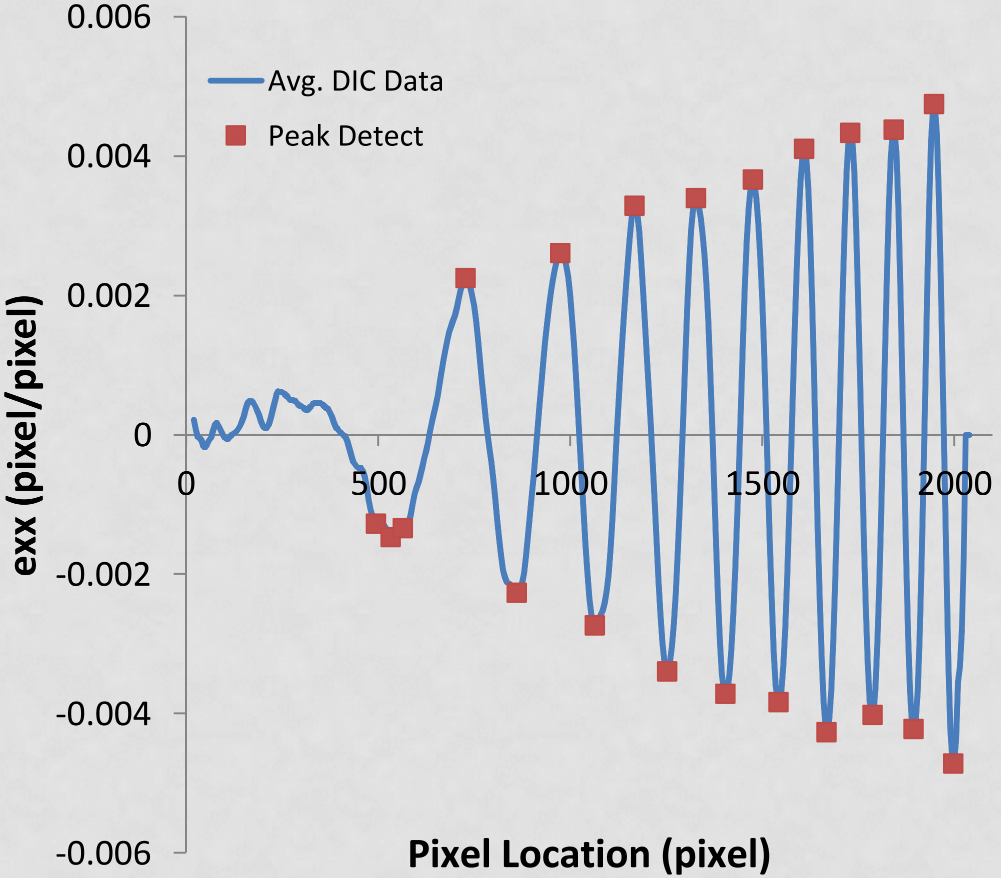


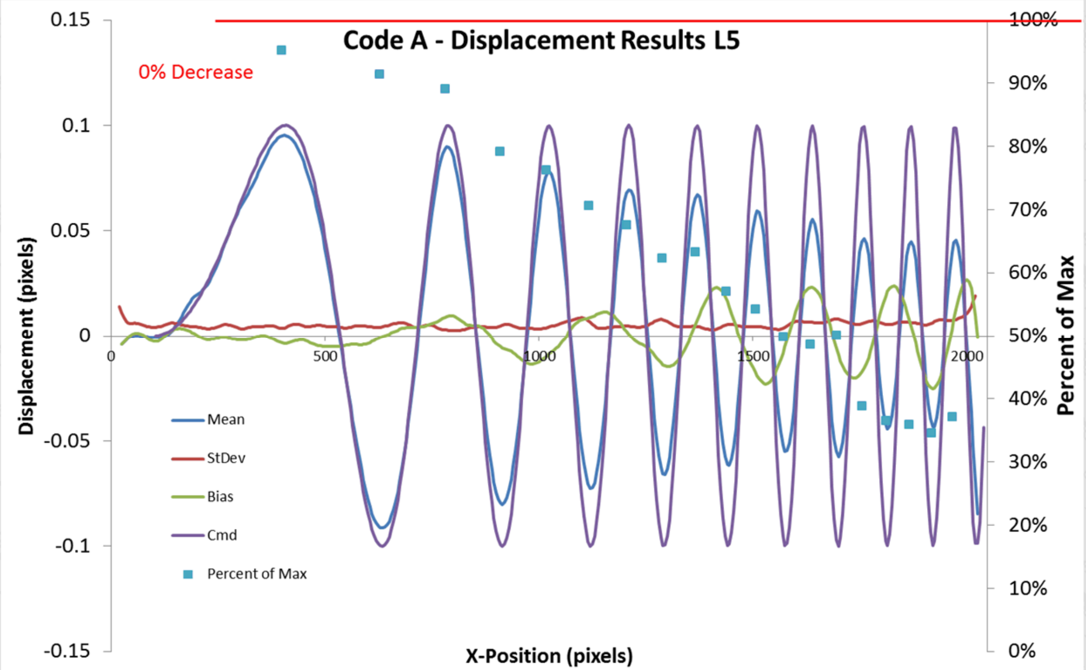
	RMSE u	Max Bias u	RMSE μe_{xx}	Max Bias μe_{xx}
Code A	0.022	0.076	1131	4129
Code B	0.014	0.068	854	4657
Code C	0.012	0.060	686	3846
Code D	0.012	0.058	754	3958
Code E	0.016	0.098	795	3405
Code F	0.013	0.074	665	3985
Code G	0.010	0.056	453	2593
Code H	0.013	0.070	601	3022

- RMSE measures the average error.
- Maximum bias measures the worst point in the measured area.

