Applications of Targetless Photogrammetry for Facilities Documentation and Close Range Metrology

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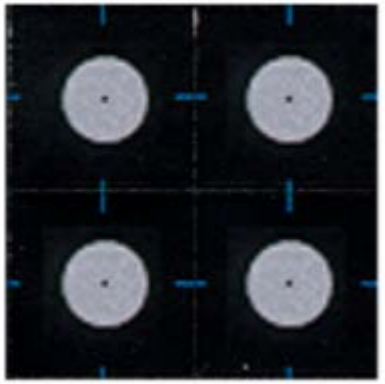
Overview

- Traditional photogrammetry is used widely throughout NNS current metrology efforts
  - Technology relies on physical stickers placed on part
  - Relatively quick measurements
  - Significant set up and tear-down required



Sticker Targets

- Variant of this tech potentially removes:
  - Material costs (photogrammetric codes and targets)
  - Survey set up time
  - Support services (JLG, crane, or staging)

Overview cont

- Targetless Photogrammetry is increasingly used in Architecture and Oil/Gas applications with forgiving accuracy requirements

- Research released in 2018 showed that advances in the tech may allow accuracy to support some Metrology surveys

- This project sought to
  - Characterize achievable accuracies in shipbuilding conditions
  - Evaluate shipbuilding applications for suitability

Tasks

1. Identify hardware needed to perform targetless photogrammetry
2. Identify hardware requirements for drone based photogrammetry
3. Identify basic software requirements
4. Identify scale and common point targets available
5. Develop minimum process to solve a point cloud from photo data
6. Develop minimum process to solve a textured mesh from photo data
7. Develop workflow to transfer and groom data to a workable format
8. Develop and run testing program to quantify the environmental characteristics required to realize 2 sigma survey accuracies
9. Determine maximum 2 sigma accuracy boundary
10. Evaluate suitable use cases (NNS + Ingalls)

Task 1 & 2 Hardware Requirements

Metrology Applications

- Digital SLR with high internal stability
  - Nikon D3200
  - Olympus E-10

Facilities Documentation

- Drone suitable for camera payload
  - DJI S1000
- Digital SLR with high internal stability
  - Cannon 5D Mark III

DJI S1000 Drone

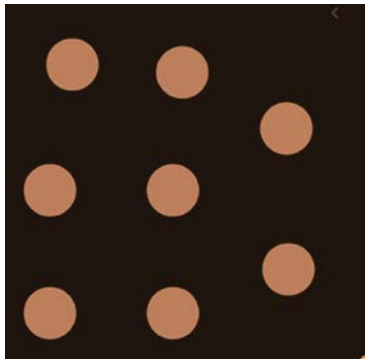
Tasks 3 and 4

Basic Software Requirements

- iWitnessPRO or Australis
  - 2D to 3D Conversion
- CloudCompare (Freeware)
  - Point Cloud Processing
- Computing requirements
  - 64-bit Microsoft Windows® 7 / 8 / 10 Operating Systems
  - Minimum 8 GB of RAM. 16 GB or more recommended for point cloud/ mesh generation.

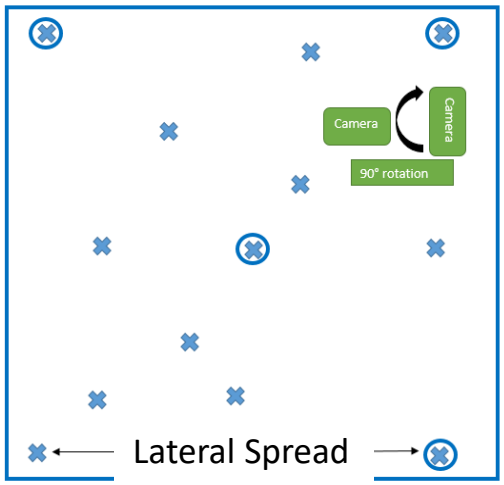
Scale and Common Targets

- Scale Bar
  - Invar adjust length bars
- 1″ retro-reflective offset targets
- Red Retro Reflective Coded Targets (optional)

