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Image-Based Bridge Defect Detection and Monitoring Technologies

Jian Zhang
Southeast University, China

Image-Based Bridge Defect Detection and Monitoring Technologies

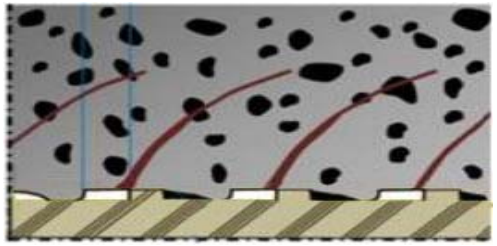
Dr. Jian Zhang
Southeast University
Email：jian@seu.edu.cn

Outline

Background

Challenges:

Harmful deterioration



Cracking

Spalling

Durability: Short-lived

Safety: Collapse

Difficult for inspection

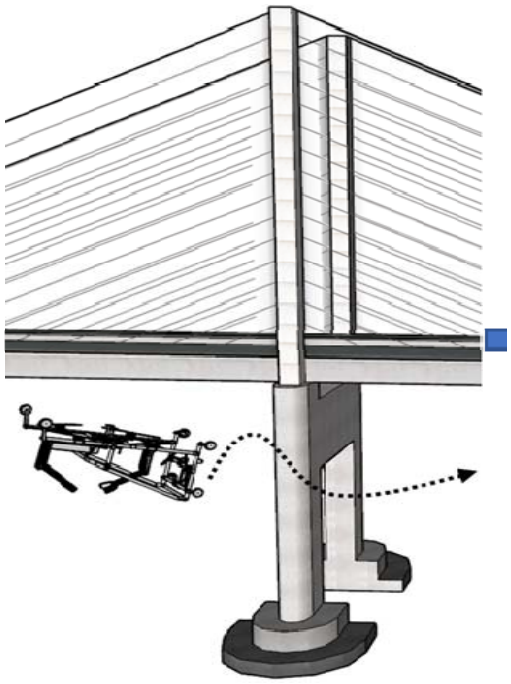
High piers and high towers

Accurate and automatic damage detection methods and equipment

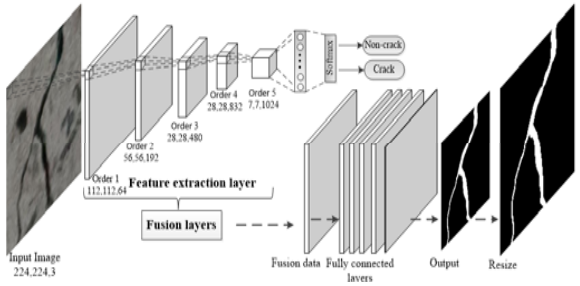
1.1 Multi-scale damage identification (level 1)

- Deep learning algorithms for automatic detection of structural damages with high-precision

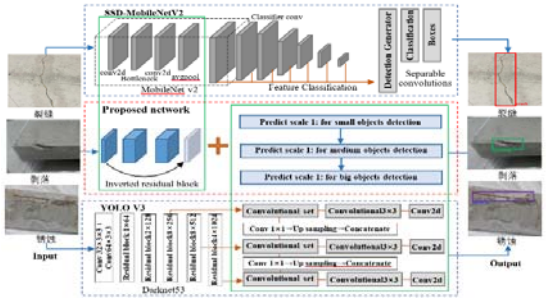
UAV for bridge inspection



Deep neural network algorithms

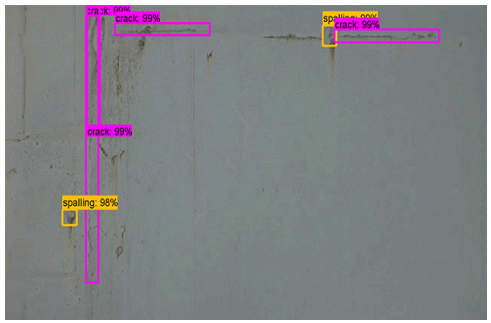


Feature extraction

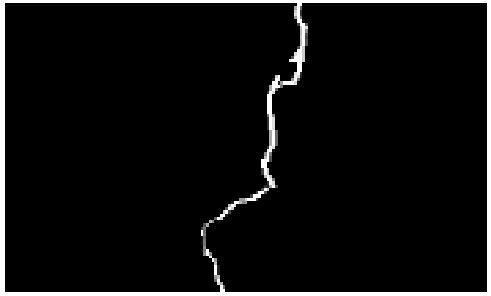


CNN for real-time detection

Real-time detection



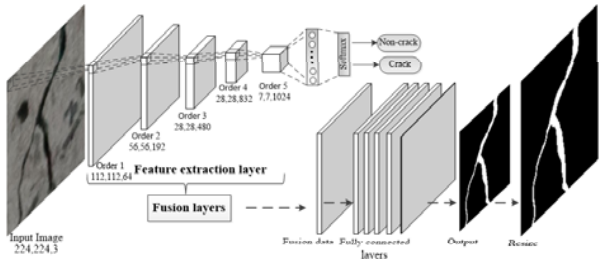
Real-time segment



1.2 Automatic crack quantification algorithm (level 2)

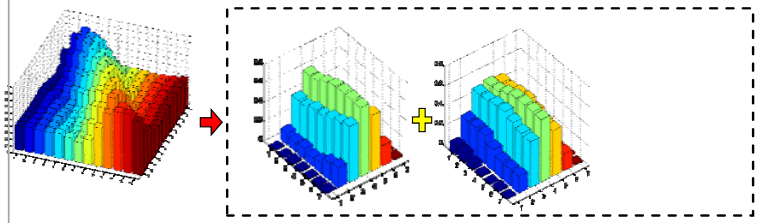
Deep learning algorithm: sub-pixel crack recognition and width measurement

Multi-scale feature fusion fracture delineation

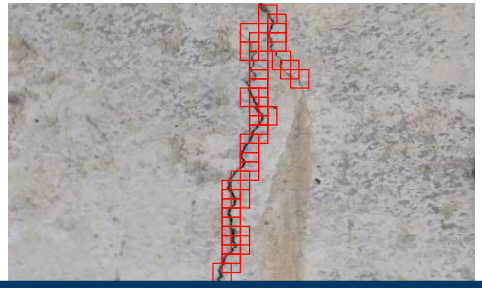


Zernike orthogonal moment width measurement

Interpolation of gray edge gradient

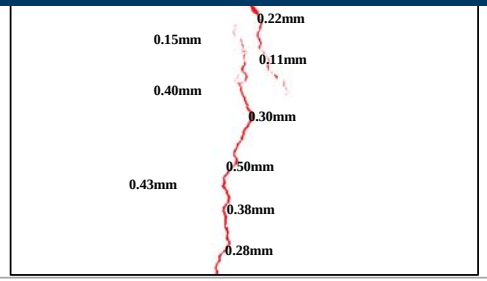


Crack identification

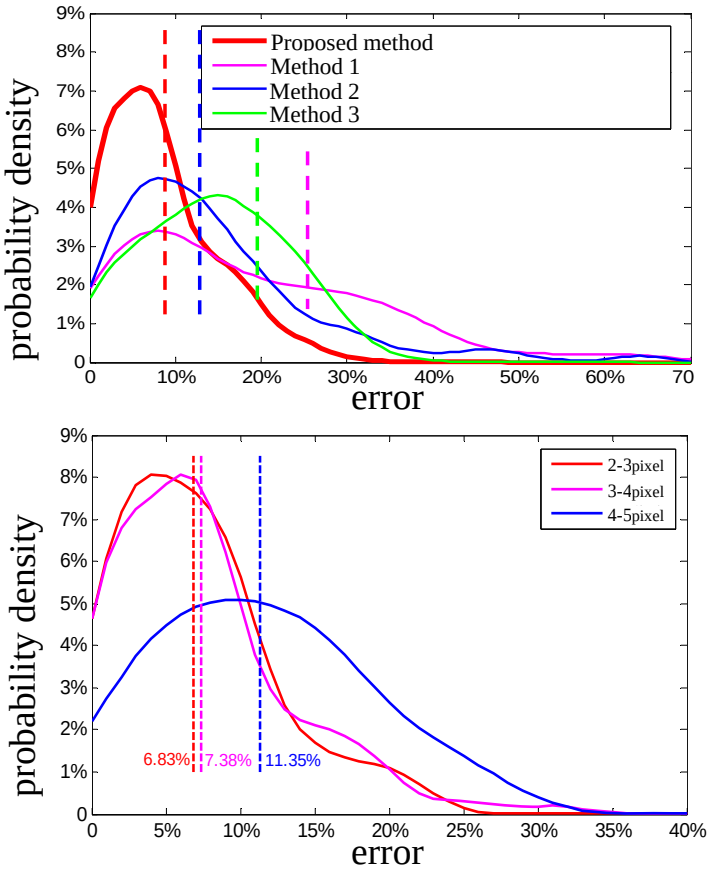


Automatic crack delineation

Crack width measurement



Accuracy comparison with traditional methods

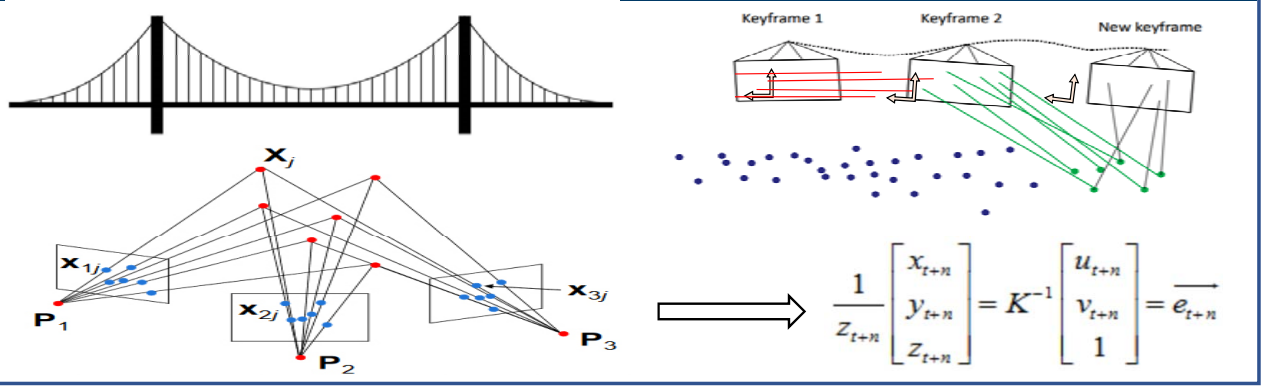


For fine cracks below 5 pixels, the proposed method has better measurement accuracy than traditional methods