SAMPLE 14 FREQUENCY RESPONSE

- LabVIEW peak detect fits quadratic polynomial to *n*-points and interpolates peak.
- Width is important to remove multiple points.
- **This indicated a need to report the DIC data with 1-pixel increments to improve (or remove the need) this step.**
- Next data reported is based on this automated peak/valley extraction.

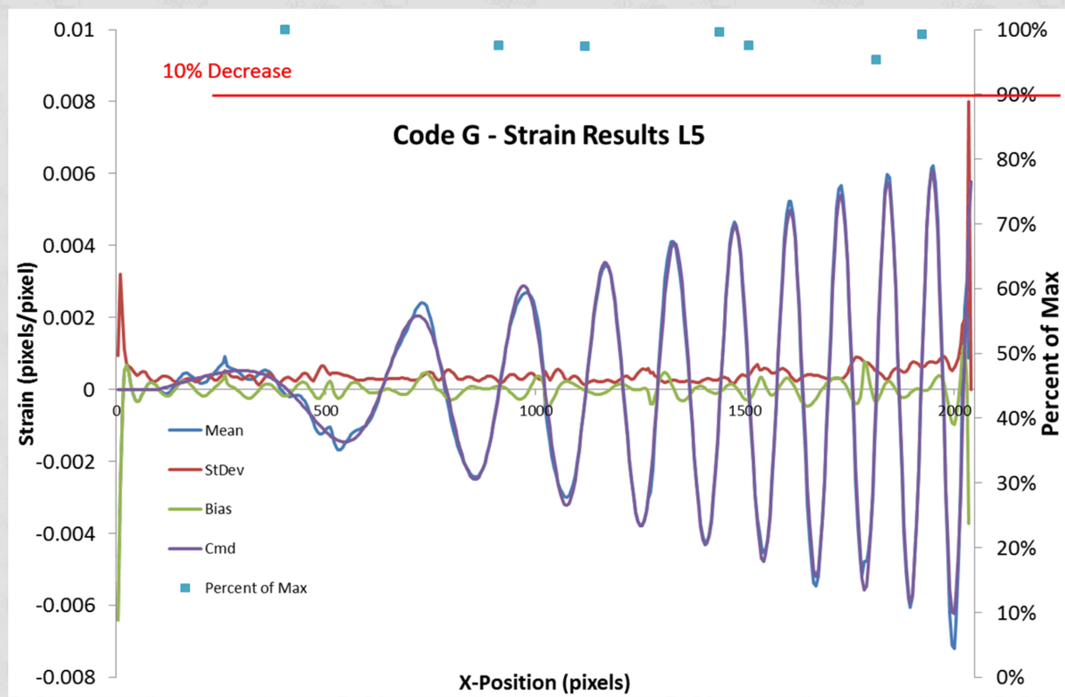




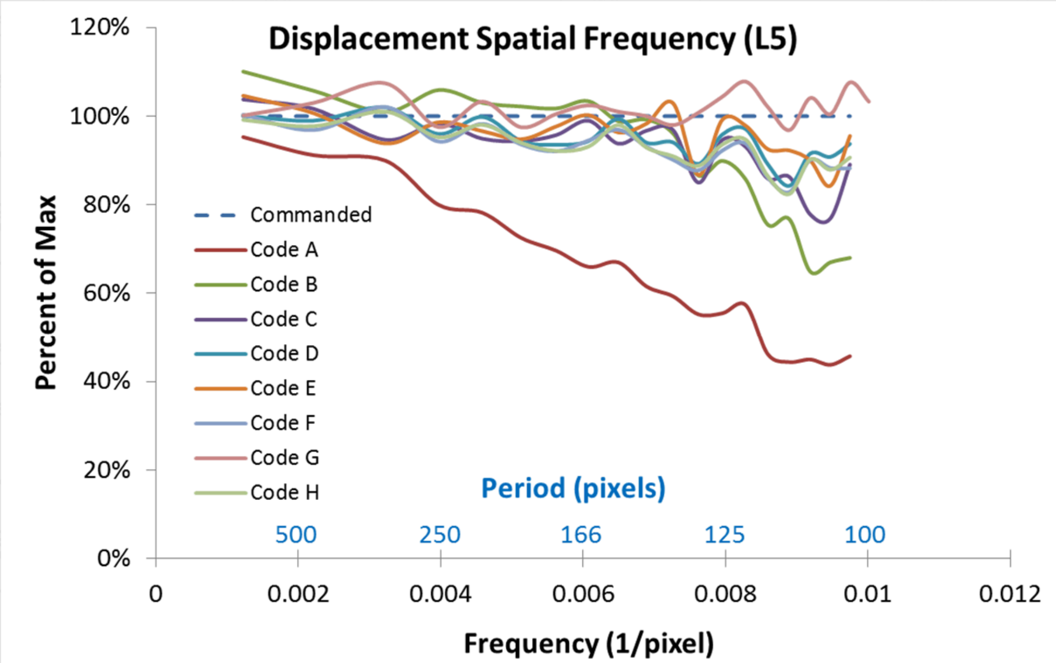
- A little heavy filtering for this code.
- The bias shows up in the green curve.

	u StDev	μe_{xx} StDev
Code A	0.005	172
Code B	0.010	676
Code C	0.010	578
Code D	0.011	686
Code E	0.015	256
Code F	0.011	542
Code G	0.010	429
Code H	0.011	341

- Good representation of the signal.
- Some rather serious edge effects.
- Spatial frequencies are not high enough to challenge this code.
- Must interpret this in light of the noise as well.