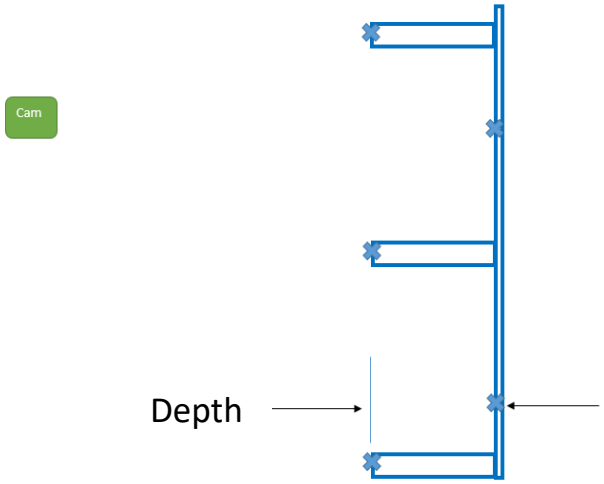


Red Retro Reflective Coded Target

Tasks 5-7 General Workflow - Calibration



Front View



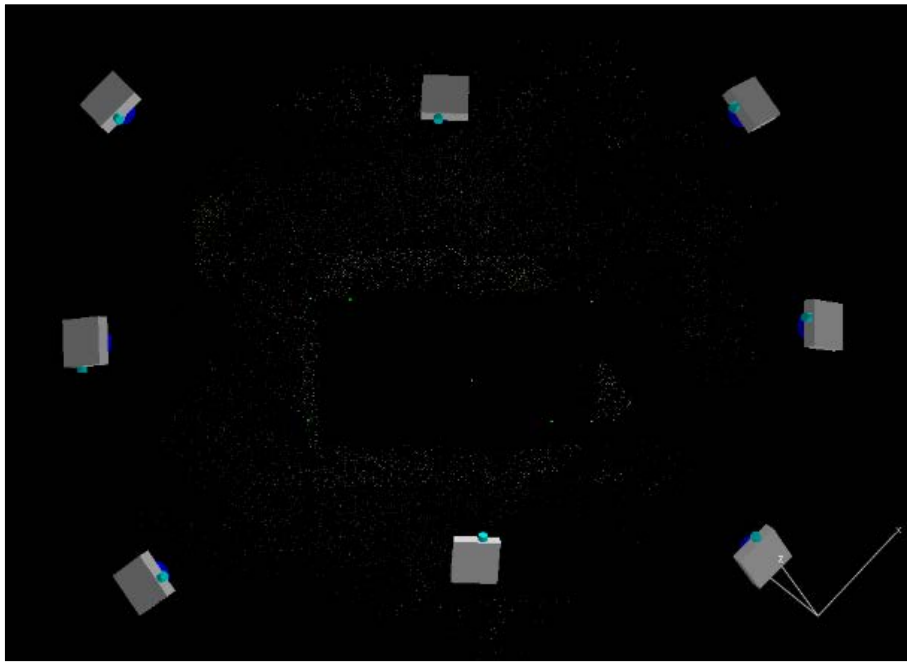
Right View

Calibration

- Achieved using:
  - Pictures taken during survey
  - Separate event before survey
    - Zoom cannot be adjusted after Calibration
- Requirements
  - Stations @ various positions
  - Rotate subset of pictures 90°
    - At least 1 station
    - Up to half of all stations
  - Depth of features used should be at least 10% of lateral area

Tasks 5-7 General Workflow - Data Capture

- 2D photographs are taken around the part
  - Number of photos depend on:
    - Size of part
    - Complexity of part
    - Distance of Camera to part
  - Processing time increases with number of photos
    - Time increase exponential with additional photos
    - Observed processing times varied from 10-150 mins



Camera stations around rectangular artifact

Tasks 5-7 Gen Workflow – 3D Conversion

1. 2D Picture matching
   - Coded Targets
   - Natural Features

2. Bundle adjustment
   - Self Calibration
   - Triangulation
   - Resection

3. Point Cloud /Mesh Creation

Blue dots show features identified for matching

Tasks 8-9 Accuracy Characterization

- Design of Experiments used with 6 variables
  - Ambient brightness
  - Camera flash
  - Distance from artifact
  - Aperture
  - ISO
  - Sensor (Camera)
    - Nikon D3200
      - Nikon AF-S 18-55mm
    - Olympus OM-D E-M10
      - Rokinon FE75MFT-B

Number	Ambient Light	Distance	Flash	Aperture	ISO
1	+1	+1	+1	+1	+1
2	+1	+1	+1	-1	-1
3	+1	+1	-1	+1	-1
4	+1	+1	-1	-1	+1
5	+1	-1	+1	+1	-1
6	+1	-1	+1	-1	+1
7	+1	-1	-1	+1	+1
8	+1	-1	-1	-1	-1
9	-1	+1	+1	+1	-1
10	-1	+1	+1	-1	+1
11	-1	+1	-1	+1	+1
12	-1	+1	-1	-1	-1
13	-1	-1	+1	+1	+1
14	-1	-1	+1	-1	-1
15	-1	-1	-1	+1	-1
16	-1	-1	-1	-1	+1

Design Configurations

Tasks 8-9 Results - Olympus

Test Number	Ambient Light (lux)	Distance (ft)	Flash	Aperture	ISO	Flatness Deviation (in.)	2σ Accuracy (in.)
1	850	3	ON	22	3200	0.609	±0.105
2	850	3	ON	8	400	0.329	±0.042
3	850	3	OFF	22	400	FAILED	
4	850	3	OFF	8	3200	0.170	±0.029
5	850	1	ON	22	400	0.328	±0.044
6	850	1	ON	8	3200	0.203	±0.049
7	850	1	OFF	22	3200	FAILED	
8	850	1	OFF	8	400	0.208	±0.035
9	90	3	ON	22	400	FAILED	
10	90	3	ON	8	3200	0.202	±0.025
11	90	3	OFF	22	3200	FAILED	
12	90	3	OFF	8	400	0.848	±0.231
13	90	1	ON	22	3200	0.403	±0.077
14	90	1	ON	8	400	0.221	±0.035
15	90	1	OFF	22	400	FAILED	
16	90	1	OFF	8	3200	0.458	±0.092