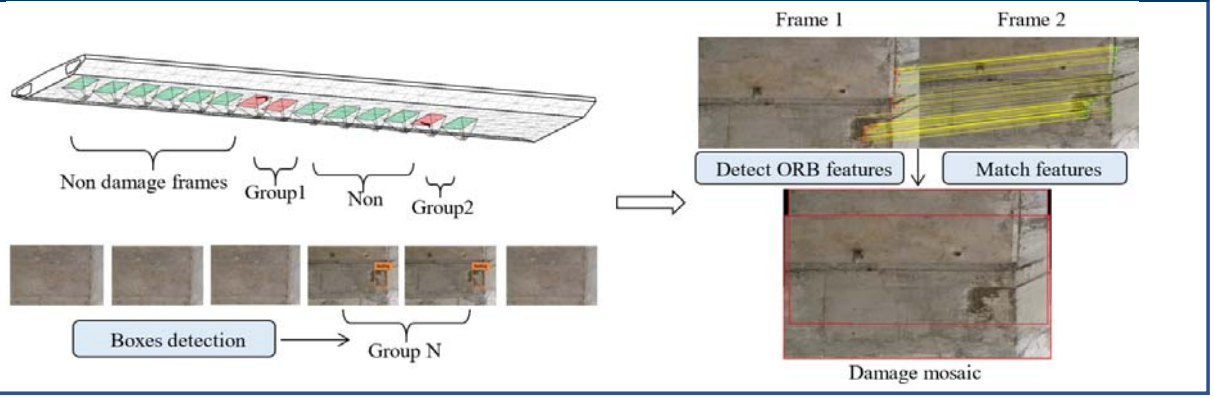
1.3 Automatic damage localization (level 3)

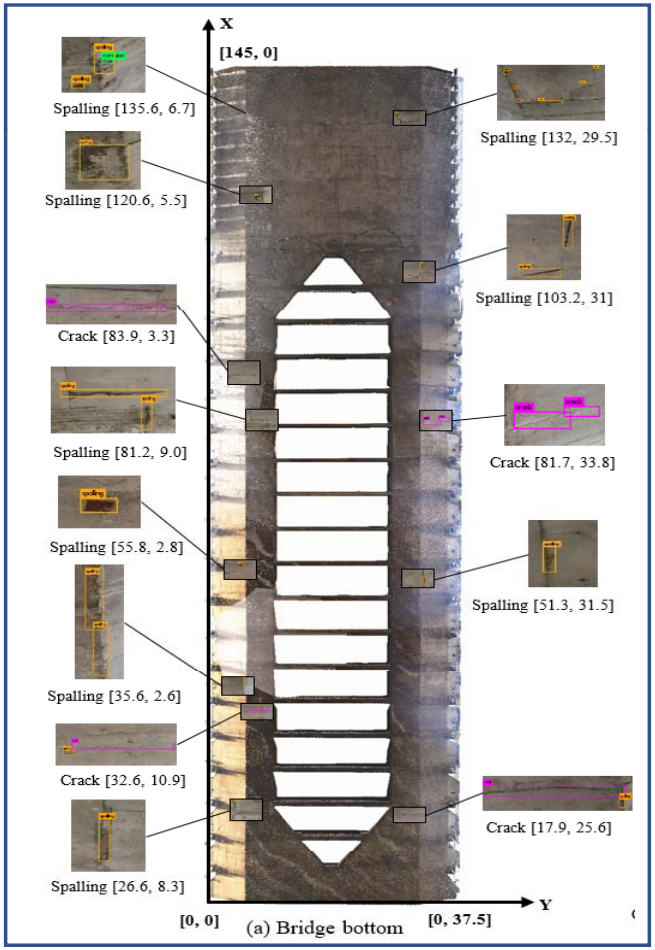
Mono-SLAM and image matching for defects localization

Multi-angle geometric image position



Automatic clustering of damage images





1.5.1 Multimode UAV for accurate crack inspection

■ Multimode UAV：switching between flight mode and wall-climbing mode

Multi-mode inspection

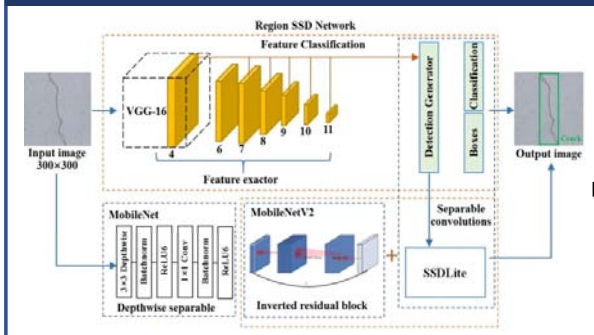
Overall check - (Wide view / High efficiency) - flight mode

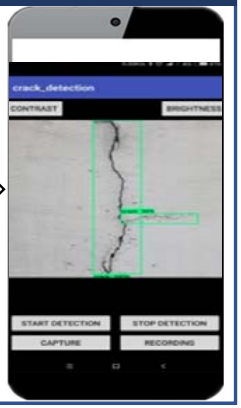
switching

Partial -(Close inspection / High precision)-crawling

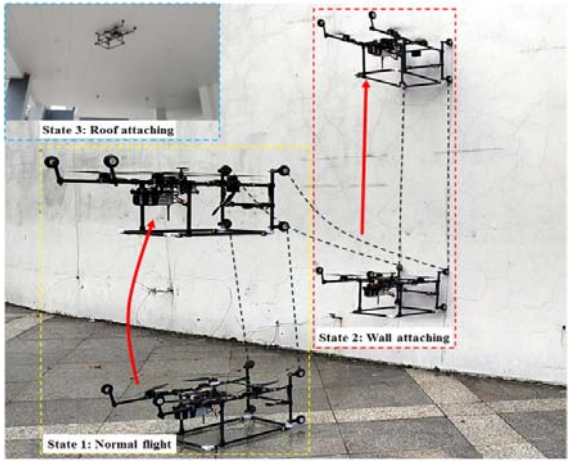
Two-mode inspection

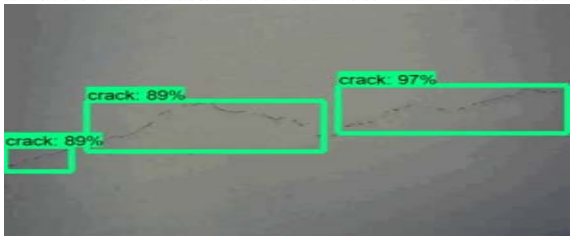
Smart phone application





- **Deep CNN**
- **Real-time recognition**





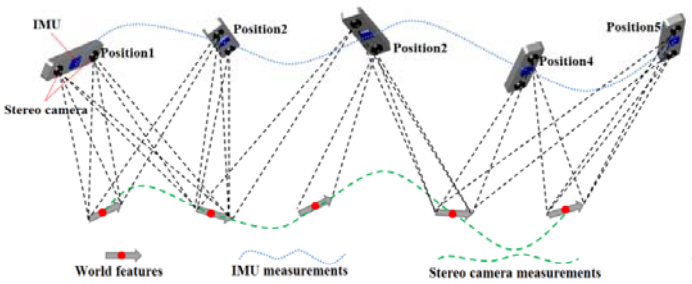
Comparison with traditional drone products

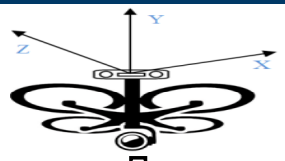
Comparison parameters	Commercial	**Proposed**
GPS Request	Strict	**None**
Detection Rate	Offline Detection	**Real-time Detection**
Width Measurement Accuracy	0.2mm	**0.1mm**