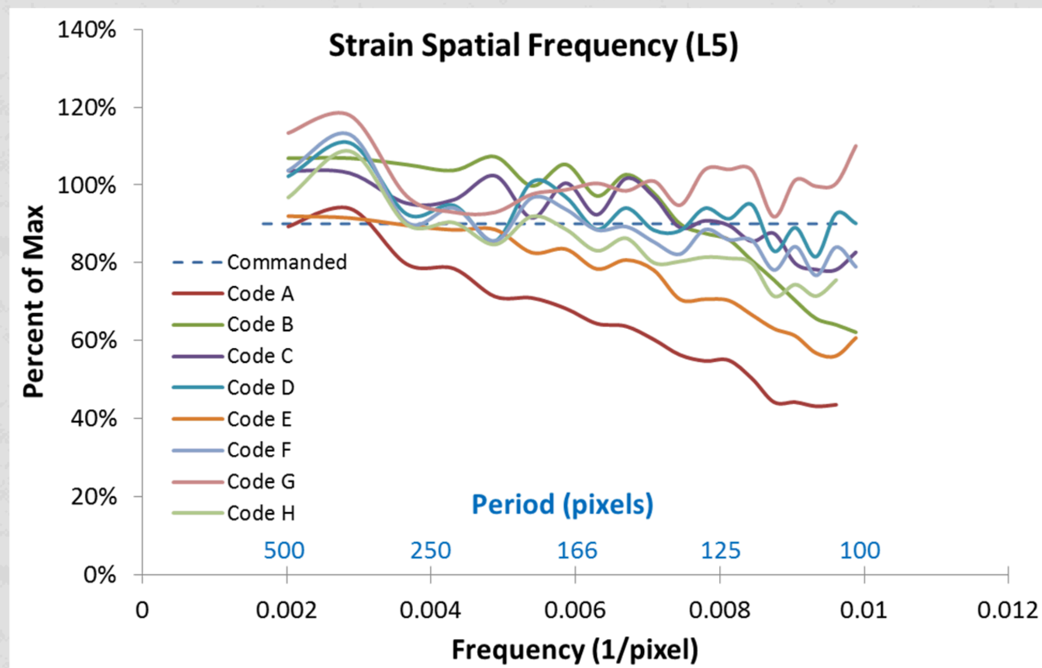


This is the old data: But not much will change.



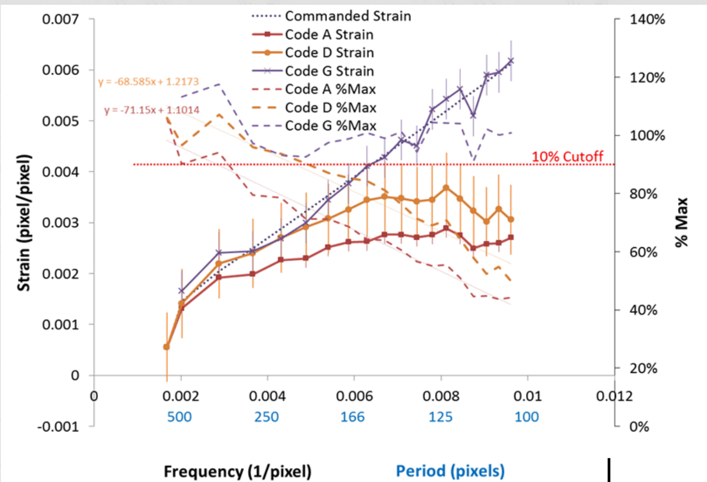
- All but one code did a good job of representing the displacement data.
- What decrease in amplitude will we use?
- Almost all of the codes represent the signal quite well.
- We will increase the spatial frequency in the next round.

- We will increase the noise in some images to challenge the codes.
- We will allow multiple (2?) entries for each image so people can optimize their settings.



This is the old data: But not much will change.

