AN IMAGE-BASED FRAMEWORK FOR AUTOMATED DISCREPANCY QUANTIFICATION AND REALIGNMENT OF INDUSTRIAL ASSEMBLIES

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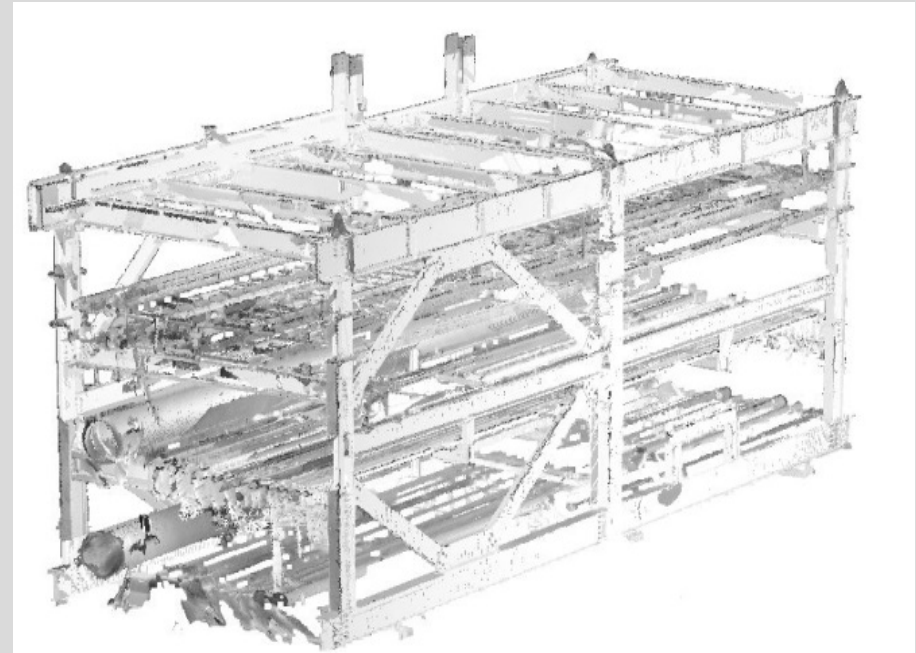Thomas Czerniawski, Jamie Yeung, Carl Haas, Scott Walbridge, Jeffrey West

OUTLINE

- Problem statement and motivation
- Related background
- Proposed framework
- Experimental results
- Conclusions and outlook

PROBLEM STATEMENT
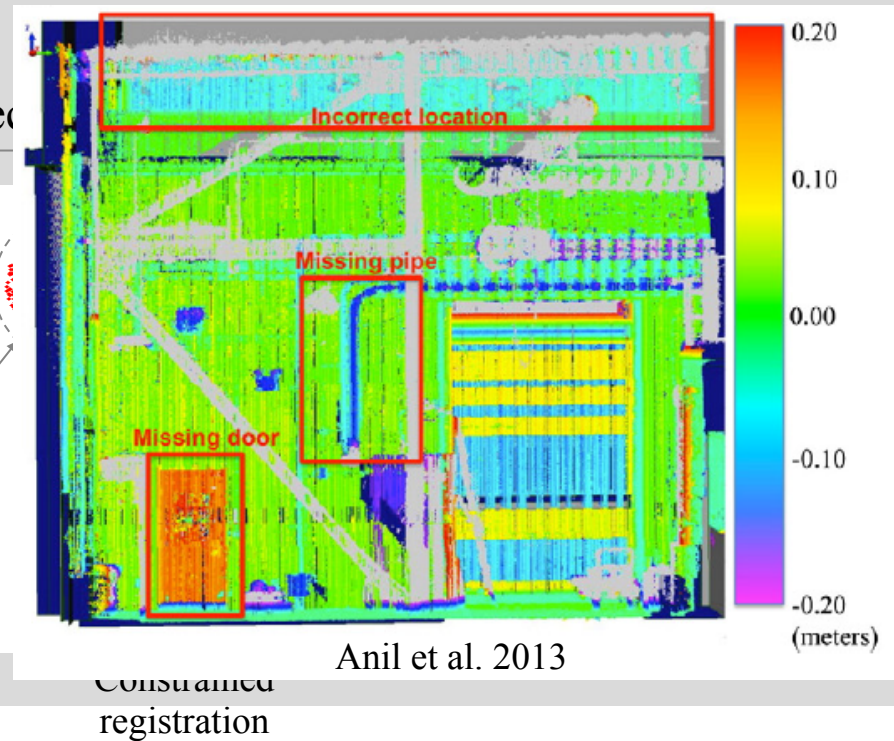
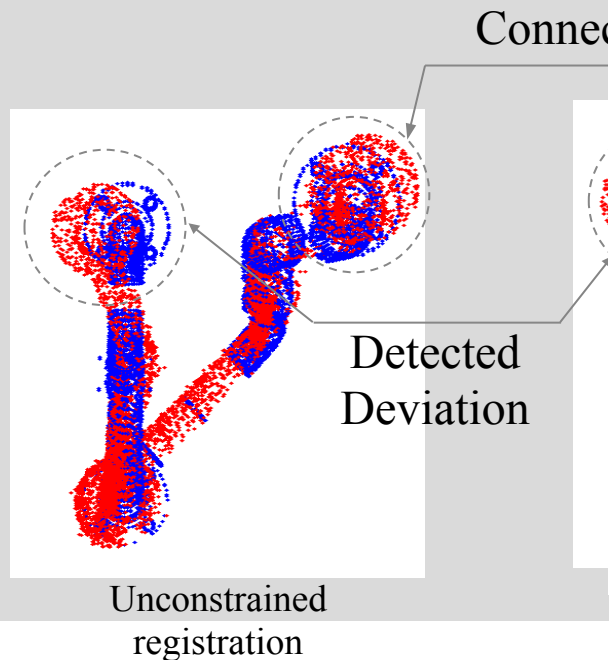# PROBLEM STATEMENT