1.5.2 Visual navigation UAV for bridge inspection

■ Vision/IMU navigation algorithm is developed in case of GPS failure

Visual and IMU fusion

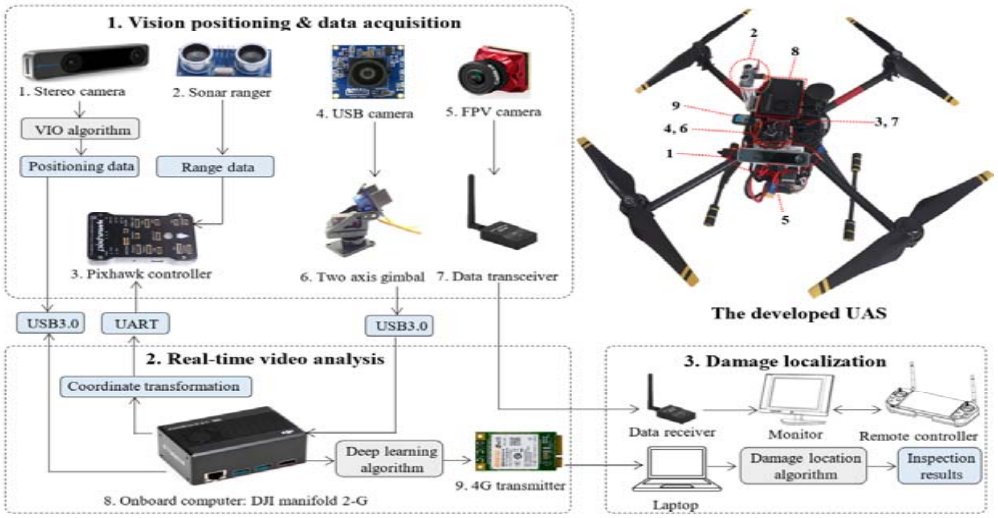




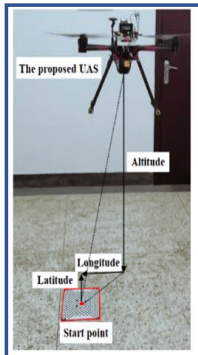
$$\begin{cases} \delta\dot{\boldsymbol{p}}_{IMUi}^{w} = \delta\boldsymbol{v}_i^w \\ \delta\dot{\boldsymbol{\theta}}_i^w = -\lfloor \boldsymbol{w} \times \rfloor \delta\boldsymbol{\theta}_i^w - \delta\boldsymbol{b}_g - \boldsymbol{n}_w \\ \delta\dot{\boldsymbol{v}}_i^w = -\boldsymbol{C}_i^w \lfloor \boldsymbol{a} \times \rfloor \delta\boldsymbol{\theta}_i^w - \boldsymbol{C}_i^w \delta\boldsymbol{b}_a - \boldsymbol{C}_i^w \boldsymbol{n}_a \\ \delta\dot{\boldsymbol{b}}_a = \boldsymbol{n}_{ba} \\ \delta\dot{\boldsymbol{b}}_g = \boldsymbol{n}_{bg} \end{cases}$$

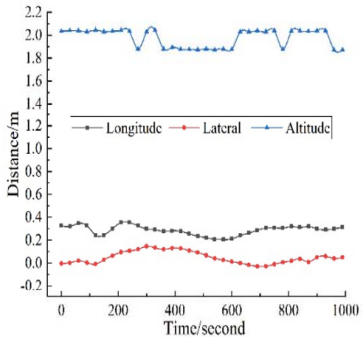
- **EKF estimation**

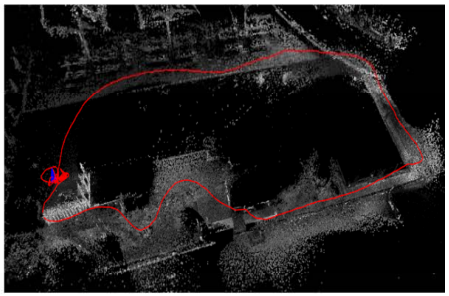
The overall composition of the bridge inspection UAV



The developed UAS







Similar accuracy as GPS positioning

1.5.4 Unmanned ship inspection system

■ Detection in inaccessible places

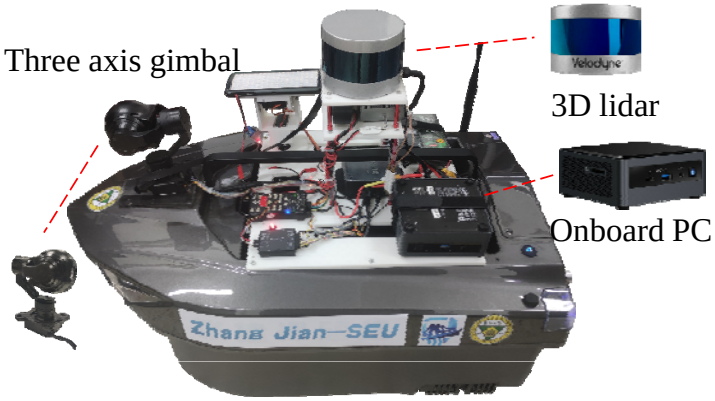
Background

insufficient clearance, difficult to enter

Poisonous gas in underground canal

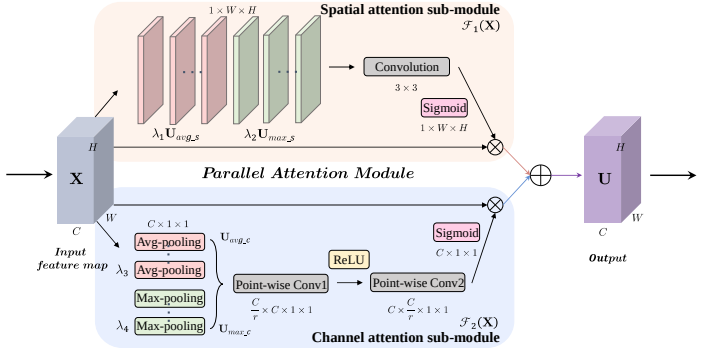
Solution

Hardware design



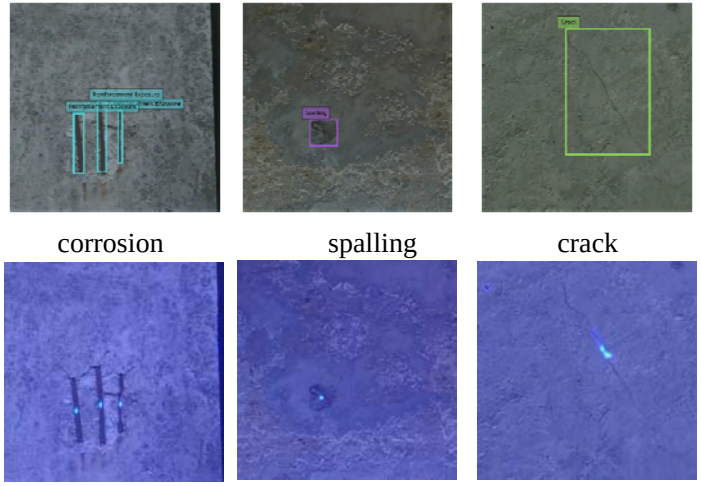
Software design

Anchor free network of attention mechanism



Lidar navigation

Automatic damage identification



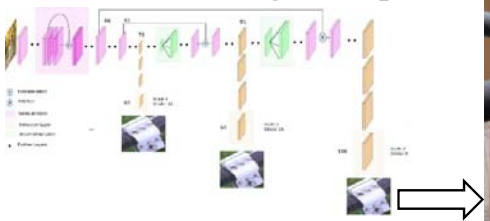
1.6 UAV-based bolt detection system and application

- **The proposed UAV-based bolt inspection system and method has been applied and verified on a bridge, and shown high accuracy and efficiency.**

Real-time UAV inspection

Cable bridge

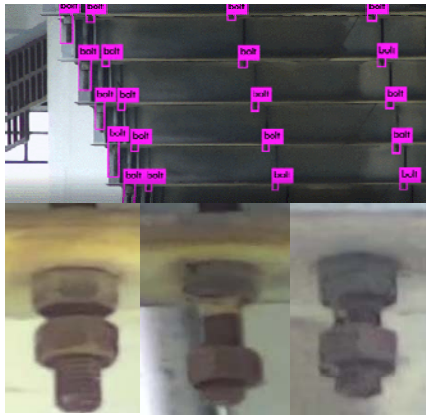
On-site flight inspection

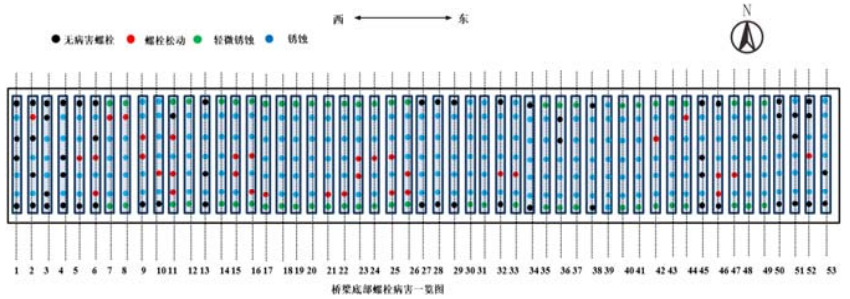


Lightweight network

Real-time inspection

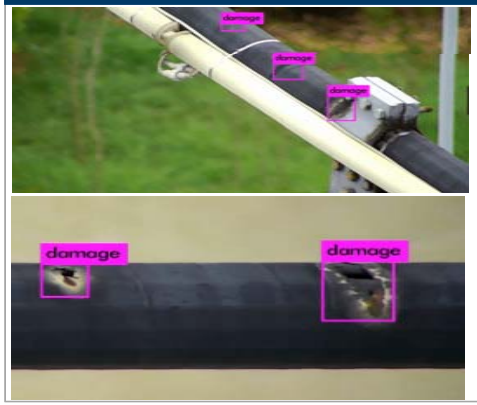
Full bridge bolt test results

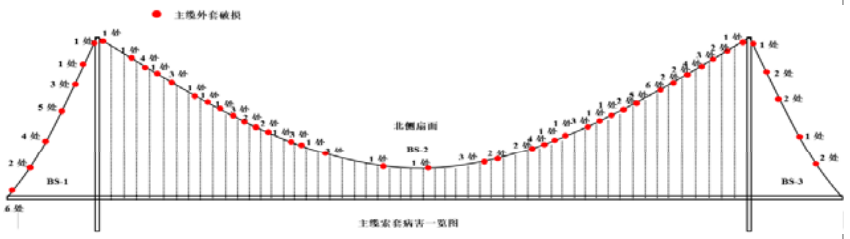




Full bridge bolt defects statistics

Cable sleeve test results





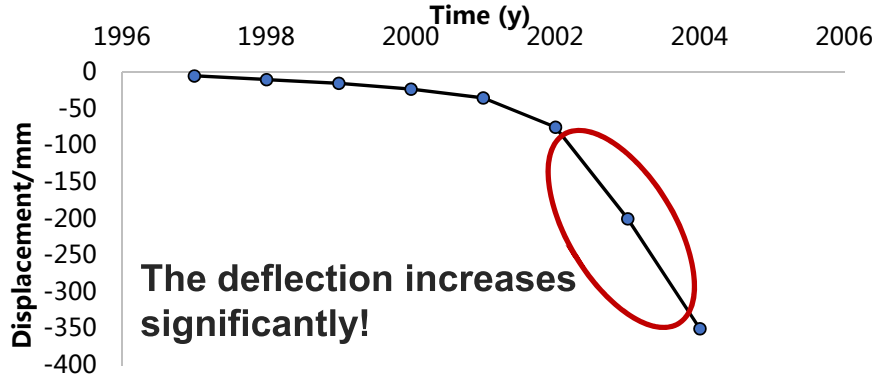
Full bridge cable damage statistics

Outline

Background

Deformation is an important indicator of bridge safety, but it is difficult to monitor the deformation of long-span bridges.