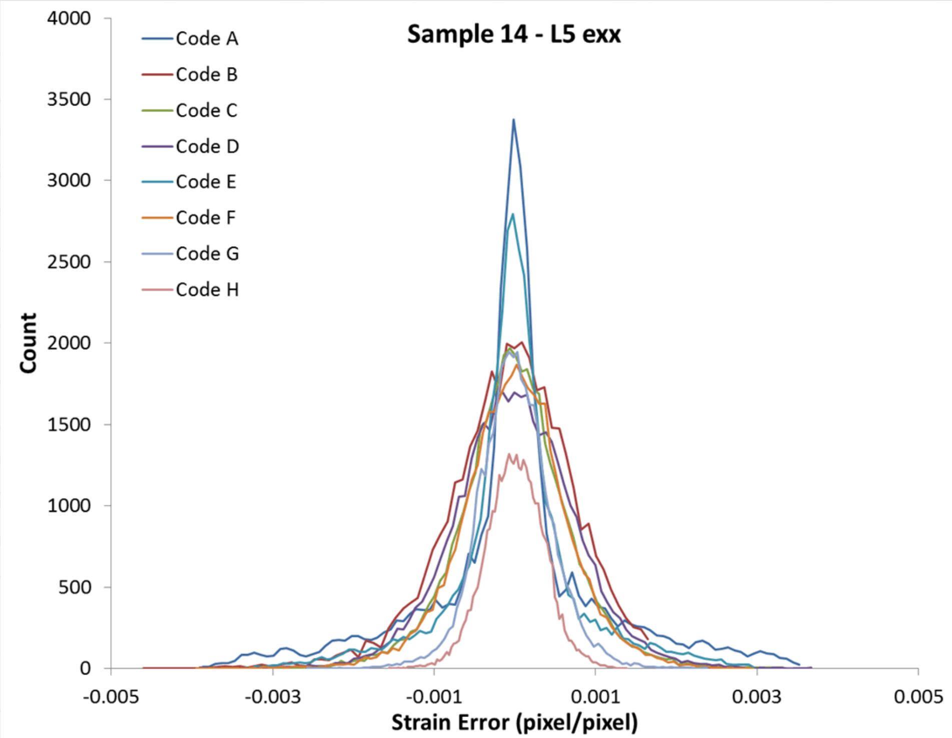
SAMPLE 14 SPATIAL FREQUENCY RESULTS



	Displacement Resolution			Strain Resolution		
Cutoff	100%			90%		
	Frequency (1/pixel)	**Spatial Res. (pixel)**	**u StDev (pixel)**	**Frequency (1/pixel)**	**Spatial Res. (pixel)**	**$\mu\varepsilon_{xx}$ StDev (pix/pix)**
Code A	0.0010	986	0.005	0.0025	396	166
Code B	0.0048	208	0.010	0.0067	149	675
Code C	0.0032	316	0.010	0.0072	138	573
Code D	0.0022	455	0.011	0.0081	123	678
Code E	0.0030	336	0.015	0.0037	267	252
Code F	0.0019	521	0.011	0.0063	159	536
Code G	0.0100	100	0.010	0.0250	40	383
Code H	0.0017	594	0.011	0.0050	202	338

This is the old data: But not much will change.

SAMPLE 14 – HISTOGRAM REPRESENTATION

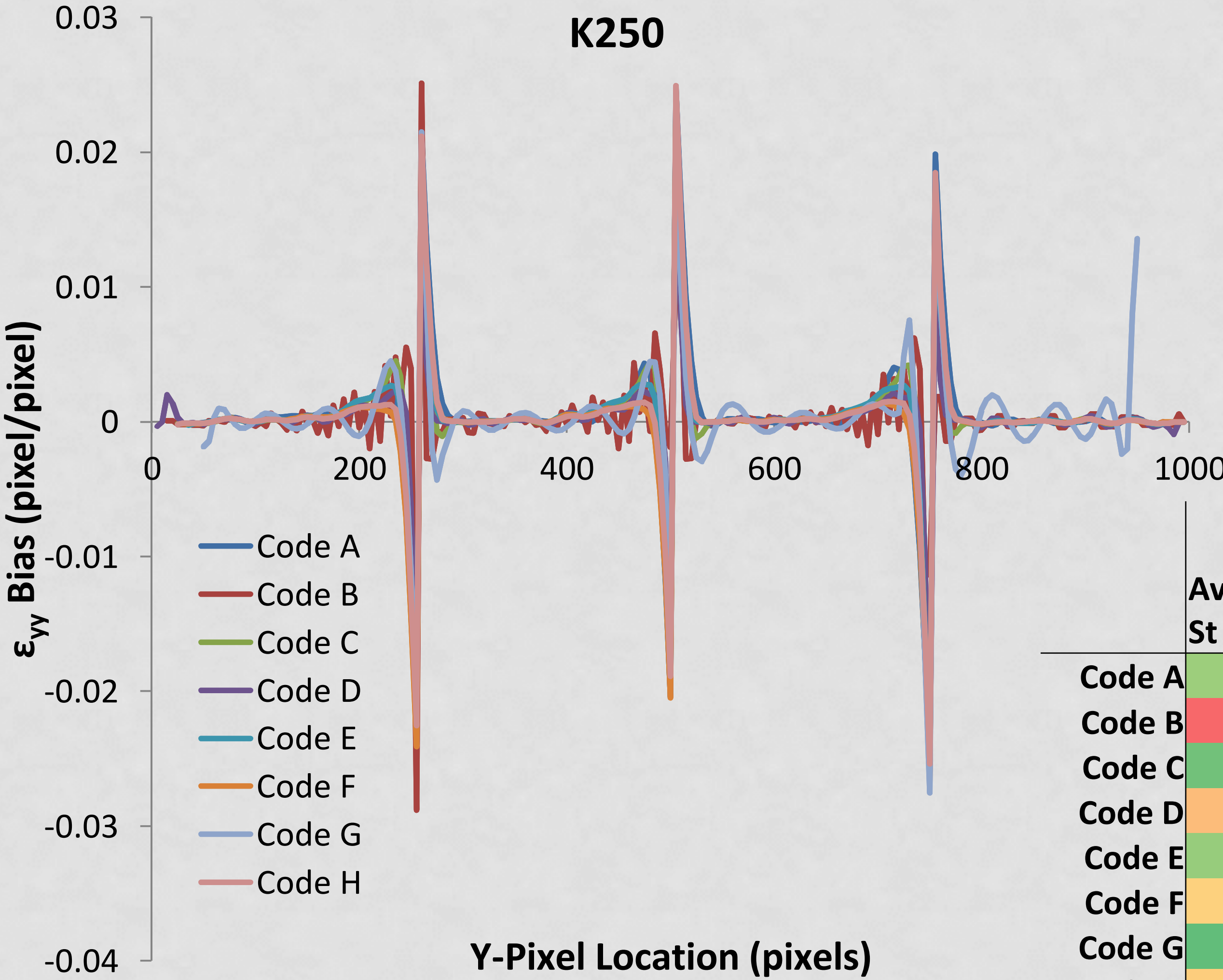


-1000 με   1000 με

- Histogram of the residuals.
- Perfect would be all points at zero.
- Most points lay within ±1000 με. Is this good? Is most of this noise?