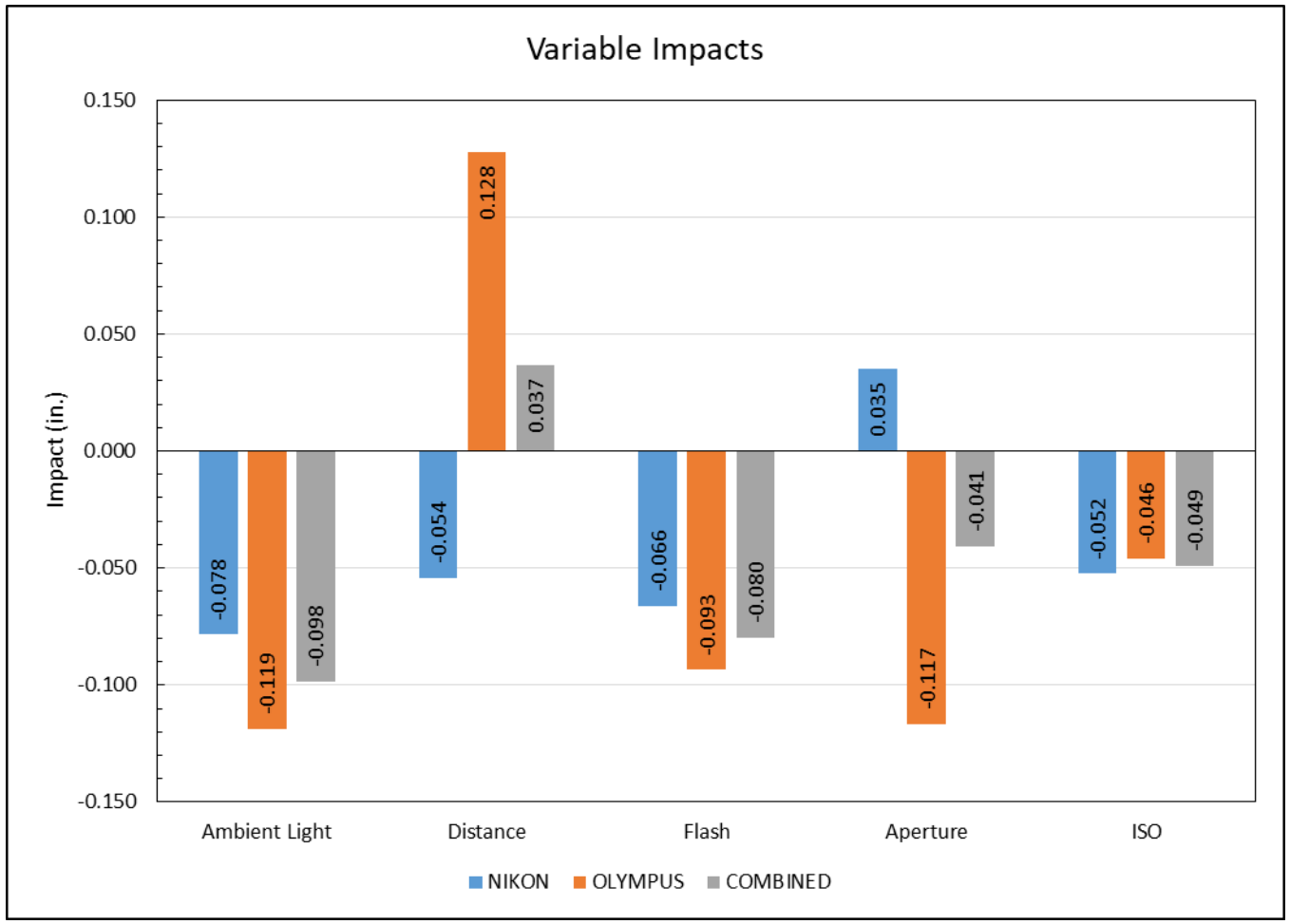
Olympus OM-D E-M10 Camera with Rokinon FE75MFT-B Lens

Tasks 8-9 Results Nikon

Test Number	Ambient Light (lux)	Distance (ft)	Flash	Aperture	ISO	Flatness Deviation (in.)	2σ Accuracy (in.)
1	850	3	ON	22	3200	0.215	±0.045
2	850	3	ON	8	400	0.096	±0.015
3	850	3	OFF	22	400	FAILED	
4	850	3	OFF	8	3200	0.180	±0.020
5	850	1	ON	22	400	FAILED	
6	850	1	ON	8	3200	0.234	±0.024
7	850	1	OFF	22	3200	0.171	±0.017
8	850	1	OFF	8	400	0.314	±0.024
9	90	3	ON	22	400	FAILED	
10	90	3	ON	8	3200	0.162	±0.018
11	90	3	OFF	22	3200	FAILED	
12	90	3	OFF	8	400	0.386	±0.053
13	90	1	ON	22	3200	0.249	±0.033
14	90	1	ON	8	400	0.287	±0.020
15	90	1	OFF	22	400	FAILED	
16	90	1	OFF	8	3200	0.316	±0.032