Bridge deformation



Deformation Monitoring is Difficult

Challenges: complicated and expensive

	High Precision	Long Distance	Real-time Stability	Multiple Points
Total Station	✓	✓	✗	✗
Connecting Pipe	✓	✗	✗	✓
GPS	✗	✓	✓	✗

Accurate, lightweight (simple equipment, fast calculation) bridge deformation monitoring technology

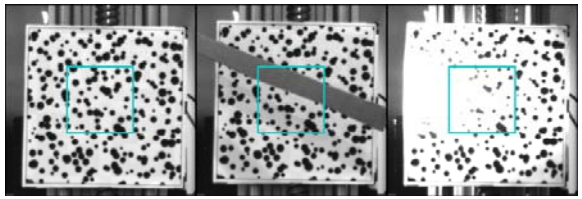
2.1 Robust target tracking under light and shadow variations based on deep learning

■ Combination of Siamese tracker and correlation-based template matching

Background

Long-term monitoring changes under environmental variations

Occlusion, lighting transformation

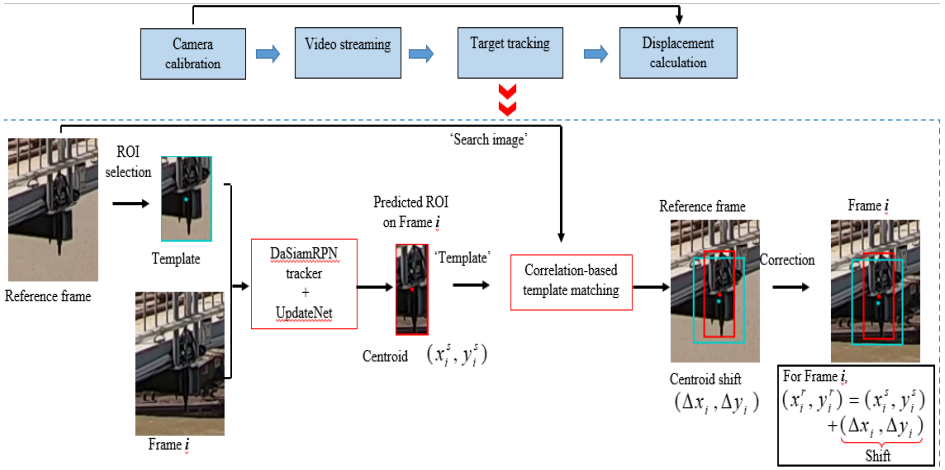


Background changes

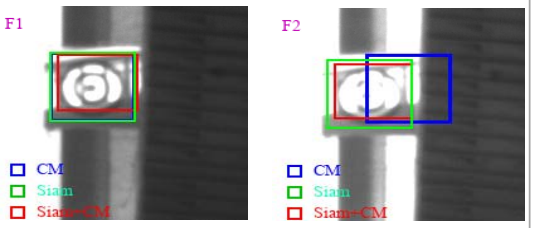
Innovation

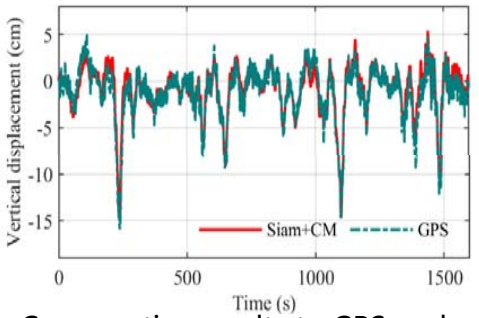
Robust target tracking method,

- Consider time-varying template changes by UpdateNet;
- Robust tracking by Siamese network + RPN regression ;
- Refinement of target positions by correlation matching.



Application Effect



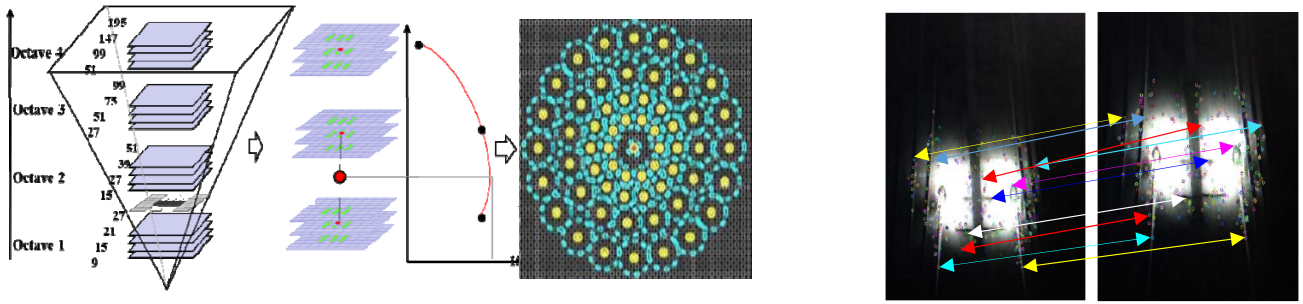


Comparative results to GPS under for long-distance under environmental variations.

Overcome the impact of environmental changes on visual displacement measurement

2.2 Image-based Remote Measurement System for Structural Deformation

- **Proposed a matching algorithm and camera disturbance elimination method and developed a real-time, high-precision deformation measurement system.**



SURF Feature point detection

Downscale SURF feature detection

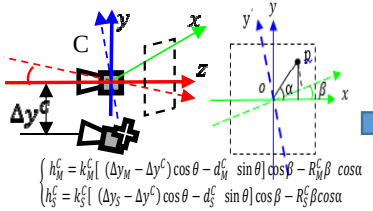
BRISK Feature point description

Add geometric consistency pre-screening mechanism

RANSAC Matching

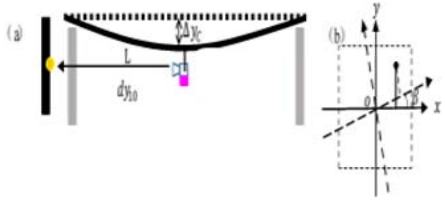
$$\begin{cases} k_i = (y_j - y_i)/(x_j - x_i) \\ d_i = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \end{cases}$$

Improved SURF-BRISK feature point matching algorithm

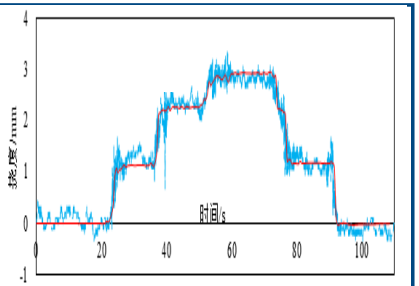


$$\begin{cases} h_M^C = k_M^C[\ (\Delta y_M - \Delta y^C)\cos\theta - d_M^C\ \sin\theta]\cos\beta - R_M^C\beta\ \cos\alpha \\ h_S^C = k_S^C[\ (\Delta y_S - \Delta y^C)\cos\theta - d_S^C\ \sin\theta]\cos\beta - R_S^C\beta\cos\alpha \end{cases}$$

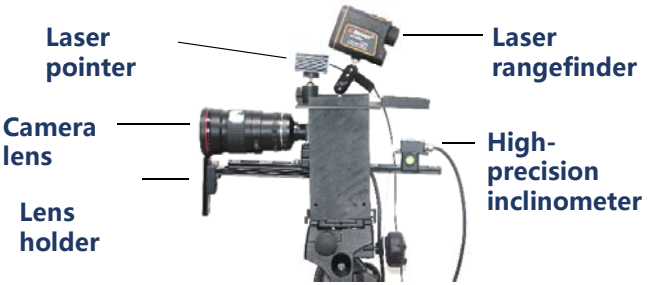
Single camera considering pitch angle



Bridge deflection measurement combining image and angle sensing



Camera disturbance elimination method



Deformation measurement system：

Real-time (calculated frame rate≥50Hz)

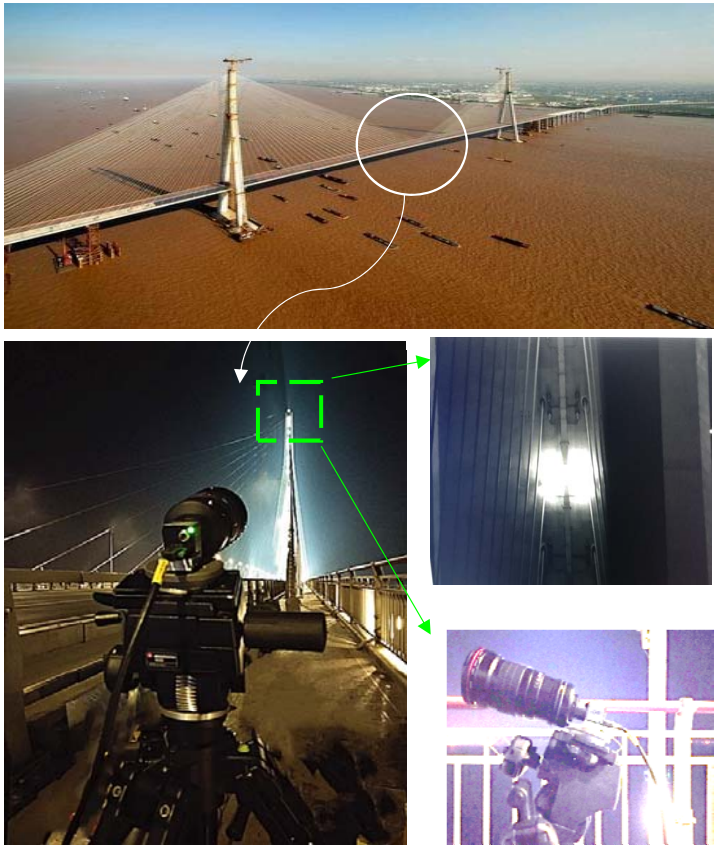
High precision (0.02pixel)