This is the old data: But not much will change.

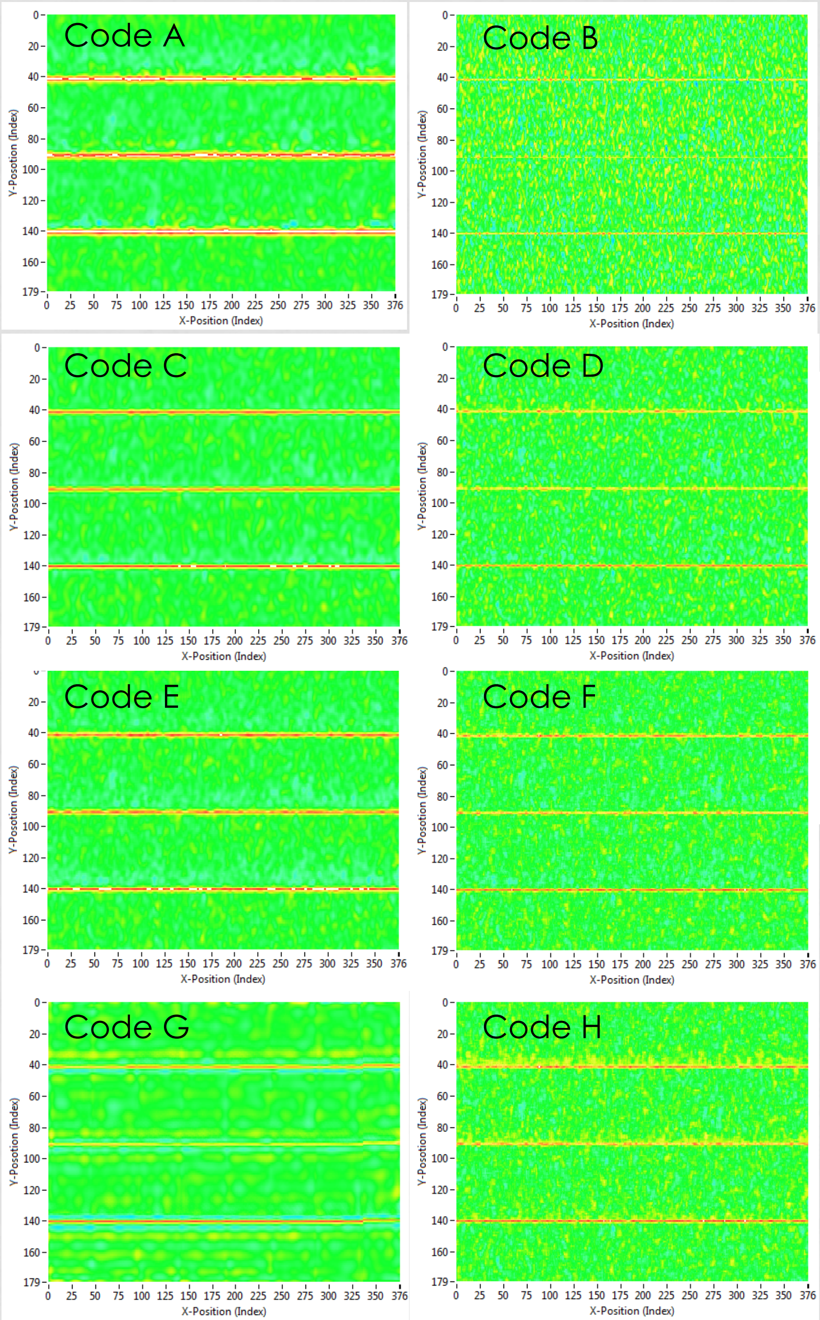
SAMPLE 15 LINE CUT RESULTS

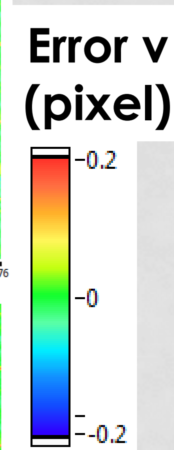


- Bias error reveals how well the discontinuity was matched.
- Line cut table below shows max error and average standard deviation.

	V		ε_{yy}	
	Average St Dev	Max Bias	Average St Dev	Max Bias
Code A	0.0111	0.27	0.0008	0.026
Code B	0.0256	0.09	0.0041	0.029
Code C	0.0101	0.19	0.0008	0.026
Code D	0.0179	0.13	0.0008	0.026
Code E	0.0110	0.19	0.0008	0.031
Code F	0.0159	0.15	0.0006	0.027
Code G	0.0096	0.16	0.0008	0.028
Code H	0.0163	0.15	0.0006	0.025