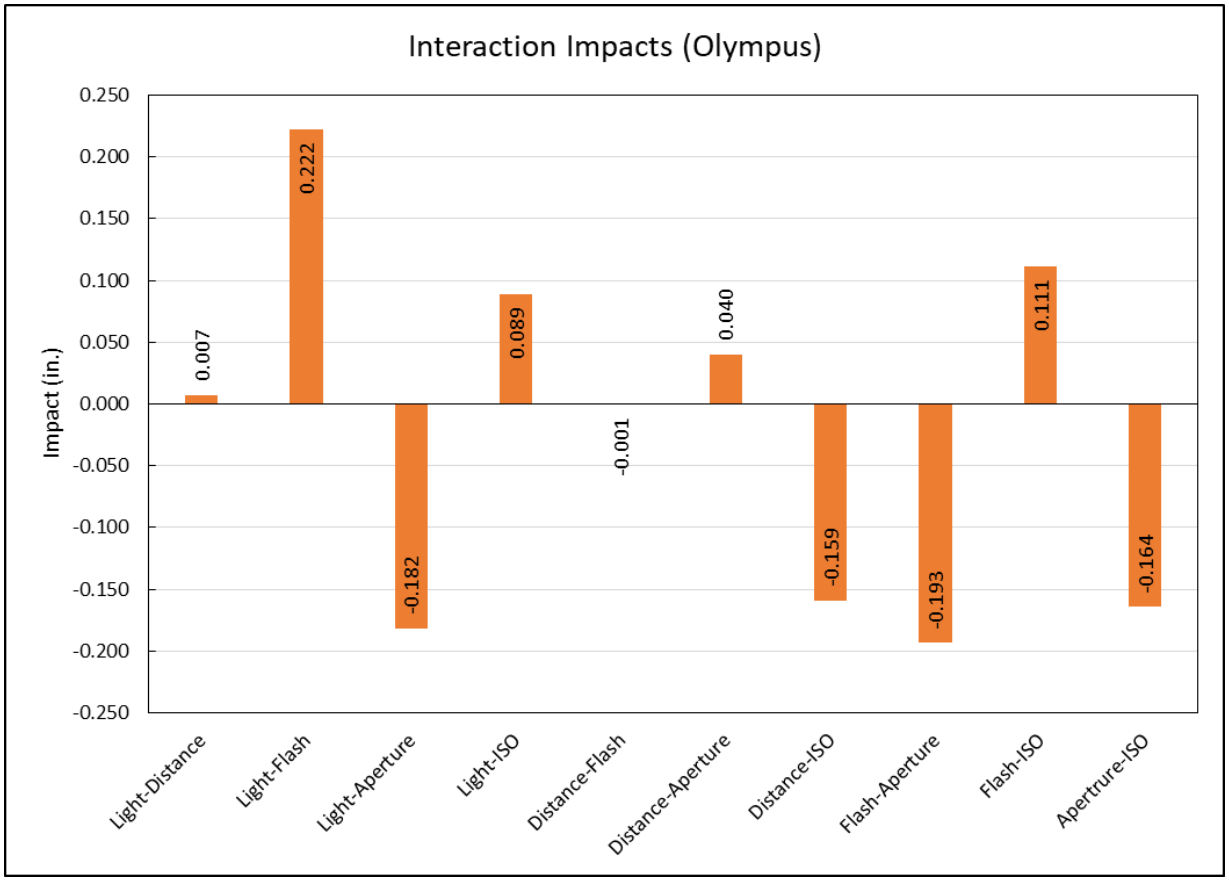
Nikon D3200 Camera with Nikon AF-S 18-55mm Lens