Standing Camera

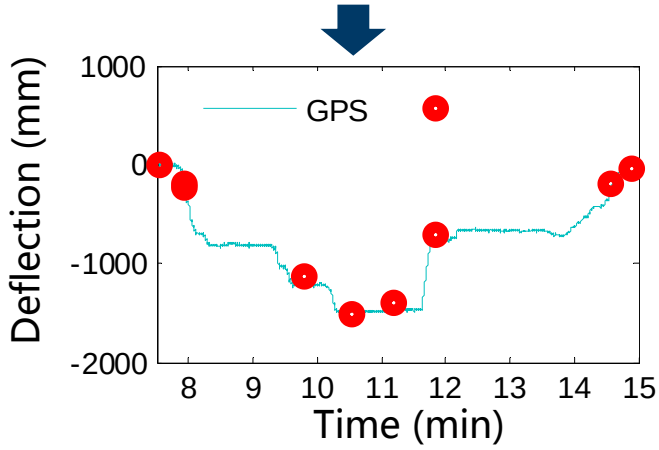
2.3 Application on a cable-stayed bridge

- **Optical measurement system to monitor the deformation of the main girder and the cable force of a cable-stayed bridge**

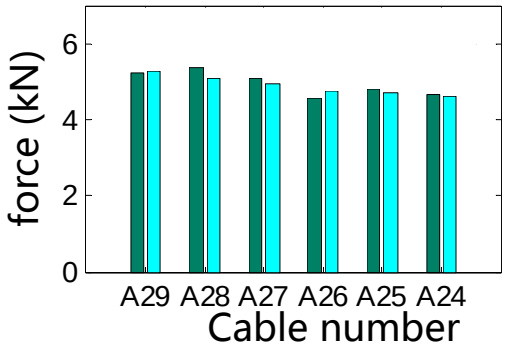
Main beam deformation and cable force monitoring



Main beam deformation test



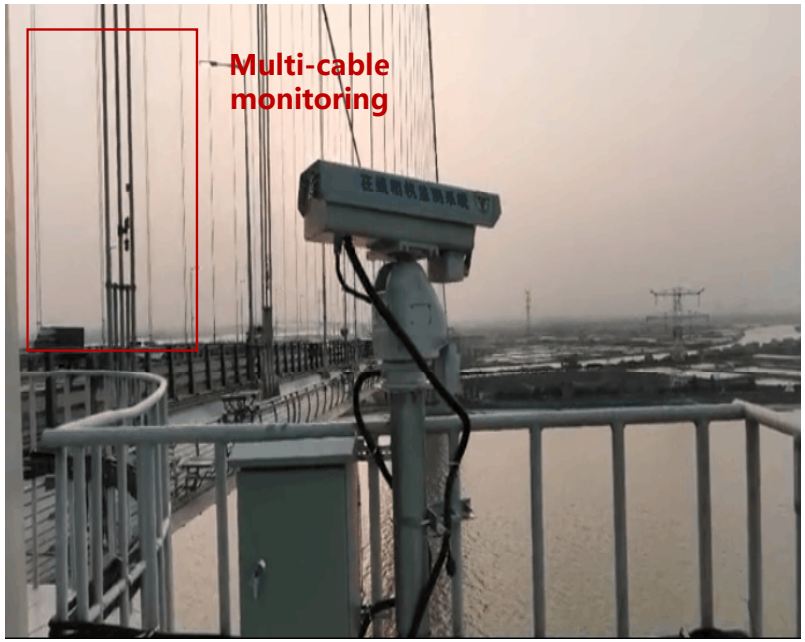
Cable force test



2.5 The system of real-time measurement camera(RMC-01)

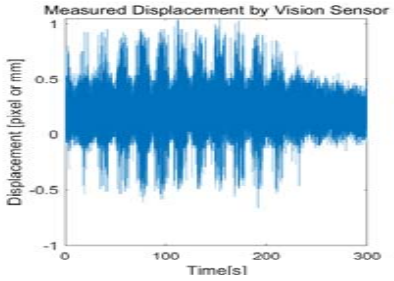
- The real-time measurement camera was also applied on the cable force monitoring of a Long span suspension bridge, and gave early warning for abnormal cable

cable force monitoring

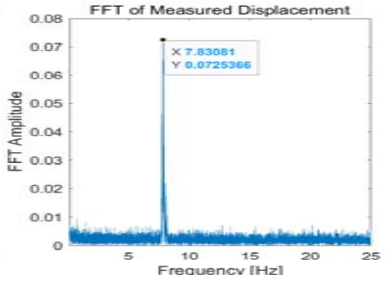


The abnormal vibration of the third cable of the side span was monitored for a long time and the early warning was successful

Results for cable force monitoring



Dynamic displacement



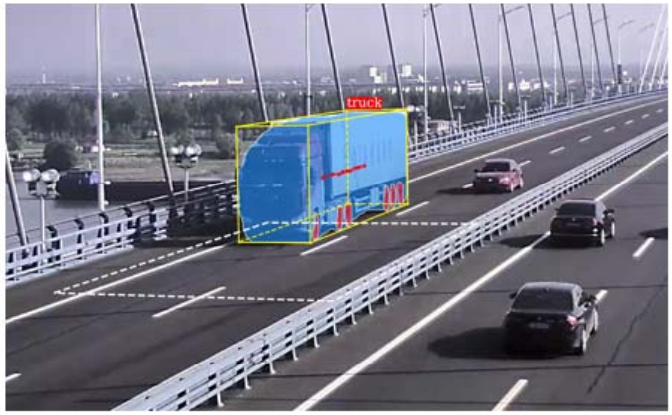
frequency spectrum

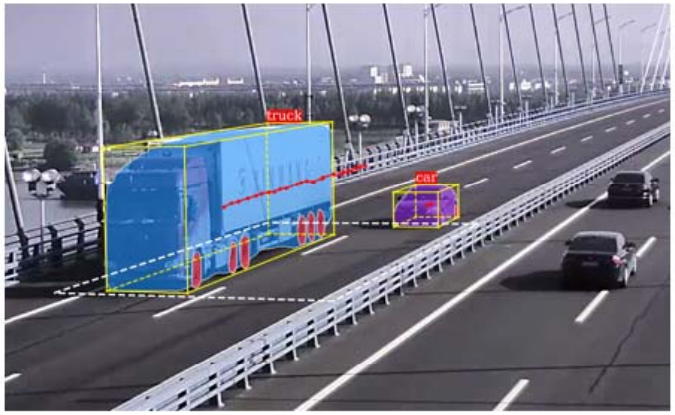
2.7 Recognition of spatial and temporal distribution of vehicle Load

- **Developed a real-time acquisition system for bridge deck vehicle information based on computer vision**

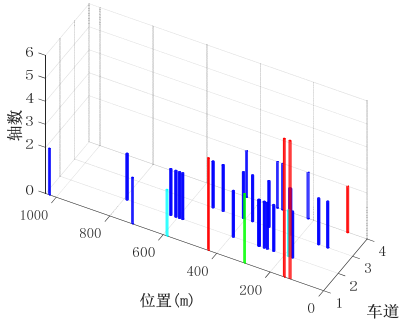
Anqing Highway Bridge

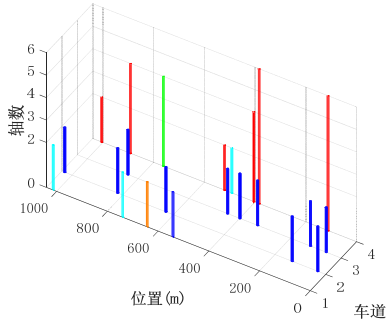
Real-time monitoring of bridge deck vehicles

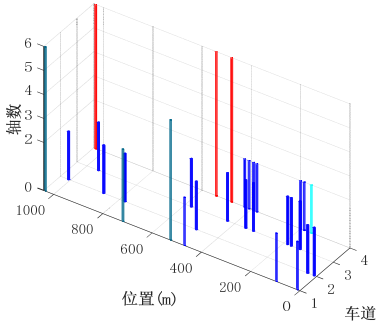


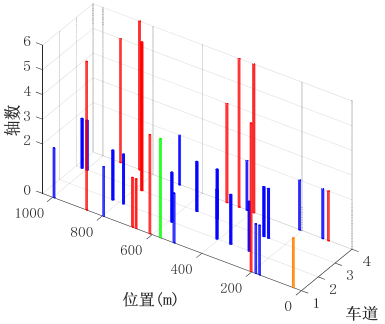


Bridge deck vehicle Temporal and spatial distribution





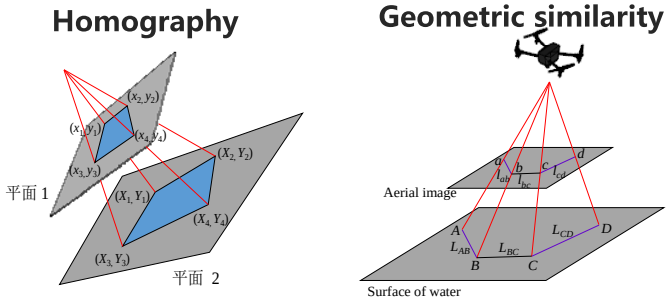




2.8 Intelligent recognition and early warning of vessel collision

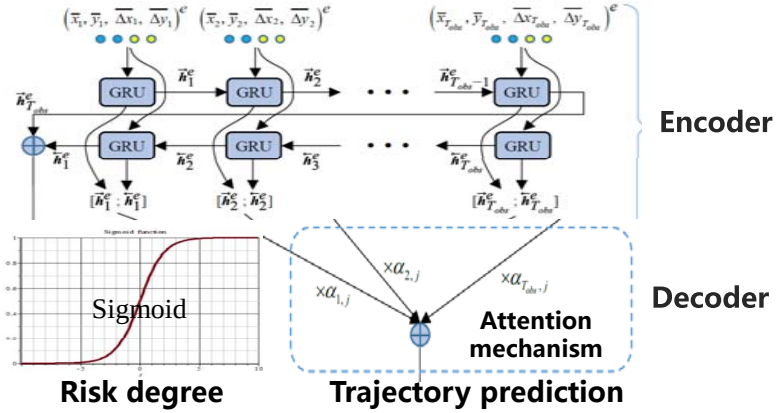
- **Developed a vessel-bridge and vessel-vessel collision warning system based on a data-driven dual-task encoder-decoder network**