levelling table
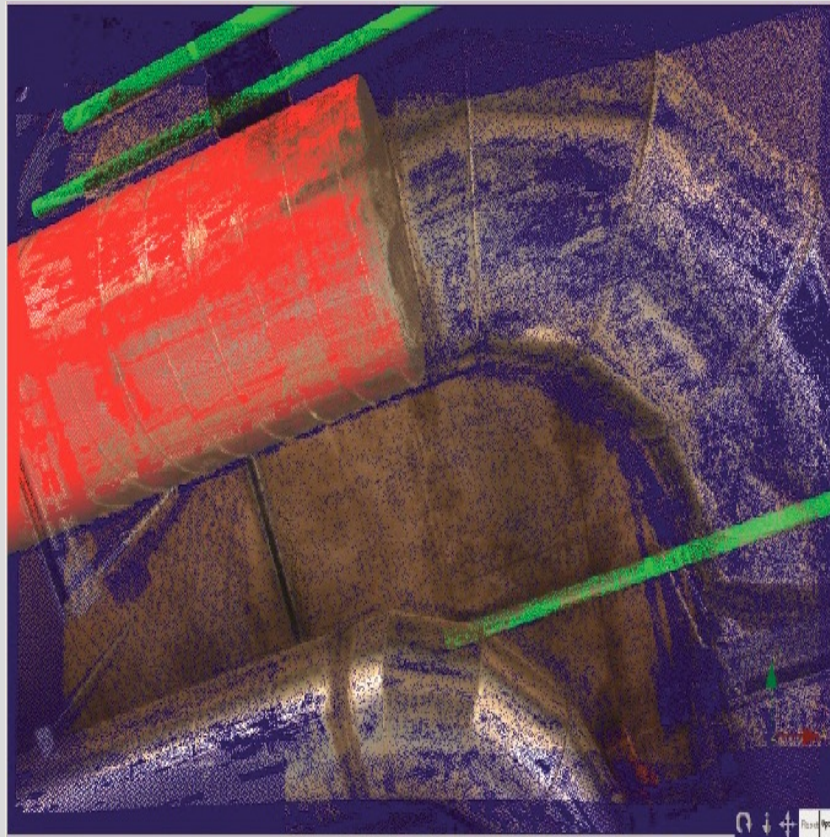
Module is lifted

Deformation occurs

RELATED BACKGROUND

- Discrepancy quantification
  - » Deviation analysis
  - » Our previous research

Connec...