Tasks 8-9 Results Variable Impacts



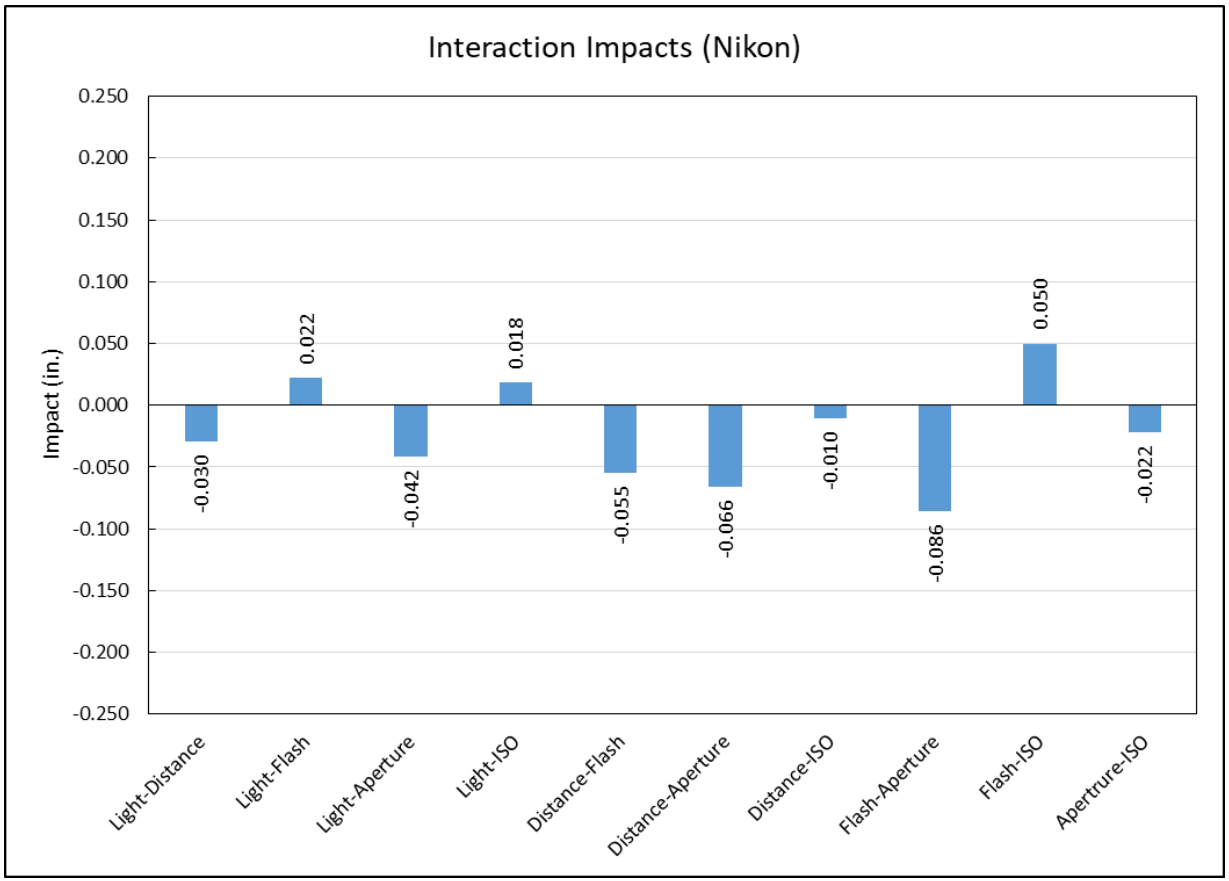
Negative values indicate that flatness deviation is lowered when that variable has a higher value. The greater the spike, the more of an impact the variable has on the value.

Tasks 8-9 Results Interaction Impacts



Largest impacts result in photos that are either too dark or too light, decreasing the contrast needed to resolve features

Tasks 8-9 Results Interaction Impacts



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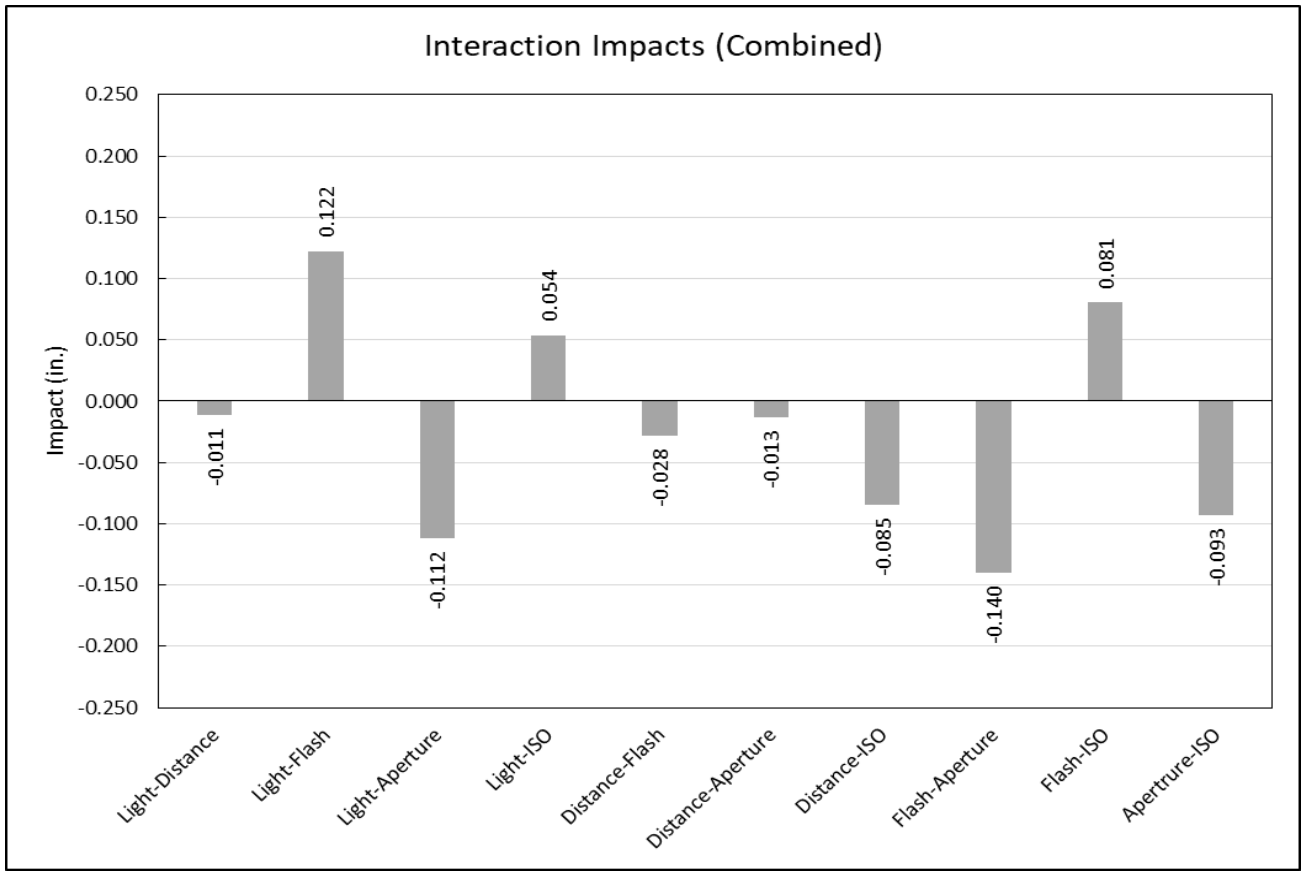
Tasks 8-9 Results
Combined Interaction Impacts