Computer vision positioning



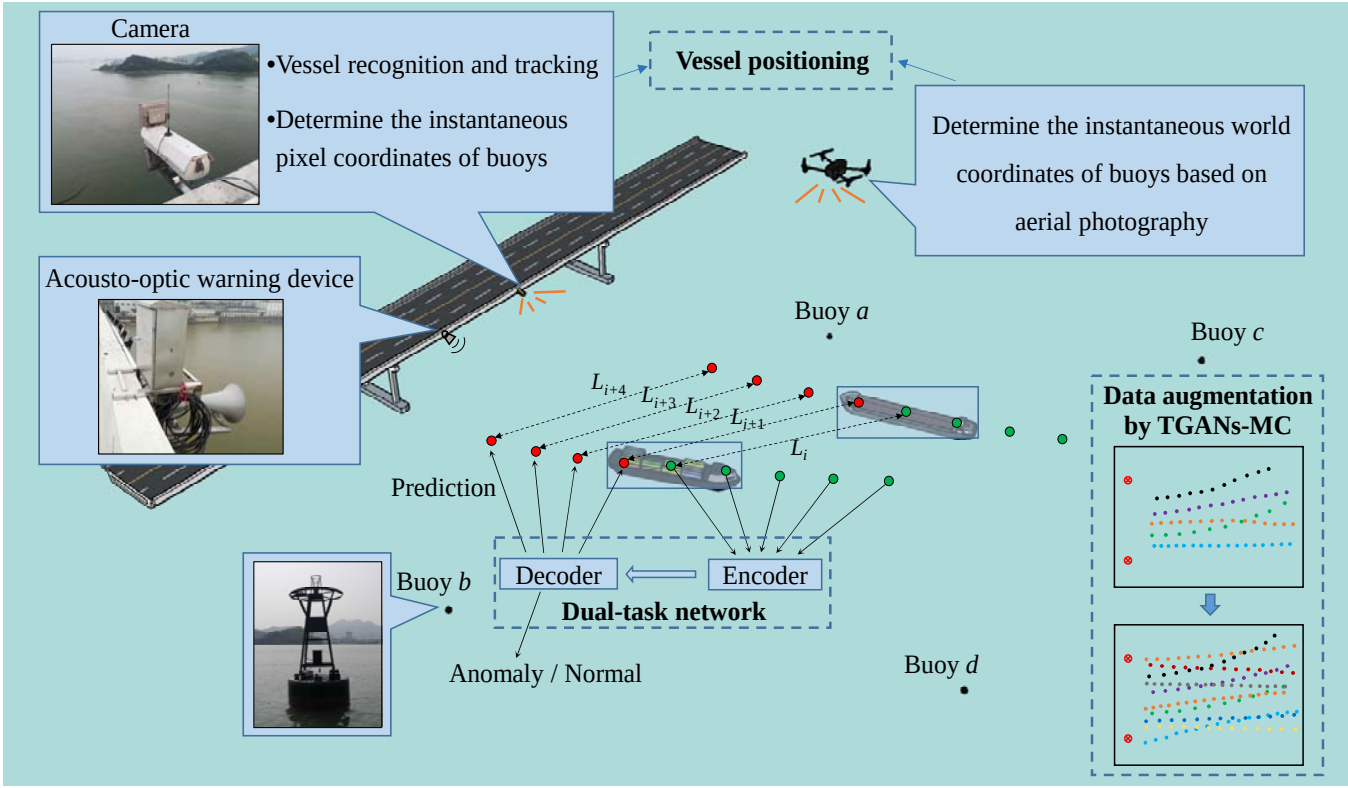
Positioning without stable reference target

Dual-task encoder-decoder network



Vessel-bridge and vessel-vessel collision simultaneous warning

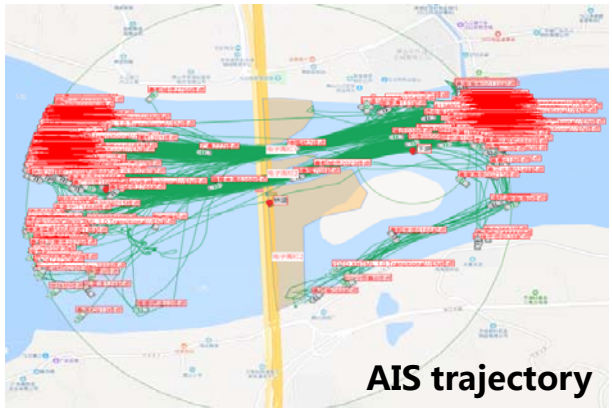
Vessel Collision Warning System of Jiujiang bridge



2.8 Intelligent recognition and early warning of ship collision

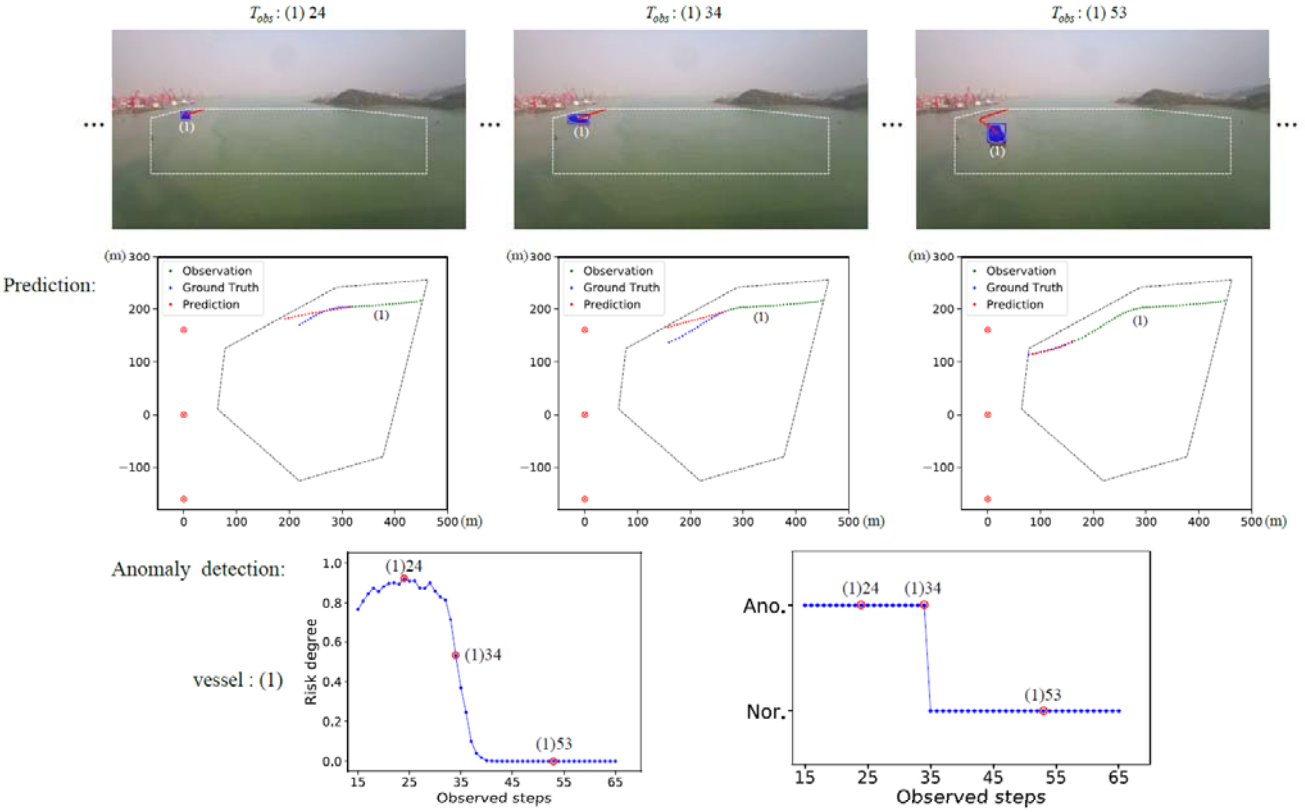
■ Application

AIS based collision avoiding method



(1) low reporting frequency
(2) low positioning precision
(3) system can be turned off