Detected
Deviation

Unconstrained
registration

Incorrect location

Missing pipe

Missing door

Anil et al. 2013

Constrained
registration

RELATED BACKGROUND

- Image-based 3D reconstruction
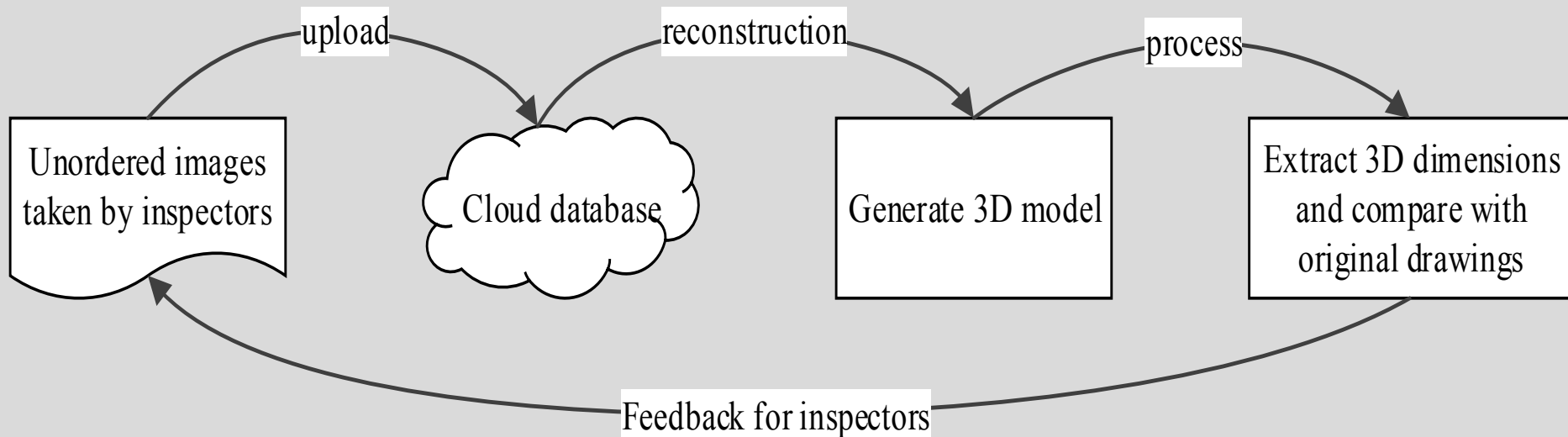

Adapted Golparvar-Fard et al. 2011

CONTRIBUTION

Developing an accurate and reliable framework for quick discrepancy quantification between the built and designed states for industrial assemblies
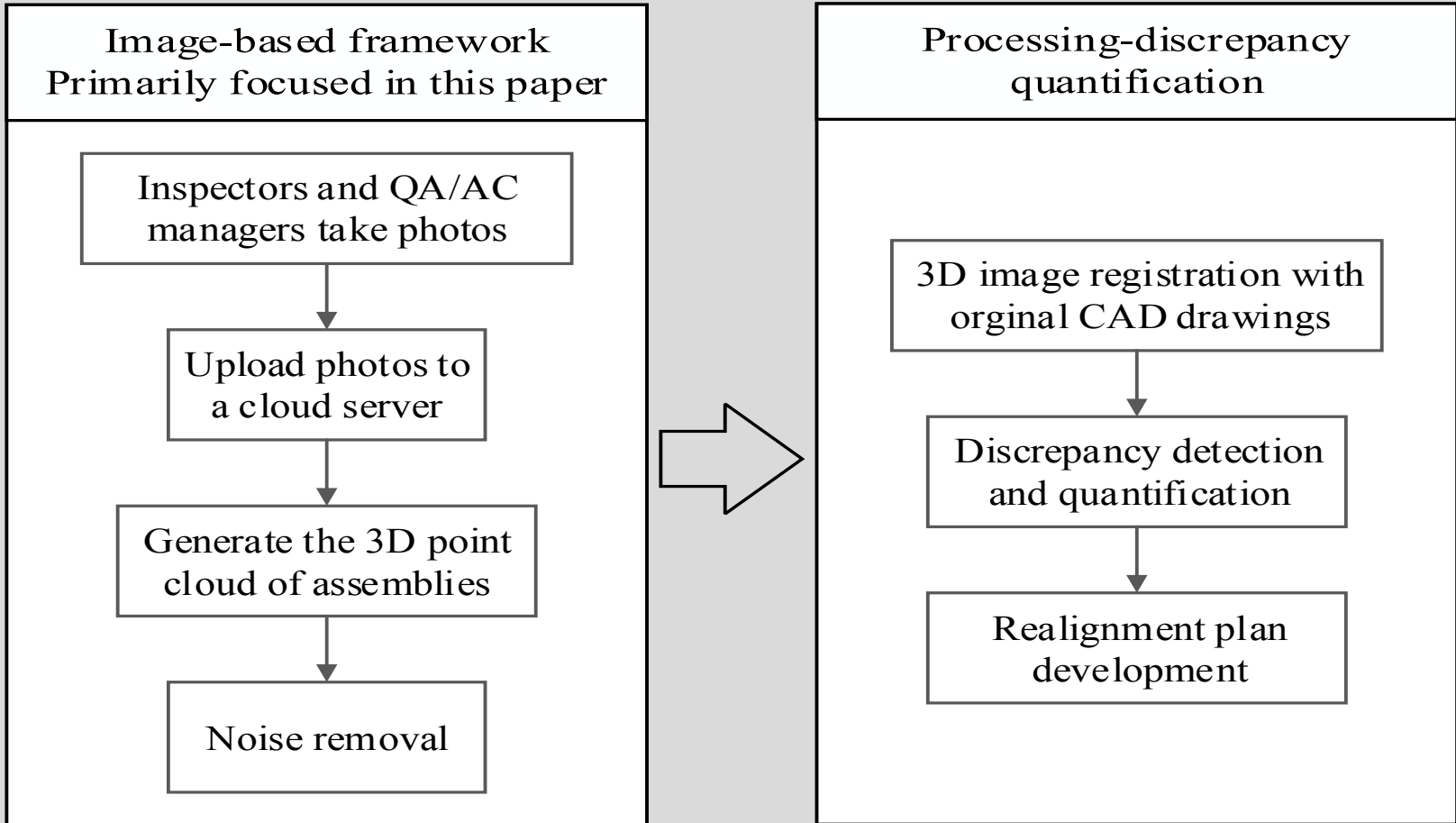
PROPOSED FRAMEWORK