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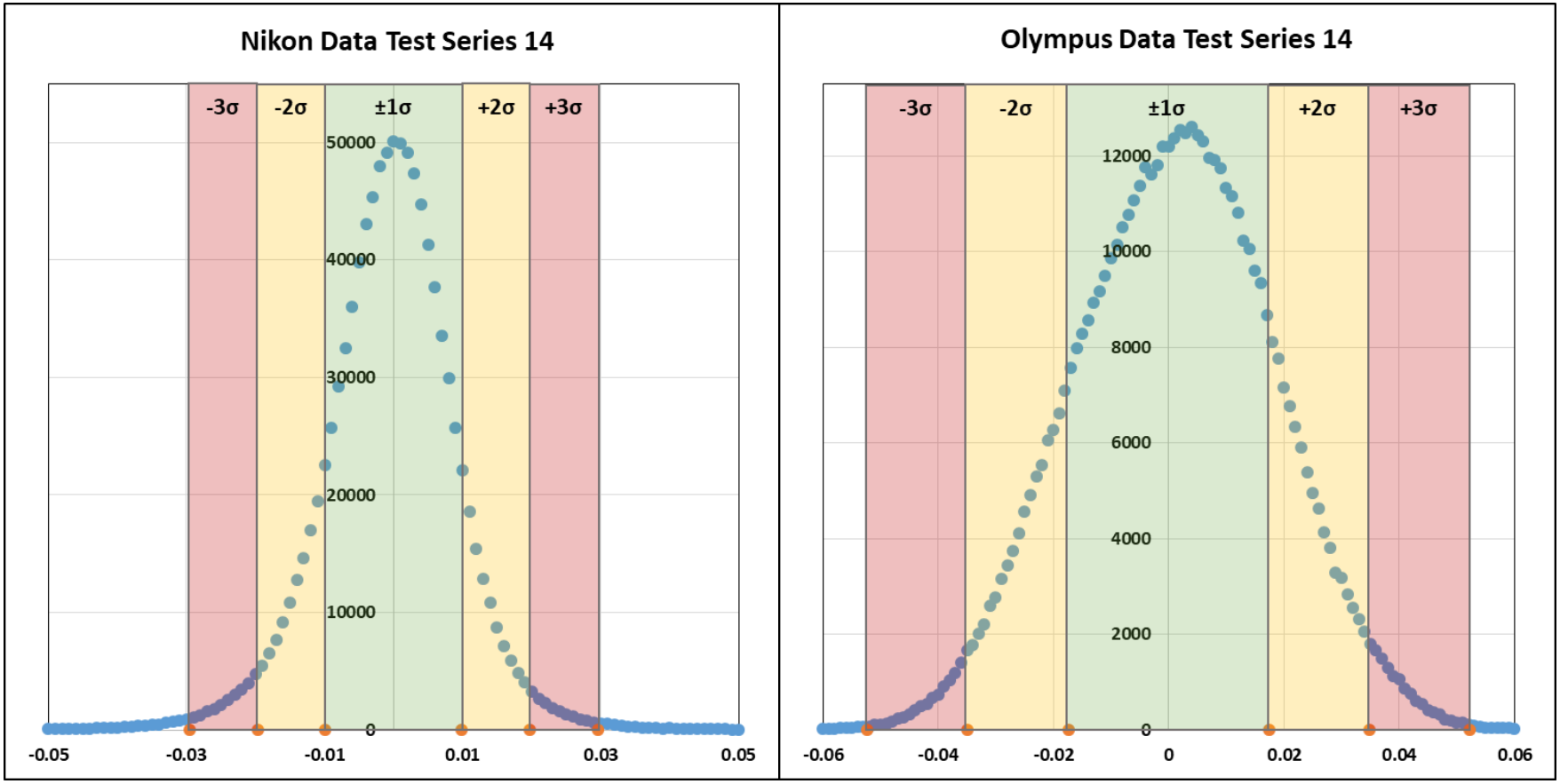
Tasks 8-9 Results – 2 Sigma Accuracy