SAMPLE 15 RMSE RESULTS

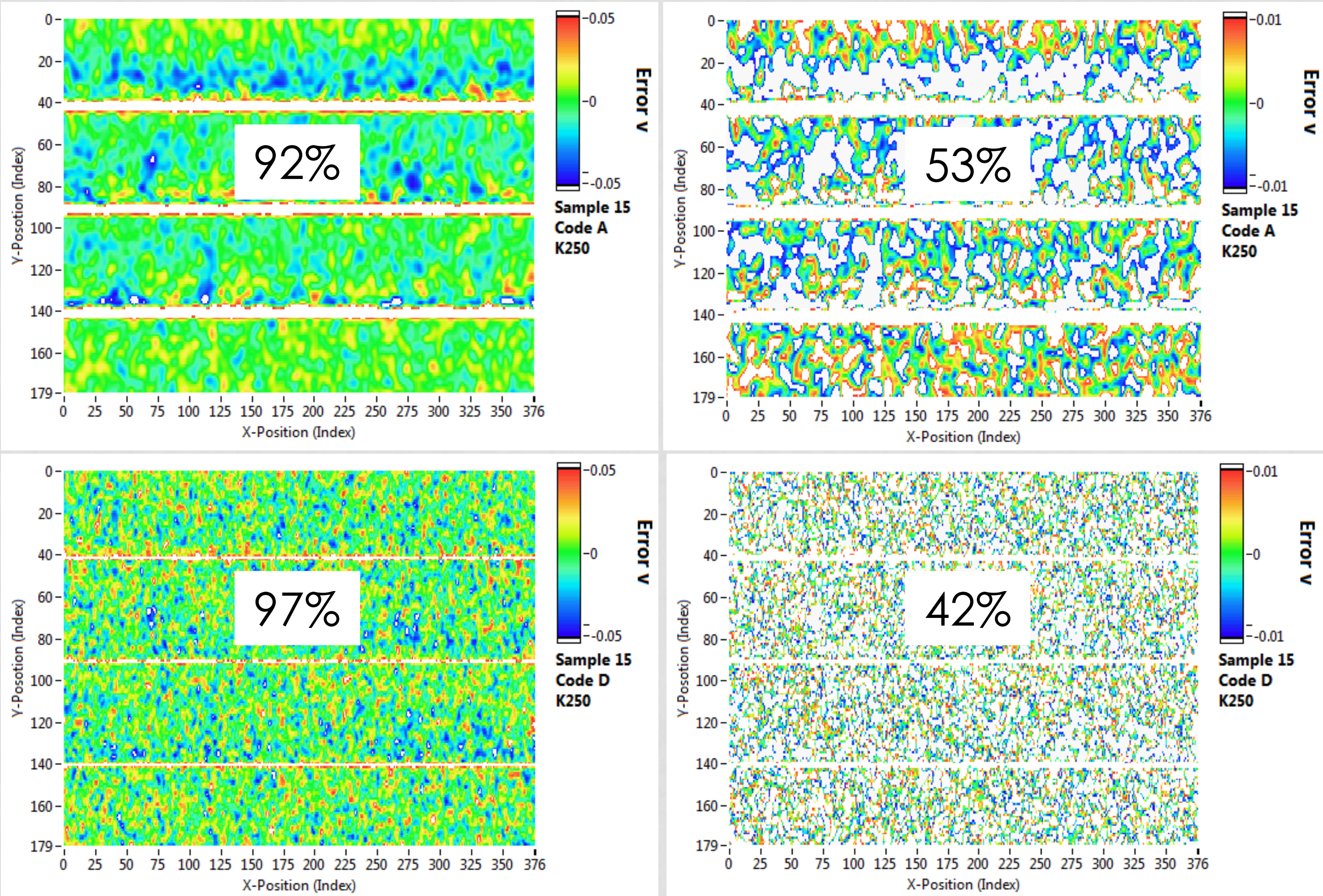




- RMSE Plots of all results.
- Where to put the graph limits is the key to this being useful.
- A strong trade between noise and

- Heavy filtering helps with a lower noise floor criterion, but not a higher.

	% within ±0.05 pixels	% within ±0.01 pixels
Code A	92%	53%
Code B	93%	30%
Code C	96%	56%
Code D	97%	42%
Code E	95%	52%
Code F	97%	45%
Code G	96%	52%
Code H	96%	43%