- 3D model generation and fabrication/assembly control

METHODOLOGY

Image-based framework
Primarily focused in this paper

Inspectors and QA/AC managers take photos

↓

Upload photos to a cloud server

↓

Generate the 3D point cloud of assemblies

↓

Noise removal

Processing-discrepancy quantification

3D image registration with orginal CAD drawings

↓

Discrepancy detection and quantification

↓

Realignment plan development

STEP 1: IMAGE-BASED 3D RECONSTRUCTION

- Potential tools for 3D reconstruction
  - » MATLAB image processing toolbox
  - » Point Cloud Library (PCL)
  - » OpenCV (Computer Vision)-University of Washington
  - » Online servers (Autodesk 123D Catch-Microsoft Photosynth)

STEP 1: IMAGE-BASED 3D RECONSTRUCTION

- Summary of 3D reconstruction
  - » Finding common features in the images taken,
  - » Matching the common features detected, and
  - » Transforming the images into a global coordinate system based on the previously matched features
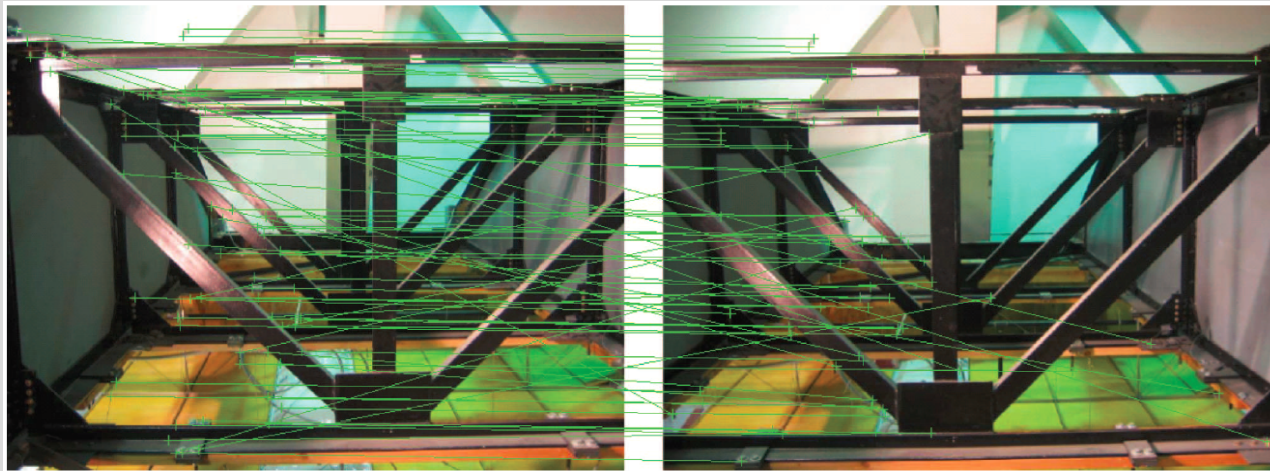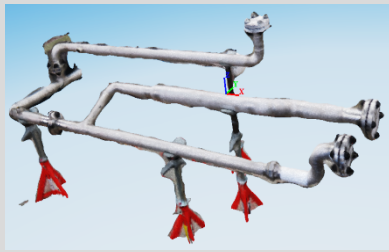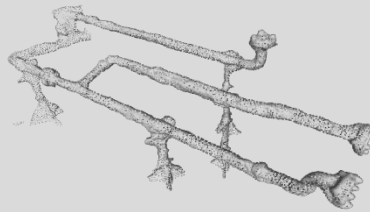