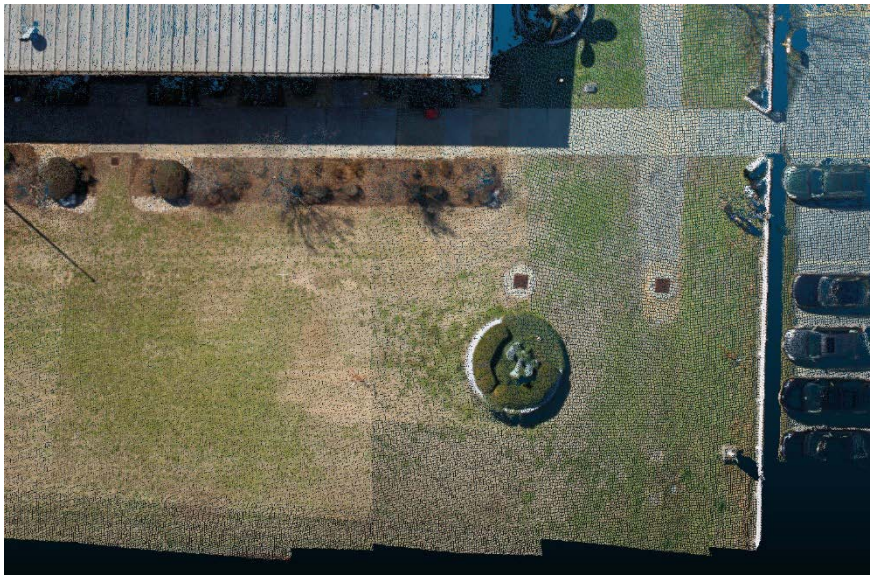
Example Data showing distribution of z-position of points with regard to as-built plane

Task 10 - Applications

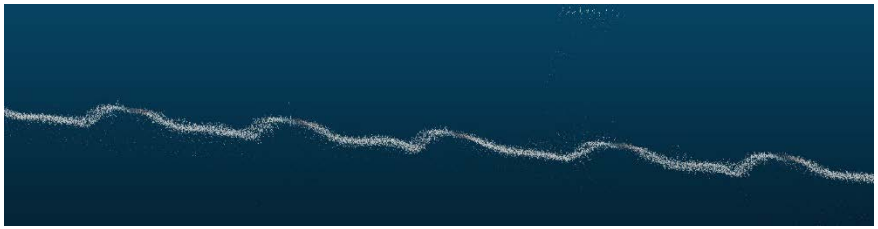
- Pilot Surveys were conducted at NNS and Ingalls Shipbuilding

- Poor Performance
  - Thin structural members
  - Part edges
  - Homogenous/reflective surfaces

- Excellent Performance
  - Facility Documentation
  - Precut in-way-of
  - Casting inspection



Top view of generated point cloud showing corrugated roof and terrain



Side view of corrugation, very low noise

Recommendations

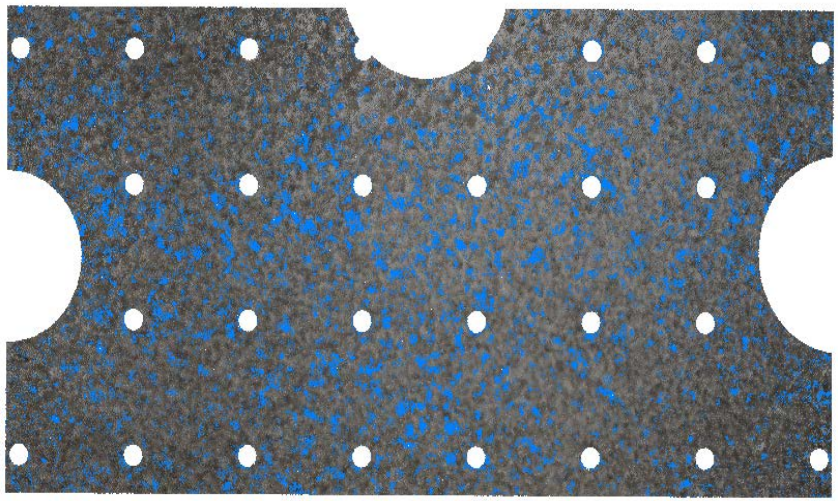
- Camera settings should favor maximum detail (color, focus, etc) as opposed to the high contrast favored by traditional photogrammetry