Code A

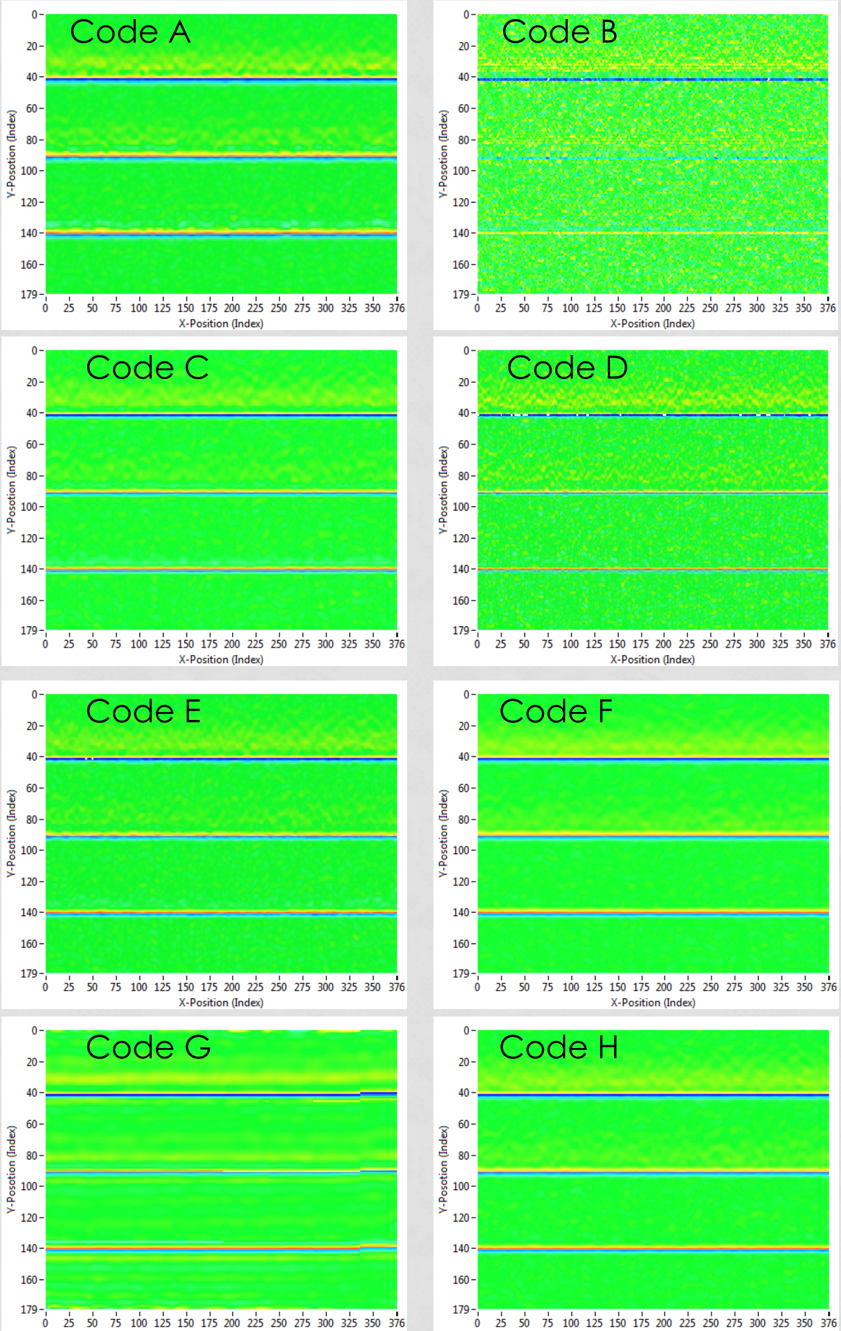
Code D

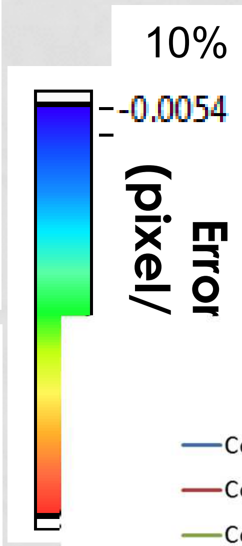
±0.05 pixels

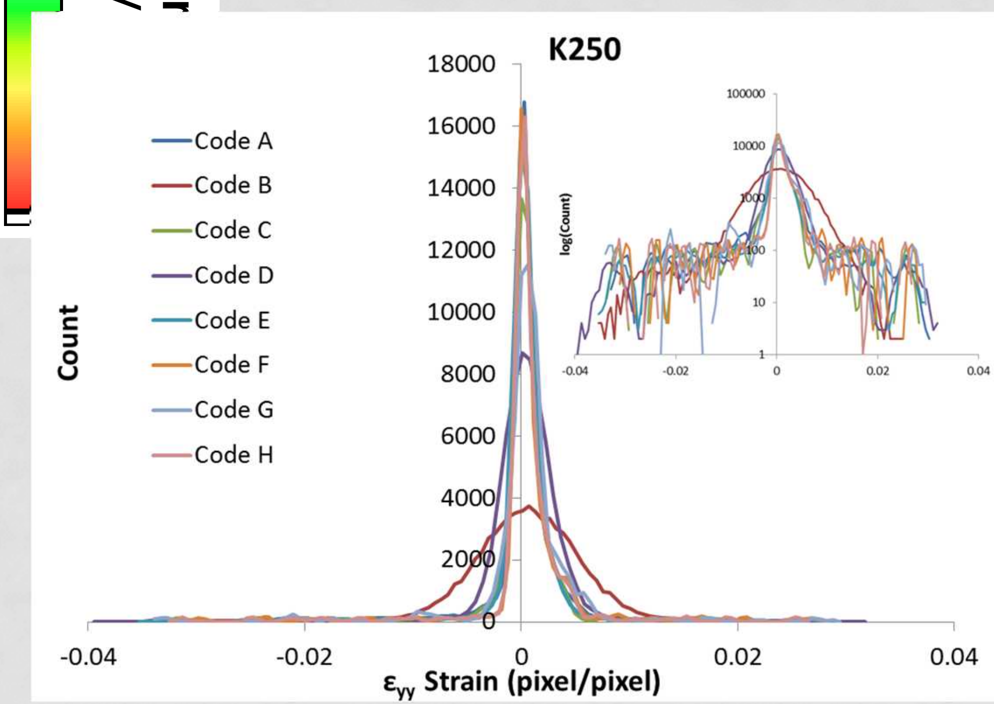
±0.01 pixels

	% within ±0.05 pixels	% within ±0.01 pixels
Code A	92%	53%
Code B	93%	30%
Code C	96%	56%
Code D	97%	42%
Code E	95%	52%
Code F	97%	45%
Code G	96%	52%
Code H	96%	43%

- RMSE Plots of all results.
- Where to put the graph limits is the key to this being useful.
- Limits are put at ±10%







SAMPLE 15 RMSE SUMMARY TABLE

	RMSE v	Max Bias v	% within ±0.01 pixels	RMSE e_{yy}	Max Bias e_{yy}	% within 10% max Strain
Code A	0.045	0.325	53%	0.0047	0.030	92.1%
Code B	0.028	0.165	30%	0.0055	0.043	76.3%
Code C	0.028	0.210	56%	0.0045	0.028	93.0%
Code D	0.023	0.174	42%	0.0042	0.032	94.1%
Code E	0.030	0.248	52%	0.0047	0.030	92.5%
Code F	0.024	0.205	45%	0.0049	0.028	91.3%
Code G	0.024	0.184	52%	0.0047	0.030	92.1%
Code H	0.027	0.210	43%	0.0048	0.027	91.6%

RESULTS DISCUSSION AND JUDGING CRITERION

- Spatial resolution versus noise
- How is the DIC Challenge being scored?
- How do I optimize my code for disparate and poorly defined objectives?
- Other minor discussion points.