Jahanshahi et al. 2009

STEP 2: DISCREPANCY ANALYSIS
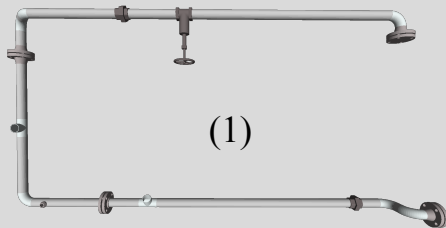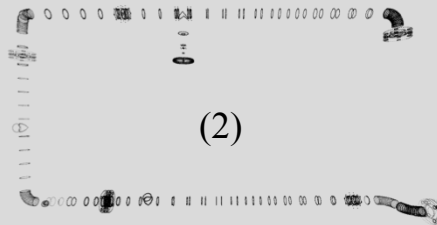
- ## Preprocessing
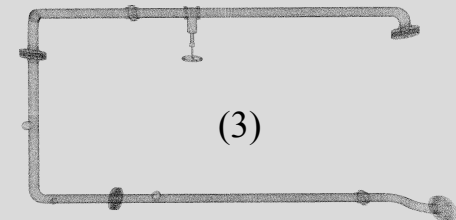 - » Clutter removal
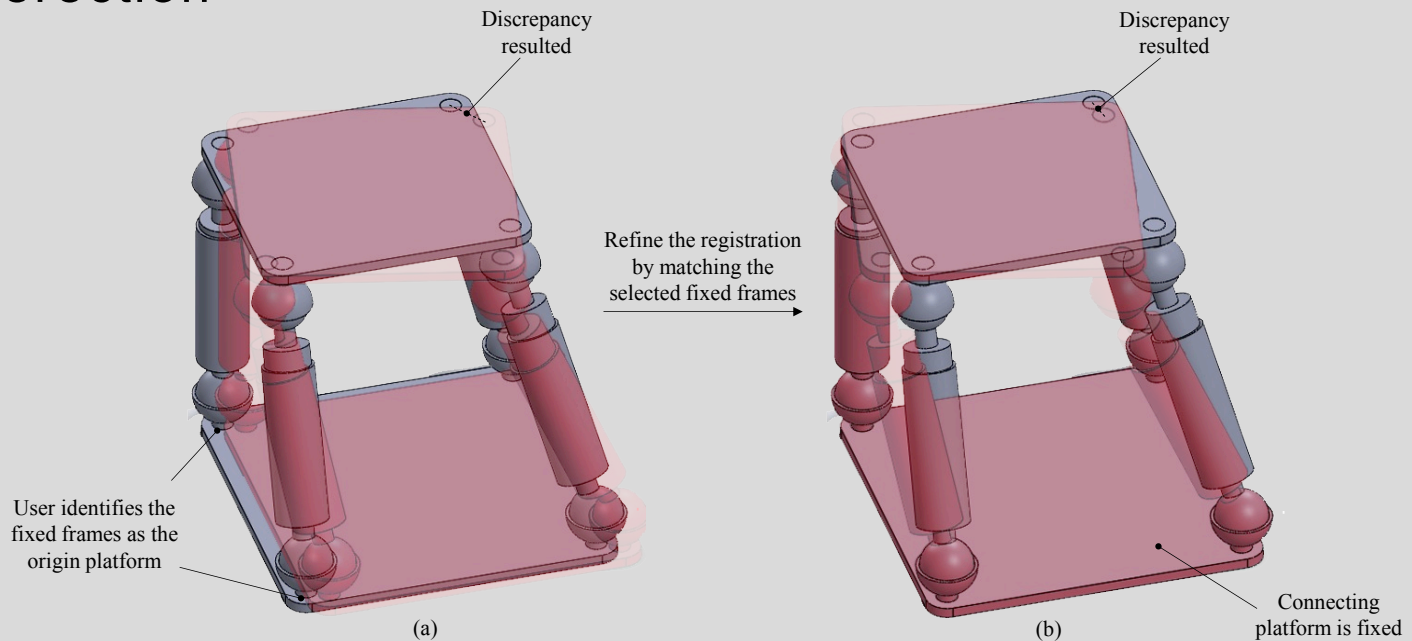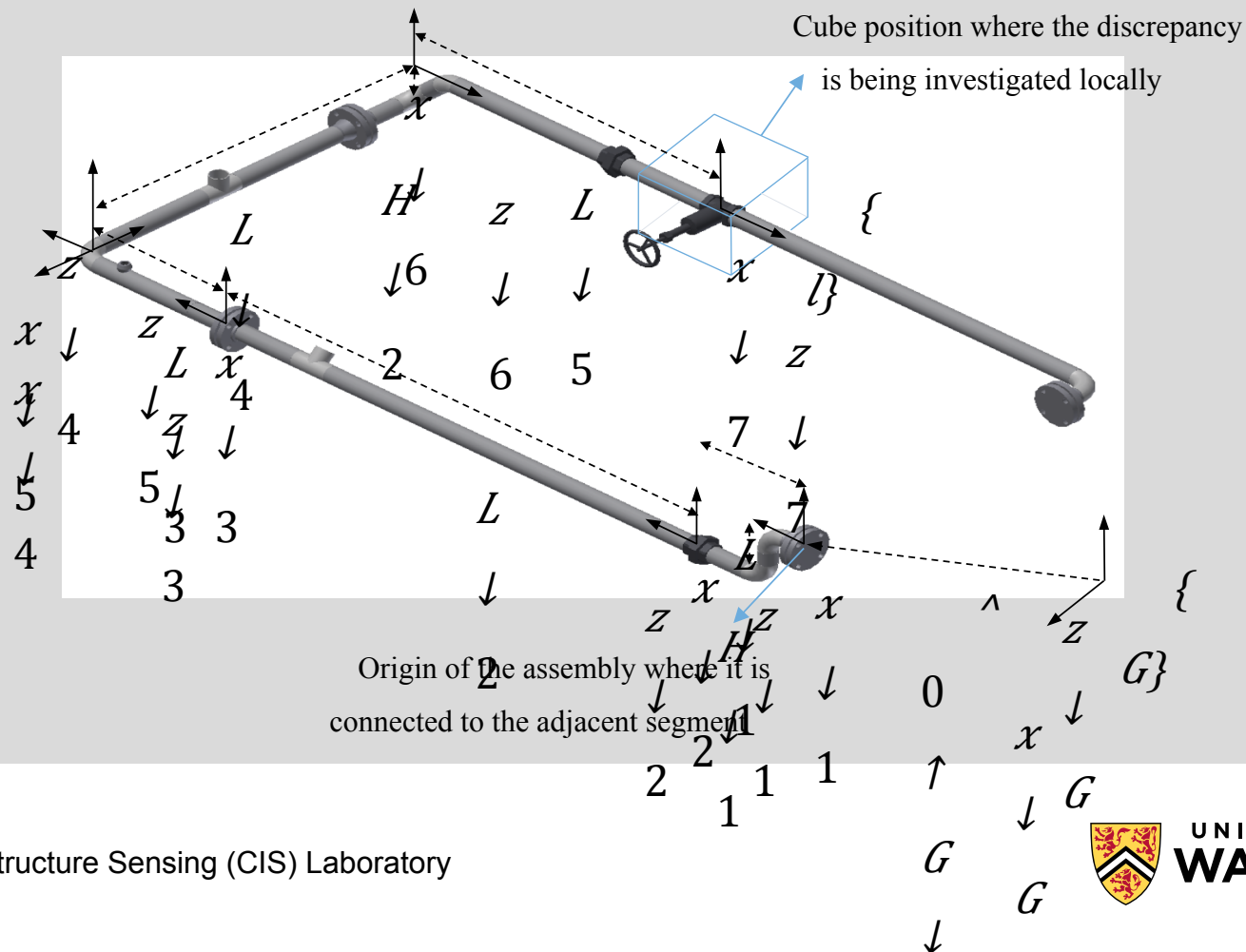