- Accuracy is driven heavily by
  - Megapixels of the sensor
  - Quality of the lens
  - Distance from part
  - Internal stability of the Sensor

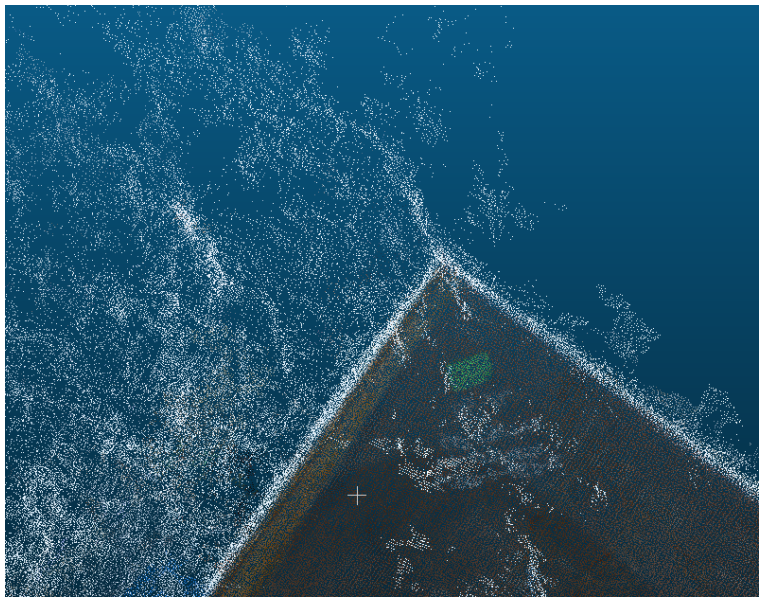
- Camera stations should be limited as post processing time can become untenable

Recommendations

- Noise generated in low light conditions/ on edges
- Technology needs to mature before complete integration into Metrology toolsets



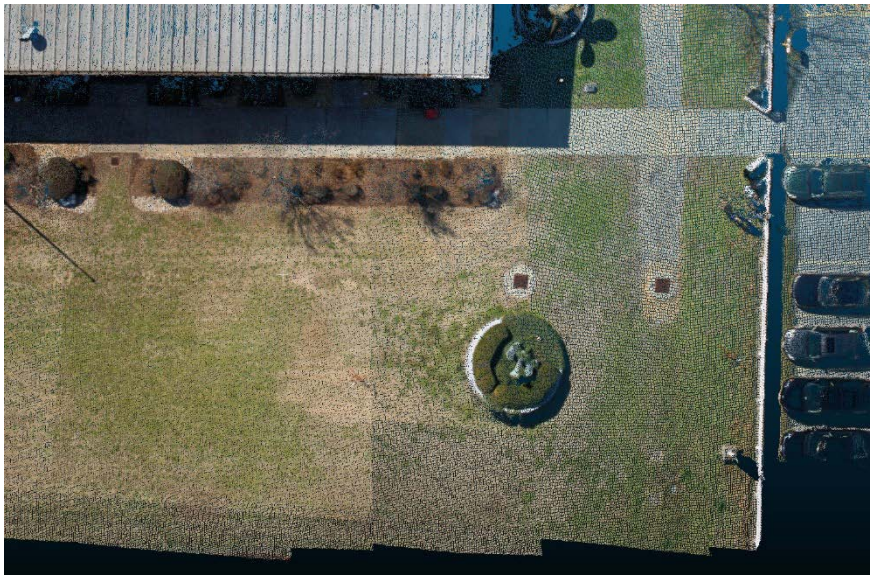
Blue points show areas of noise outside the 2 sigma boundary of ±0.018”



Noise on plate edge generated from distant objects

Recommendations

- Ready for immediate integration into Facilities Documentation processes
- Independently or in parallel with laser scanning
  - Large, outdoor areas covered in a relatively low amount of time
  - Difficult to capture areas such as roofs, high altitude features, etc
  - Low implementation costs
  - Fast survey time
    - Area covering 8 terrestrial scans (~2 hours) surveyed in 8 mins



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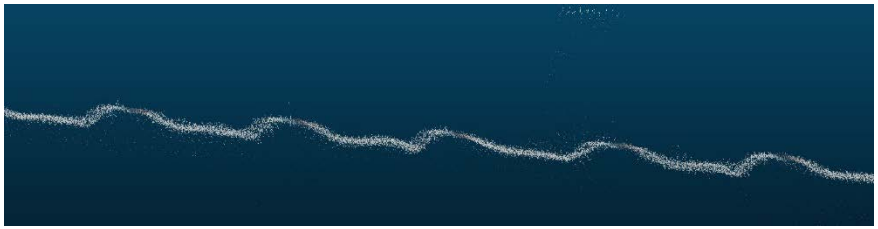

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