Developed vessel collision warning system



Data-driven method

The vessel which has high collision risk with the bridge bas been detected

Outline

01 Intelligent Detection of Structural Defects

02 Vision-based Monitoring Technology

03 3D Reconstruction Measurement Technology

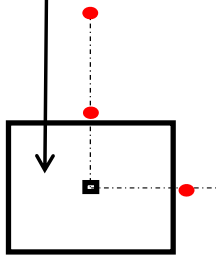
Background

Labor intensive

Time consuming

Pre-installed targets

Theodolite

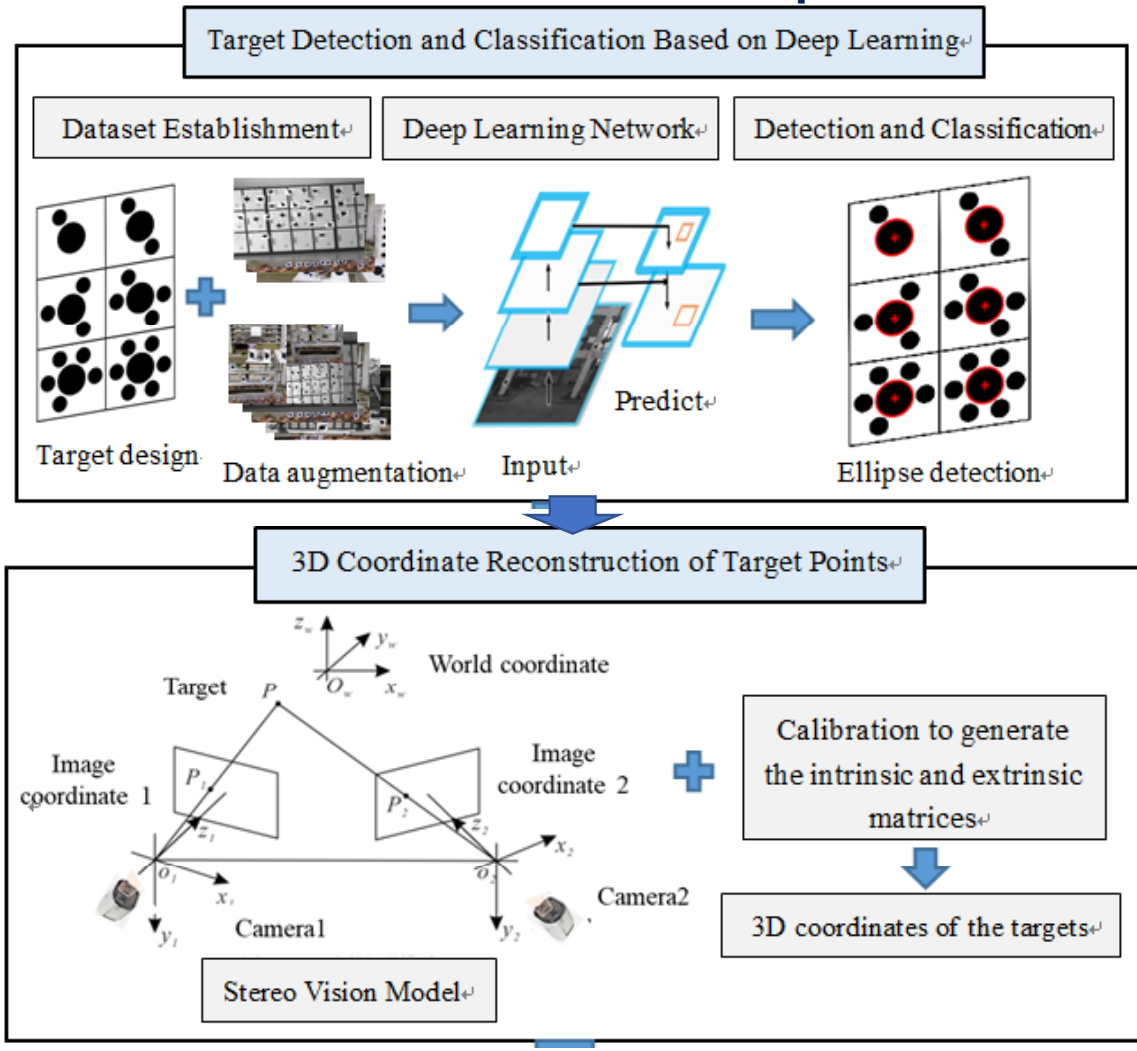


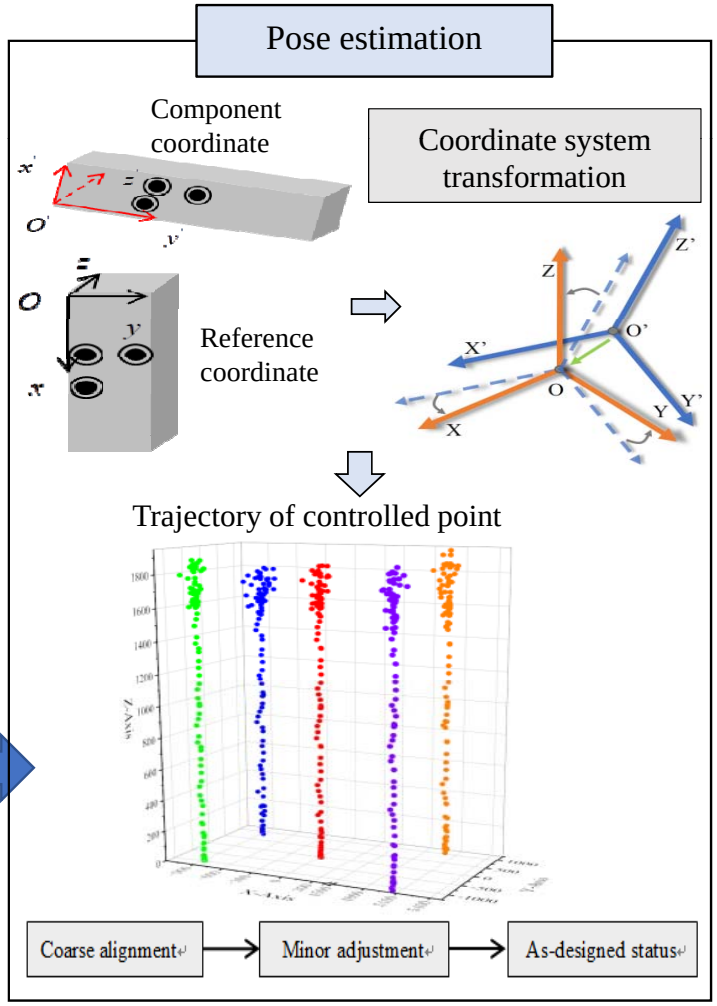
Theodolite 2

Requirment on fast and labor-saving measurement and monitoring technology

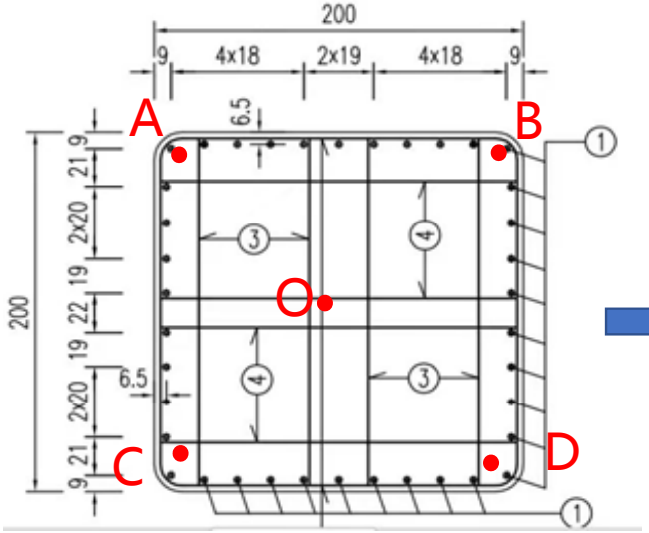
3.1 Construction quality control of precast components hoisting based on binocular vision

- **A stereo-vision based trajectory monitoring system is proposed for the guidance of construction on site with non-contact and consecutive acquisition in real-time**

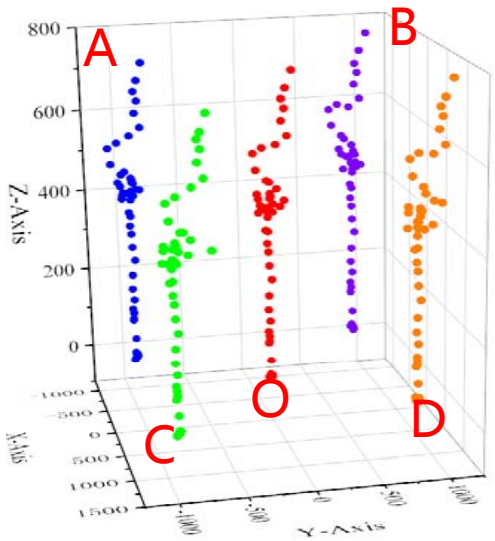




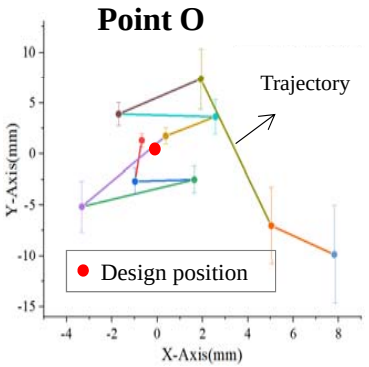
3.1 Construction quality control of precast components hoisting based on binocular vision

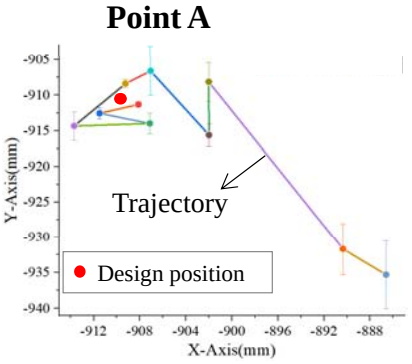


Trajectory of controlled point during installation

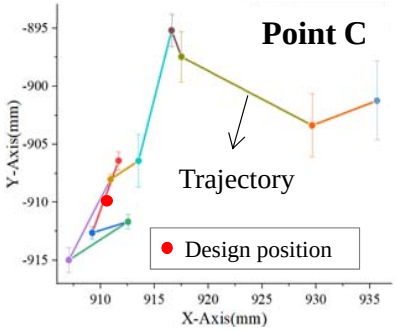


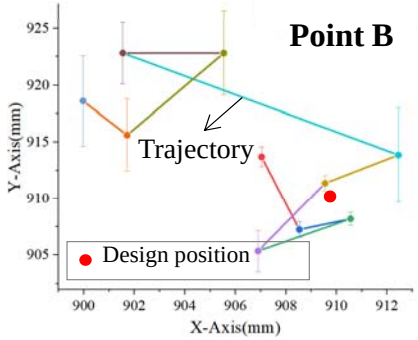
Minor adjustment in XY-plane

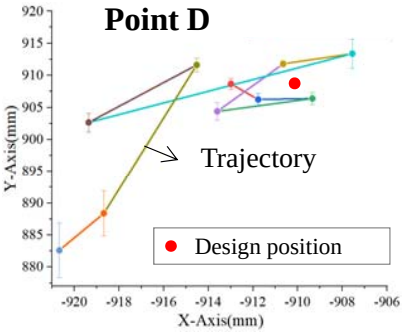




Output accurate pose for guidance of construction on site!