(a) (b) (c)

  - » 3D CAD model format conversion

(1) (2) (3)

STEP 2: DISCREPANCY ANALYSIS

- Point cloud registration-Iterative Closest Point (ICP)
  » A modified (constrained) registration is developed for considering real, on-site situations for assembly and erection

Discrepancy resulted

Discrepancy resulted

Refine the registration by matching the selected fixed frames

User identifies the fixed frames as the origin platform

Connecting platform is fixed

(a)

(b)

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- Kinematics chain development-robotics analogy

Cube position where the discrepancy is being investigated locally

Origin of the assembly where it is connected to the adjacent segment
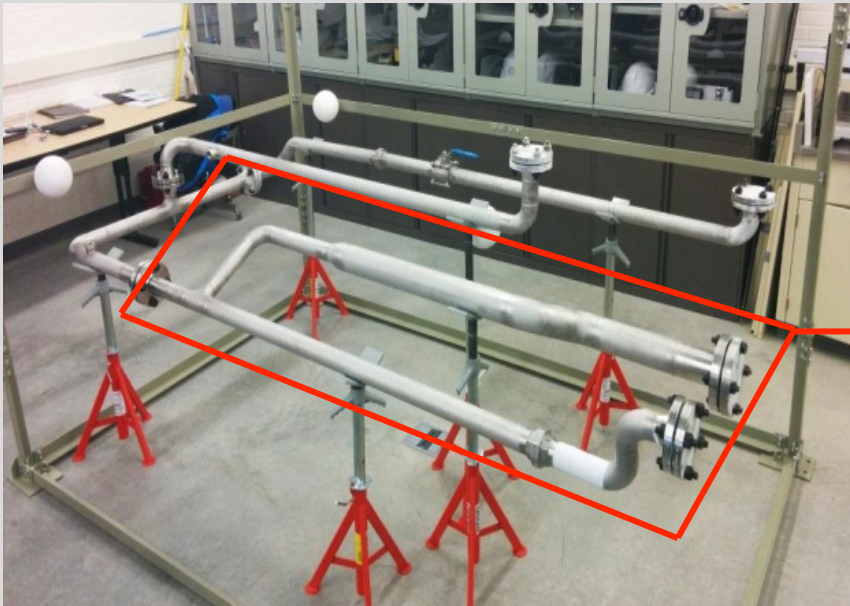
STEP 2: DISCREPANCY ANALYSIS

- Quantification of local discrepancies and transformation into global coordinate system