HOW WILL THE DIC CHALLENGE BE SCORED?

- The point of the challenge is not to have winners and losers.
- There will not be a score or a ranking of codes from 1 to *N*. Results as seen above will be created – each person can interpret them for themselves.
- What is the point?
  - A better understanding of the compromise between filtering and noise.
  - Verified and validated images (and displacement fields) for people to use in publications and code development.
  - Prompt improvements in DIC codes.

THE STORY ALWAYS SEEMS TO BE: NOISE VERSUS SPATIAL RESOLUTION

- This was mentioned multiple ways: Regularization length, subset size, strain window, etc.
- The point of Sample 14 and Sample 15 is that the codes will be tested on the optimum compromise between filtering and noise. This is why there are no requirements on subset size.
- One metric will never be adequate.
- Sample 14 should be constant displacement sine and constant strain sine functions.

HOW DO I OPTIMIZE MY CODE FOR DISPARATE AND POORLY DEFINED OBJECTIVES?

- This is related to the scoring.
- Aren't most engineering questions poorly defined?
- It seems reasonable to have a couple of submissions with differently optimized settings.
- There are too many images for Sample 15. It seems better to have fewer images, but more submissions.

OTHER COMMENTS

- Reported data density is not high enough to capture the peaks
  - Board agrees. Future submission requirements will be at 1-pixel step size.
- Data processing should be in MatLAB.
  - You are welcome to write your own analysis code and we can compare results for consistency.
  - We should possibly post the analysis code for all to see on the website.
  - We should post the results on the website for others to analyze?
- Sample 14 needs higher frequencies.
- Problems with submitted data formats.
  - A balance between actually getting results and enforcing data formats.
  - With a larger audience we will be more strict.
- Compare only displacements
  - We cannot avoid comparing strain. This is likely where the largest difference may occur. It is also a strong filtering process.
  - We must compare the same strain type. Lagrange has been selected, but others could be considered.

STEREO-DIC CHALLENGE

- Tensile test sample. Aluminum 2024. ASTM 12.5-mm wide flat sample. Pulled equally in both directions.
- 6-camera system
  - Telecentric 2D system
  - 35-mm (5-mm extension tube) 2D System
  - Stereo 35-mm (5-mm tube) on both sides
- Dummy gage on the sides.
- Idealized ink-jet printed speckle pattern.
- Get a calibration target of each type
- Post calibration and data images from the test for people to analyze.
- This is a pre-trial run. For real attempt I believe interested parties should attend the testing.

PROPOSED BLIND IMAGE SETS (6)

- Two Translation (both contrast and noise may vary)
  - FFT – Rotation and/or translation
  - TexGen – Rotation and/or translation
- Two Spatially varying (Similar to Sample 14 and 15)
  - FFT – Spatially varying
  - TexGen – Spatially varying
- Two Experimental Sets
  - Sample 12
  - Sample 13

SUBMISSION GUIDELINES – RIGID BODY MOTION (BLIND 1 AND BLIND 2)

1. Define
   a. 5-pixel step size for results
   b. Subset size and/or element size, Define element type (shape function), Structured mesh
   c. No post-process filtering.
   d. Define strain window. Finite difference scheme, shape-function derivatives, fitting.
2. Submit
   a. File Header: Shape function, Incremental Correlation (T/F), Interpolation method, finite difference/Other (Supply a list - include unknown), List of Reference images
   b. x, y, u, v, exx, eyy, exy, Subset/Element size, gauge length, Match(T,F), Correlation Score(if available) at defined
   c. y is up and x is to the right

SUBMISSION GUIDELINES – SPATIALLY VARYING (BLIND 3 AND BLIND 4)

Original Submission Rules!

- Origin (0,0) Top – Left
- 5 pixel step size for data
  - Displacement
  - Strain in x, y, and shear (Lagrange)
  - Initial Guess? y/n
  - Correlation parameters
- Submit:
  - File Header. Shape function, Interpolation method, finite difference/Other (Supply a list - include unknown)
  - x, y, u, v, exx, eyy, exy, Subset/Element size, gauge length, Match(T,F), Correlation Score(if available)
  - Y is up and x is to the right

SUBMISSION GUIDELINES – EXPERIMENTAL (SAMPLE 12 AND SAMPLE 13)

- Origin (0,0) Top - Left
- 5 pixel step size for data
  - Displacement
  - Strain in x and y and shear Lagrange
  - Initial Guess: yes/no
  - Submission ideas
    - File Header, Shape function, Incremental Correlation (T/F), Interpolation method, finite difference/Other (Supply a list - include unknown), List of Reference images
    - x, y, u, v, exx, eyy, exy, Subset/Element size, gauge length, Match(T,F), Correlation Score(if available)
    - Y is up and x is to the right
  - Report at Image
    - Sample 12 (Plate with Hole) report at image 6 and 11
    - Sample 13 (Weld) Report at 6, 49, and 51

HOW DO WE CHARACTERIZE SPATIAL RESOLUTION?

- Point-by-point comparison between the known answer and the calculated answer (RMS or some such). Data will be on a 5×5 grid to assist with this.
- For rigid-body motion tests, subset size (or element size) will be defined.

GENERAL DISCUSSION

- 2D blind image sets.
- 3D Experiments
- 3D Synthetic data
- I need help doing the analysis. I don’t have time.