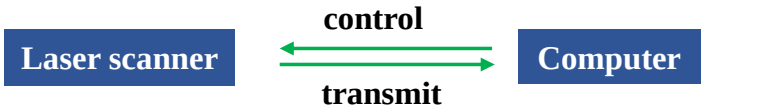


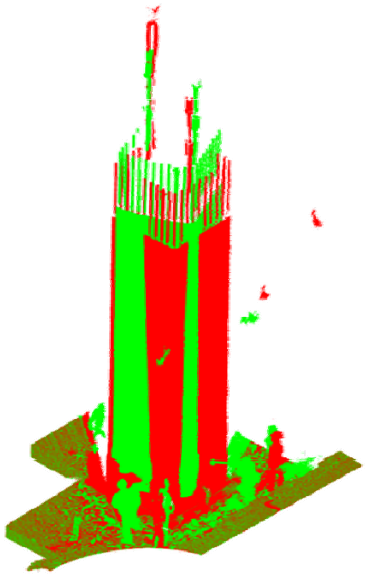




3.2 Laser scanning based erection monitoring

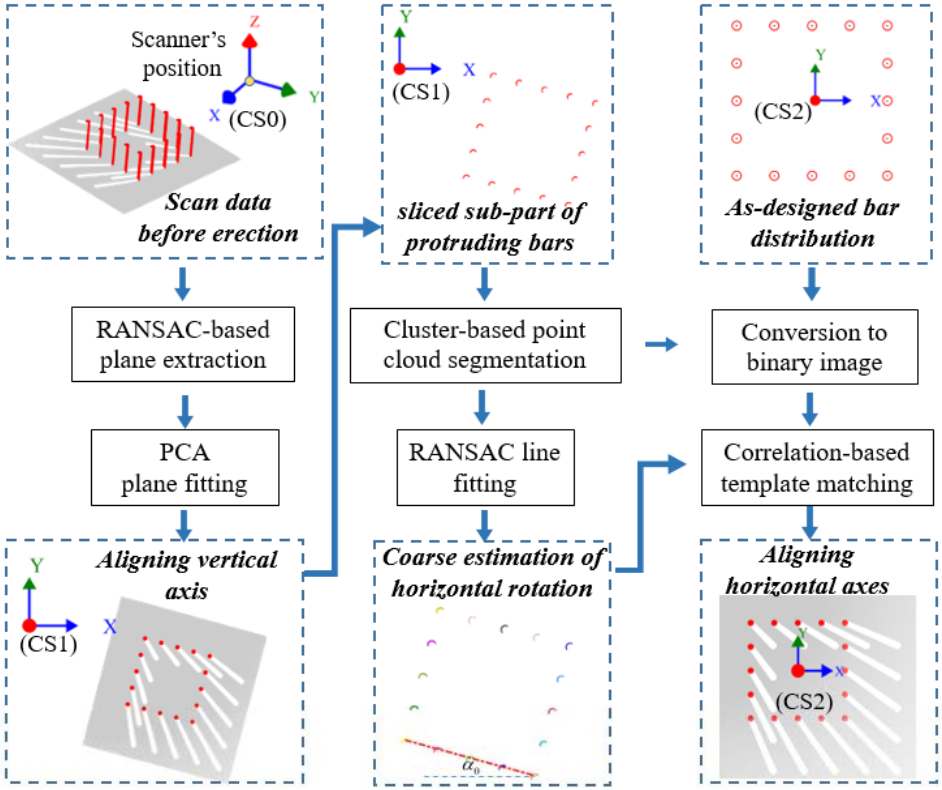
Monitoring process





Pre-calibration

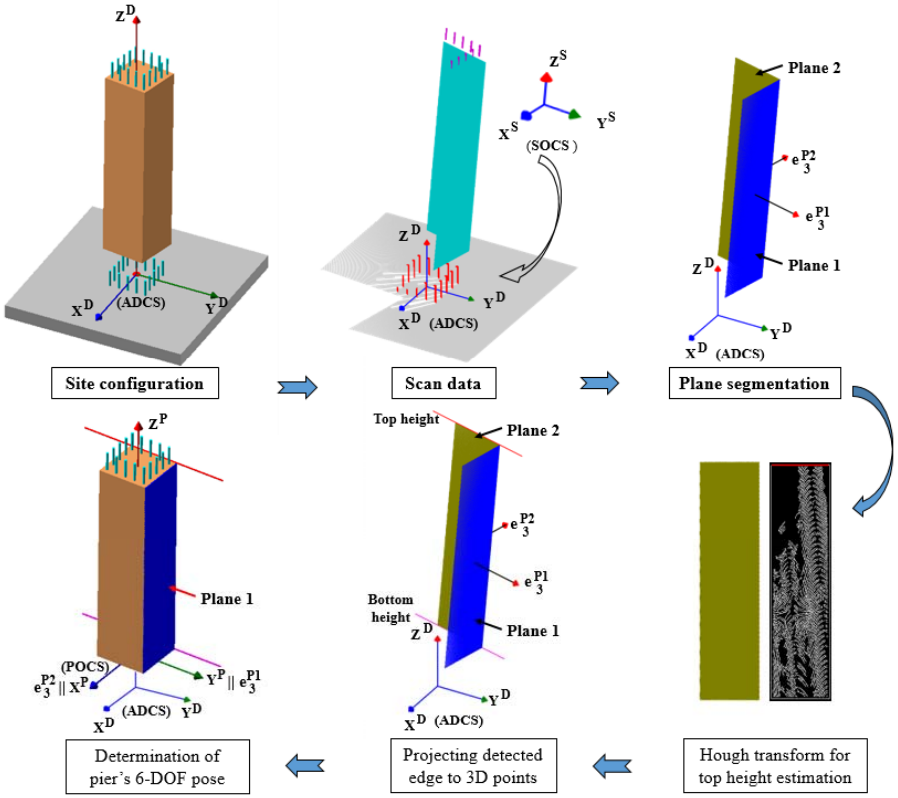
Scanner's own CS->As-designed CS



3.2 Laser scanning based erection monitoring

Erection process

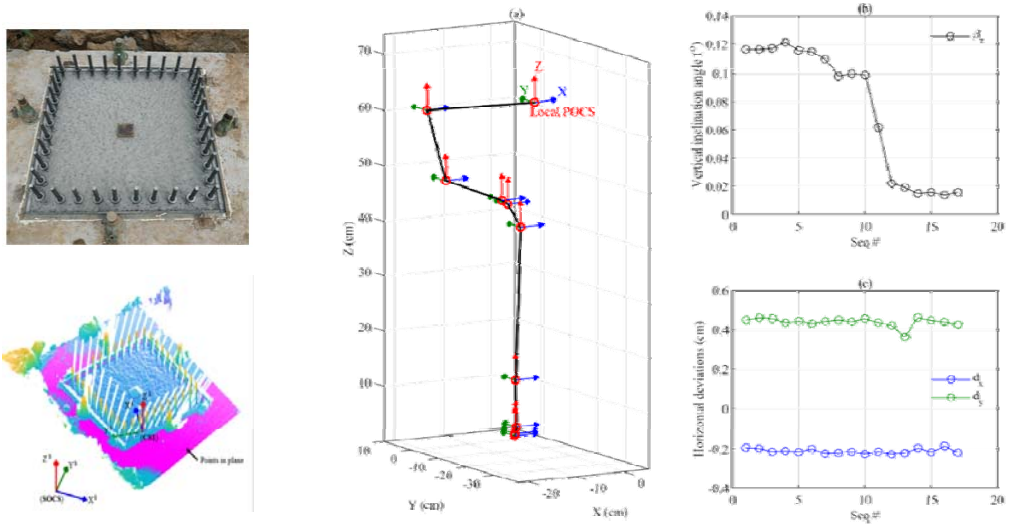
Scanner's CS->Pier's local CS->As designed CS



Advantage

- Non-contact, no need to assist, arbitrary station
- Automatic output component 6 DOF posture
- Guidelines the pier column to fine tune

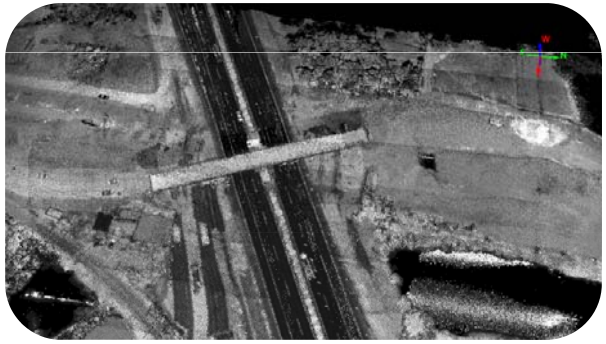
Measurement results



Conclusion

1.Intelligent Detection of Structural Defect

2.Vision-based Monitoring Technology



3.3D Reconstruction Measurement Tech

Thanks for your attention!

Dr. Jian Zhang

Email：jian@seu.edu.cn