Cube located at a critical location

M

S

Fixed frame

$(r, t)_{li} l$

$(\delta)_i$

$\{l\}$

i

m

$(T_{g} \{ \uparrow g \ l \})$

$(r_i, t)_{li \uparrow g}$
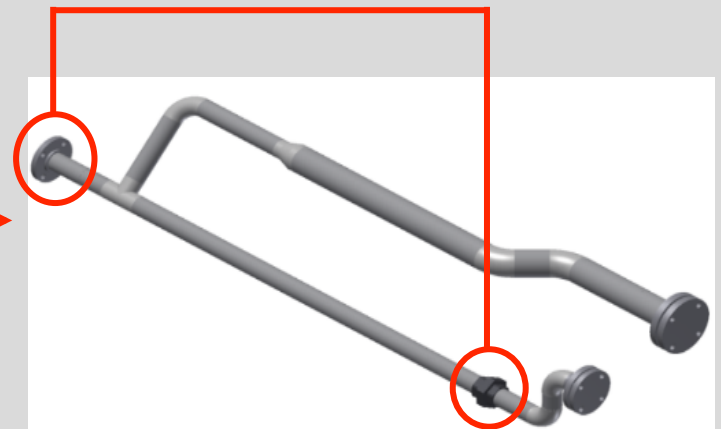
$\leftarrow ICP(m_{li}, s_{li})$
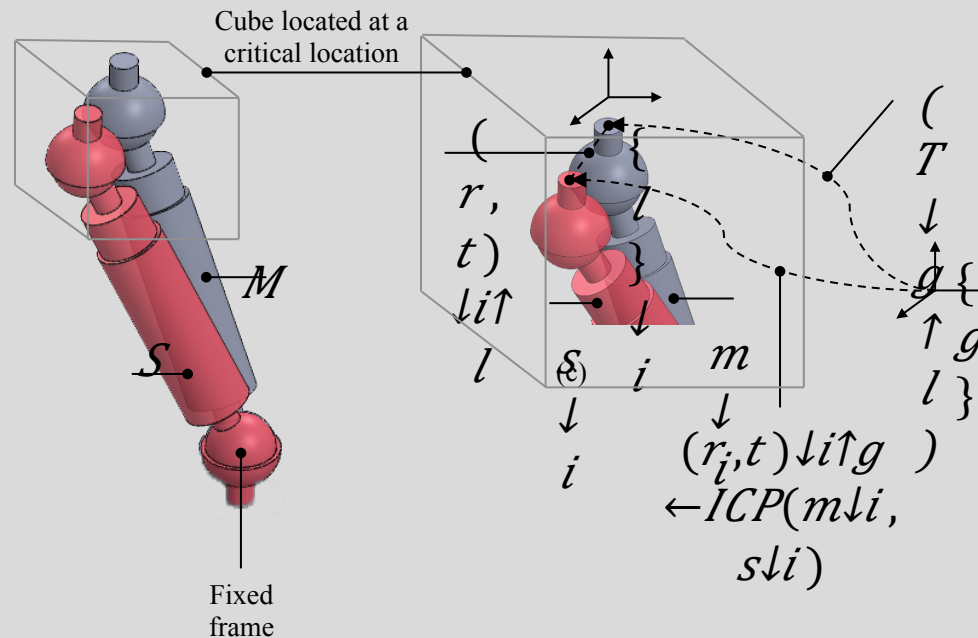
EXPERIMENTAL RESULTS

- Design of experiments

Adjustable connections
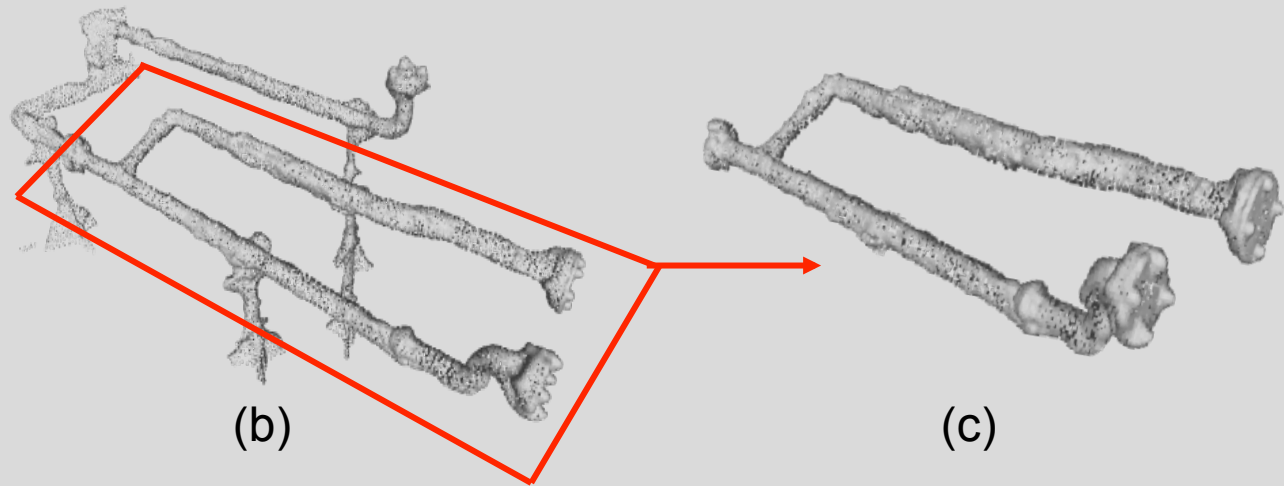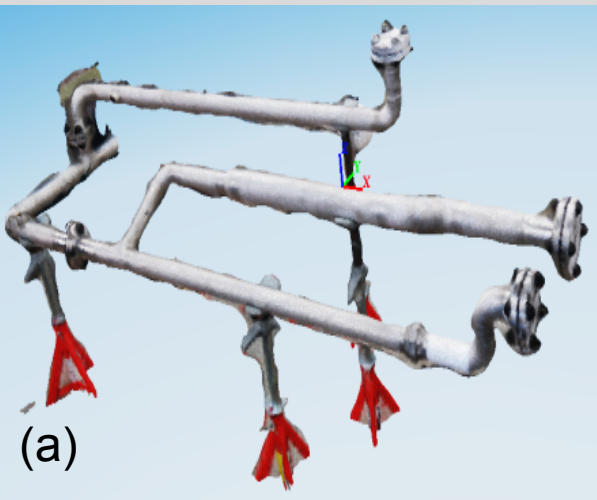
EXPERIMENTAL RESULTS

- Camera properties (Canon SX 40-HS)

| Camera type	Digital camera
Image resolution (size)	4000×3000 [L] *, 2816×2112 [M1] * 1600×1200 [M2] *, 640×480 [S]
Shutter speed	1/3200 sec (min)- 15 sec (max)
Focal length	24-840 mm

* [L]: Large, [M]: Medium, [S]: Small.

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EXPERIMENTAL RESULTS

(a)

(b)

(c)

EXPERIMENTAL RESULTS

Size of images taken	[L]: 4000×3000
Number of images processed	59
Total number of points retrieved	134,742
Number of points retrieved from the pipe spool	15,152
Total processing time	26 min

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EXPERIMENTAL RESULTS
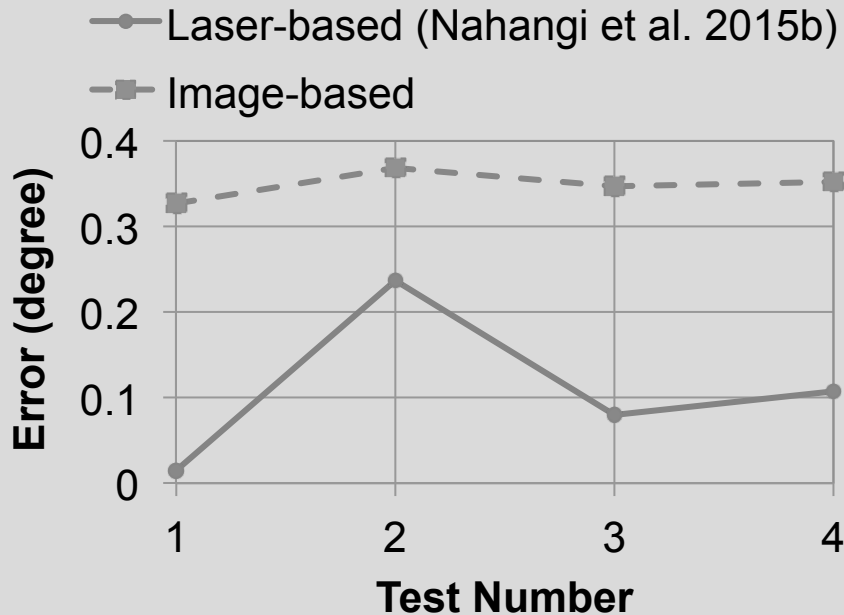
Rotational
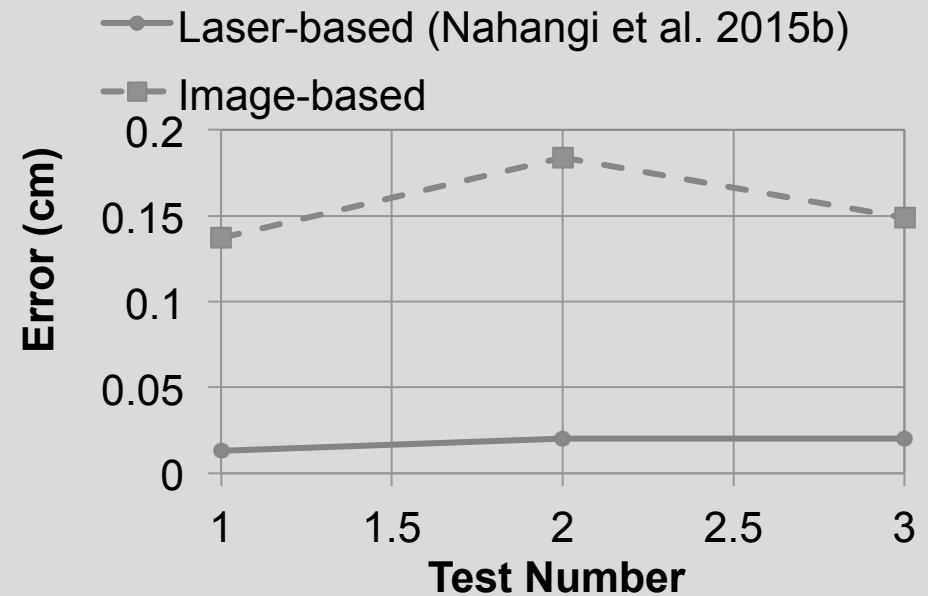
Translational

CONCLUSIONS

- Remarked observations
  - » Accuracy (concurs with previous studies)
  - » Time-related aspects
  - » Applicability

- Path forward
  - » Time effectiveness improvement
  - » Real-time assembly
  - » Smart and guided quality control

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Question & Discussion