

# 초실감 시각지능 뉴럴 렌더링을 활용한 디지털 트윈 기반 구조물 이상진단 기술

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25 추계 원자력학회 워크숍  
최신 연구활용 원자로계통 설계기술  
창원컨벤션센터  
2025년 10월 29일



# MEIC Lab (Mechanical Systems with Intelligence and Computer Vision Laboratory) <http://meic-lab.com>

## 한국뉴욕주립대학교 최종성 조교수



### 핵심 역량

- MEIC Lab에서는 시각인공지능을 공학, 산업 및 공공분야에 적용하는 학문적 토대를 연구하고 개발합니다.
- 대표보유기술: 1) 혼합현실 내 인간-기계 협업 및 Teleoperation 시스템; 2) 시각지능 기반 초실감 디지털 트윈 모델링 및 렌더링; 3) 데이터 학습기반의 미래차 SDK 시스템 개발; 4) 시각지능 기반 3차원 객체인식 및 제어

### 주요 경력

- (2020~현재) 조교수, 기계공학과, 한국뉴욕주립대학교, 대한민국
- (2020~현재) Research Professor, Stony Brook University, NY, USA
- (2020) Postdoc, Argonne National Lab., IL, USA
- (2020) Purdue University, IN, USA, 기계공학박사
- (2014) University of Mississippi, 기계공학석사
- (2012) University of Mississippi, 기계공학학사
- (2021~현재) 대한기계학회 신뢰성부문 사업분과 수석이사
- (2020~현재) 한국PHM학회 대내사업분과 수석이사
- (2025~현재) 한국신뢰성학회 총무이사
- (2015~현재) IEEE 국제 전기전자공학협회 회원

### 주요 정부출연 개발과제 - 27억 63백만원 as PI

- (2025~현재) PI, NRF 우수신진연구, True Twin: 혼합현실에서의 다자간 분산 협업 및 AI 기반 초실감형 산업 디지털 트윈, 12.5억원
- (2025~현재) PI, 한국전파진흥협회, 메타리얼: 초실감 부동산 공간정보 메타버스 기술 사업화, 6.6억원
- (2022~현재) PI, 우주항공청, 미래 우주탐사 및 우주자원 활용 기술 연구센터, 4.75억원
- (2019~2019) NASA, USA, RETH: Resilience ExtraTerrestrial Habitat Institute, 참여연구원
- (2019~2020) NSF, USA, Integrating Human and Machine for Post-Disaster Visual Data Analytics, 참여연구원
- (2017~2019) New Horizon, EU, Safeguarding Cultural Heritage through Organisational Resources Management, 참여연구원

### 주요 기업체 개발과제 - 3억 28백만원 as PI

- (2025) PI, 현대자동차, 물리 기반 신경망(PINN)을 활용한 전기차 에너지 예측 PHM 모델 및 전기차 전용 내비게이션 시스템 개발, 6천만원
- (2024) PI, 한국선급, 지각지능 활용 무인선박 검수 플랫폼, 8천만원
- (2024) PI, MDS Intelligence, 초실감 사진기반 실내 모델링 기술 개발, 6천만원

### 주요 특허 - 등록 1건, 출원 7건

- 3D 가우시안 스프래iting 디지털 트윈 플랫폼, 대한민국, 10-2025-0058453
- 라이다 스캐닝 정합과정을 MR헤드셋에서 실제환경에 맞게 시각화하는 혼합현실장치, 대한민국, 10-2025-0017754
- 속도 로그 데이터 및 물리 지식 신경망을 활용한 전기차 동역학 계수 추정 및 에너지 소비 예측방법, 대한민국, 10-2025-0017752

### 주요 논문 - SCI 저널논문 27건, 저서 1건, 학회논문 48건

- Jonathan Boyack and **Jongseong Choi\*** et al., (2024), Photogrammetry engaged automated image labeling approach, *Visual Analytics*
- Jonathan Boyack, **Jongseong Choi\*** et al., (2024), LogPath: Log data based energy consumption analysis enabling electric vehicle path optimization, *Transportation Research Part D: Transport and Environment*
- **Jongseong Choi\*** et al., (2022), Similarity Learning to Enable Building Searches in Post-event Image Data, *CACAI/E (IF: 11.775, JCR 상위 0.72%)*
- Xiaoyu Liu, **Jongseong Choi** et al., (2022), Automated Image Localization to Support Rapid Building Reconnaissance in a Large-scale Area, *CACAI/E (IF: 11.775, JCR 상위 0.72%)*
- **Jongseong Choi\*** & Shirley J. Dyke (2021), CrowdLIM: Crowdsourcing to Enable Lifecycle Infrastructure Management, *Computers in Industry. (IF: 7.635)*



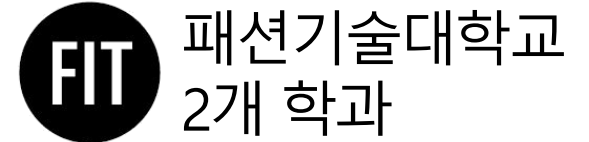
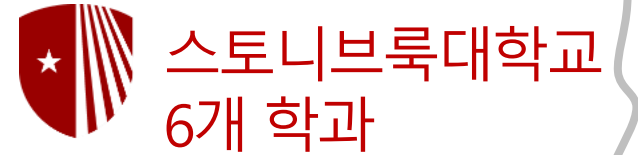
**Director**  
Dr. Jongseong Brad Choi

# About SUNY Korea (Location)



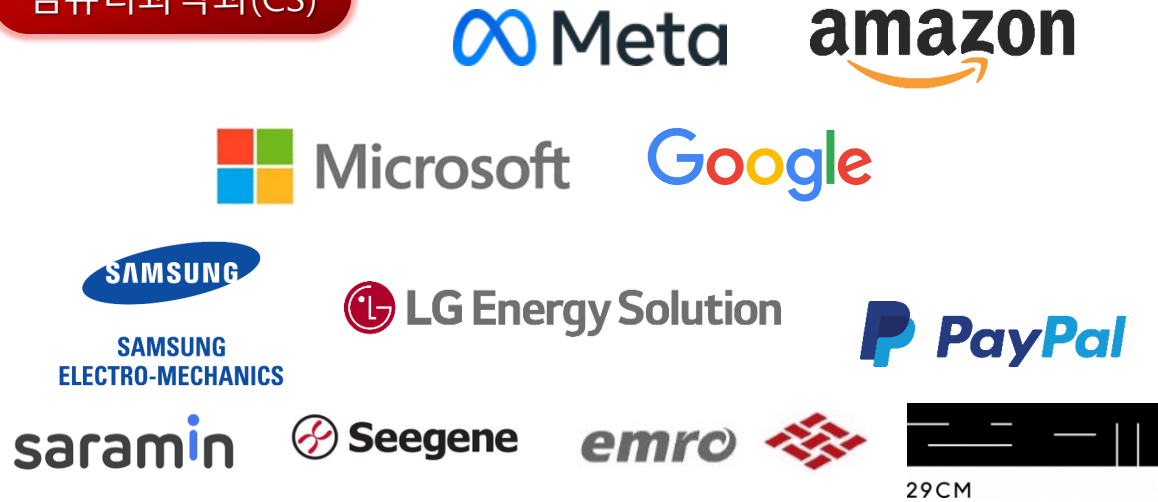
확장 캠퍼스

2012년  
설립



# About SUNY Korea (Career)

## 컴퓨터과학과(CS)



## 기술경영학과(TSM)



## 경영학과(BM)

Deloitte.



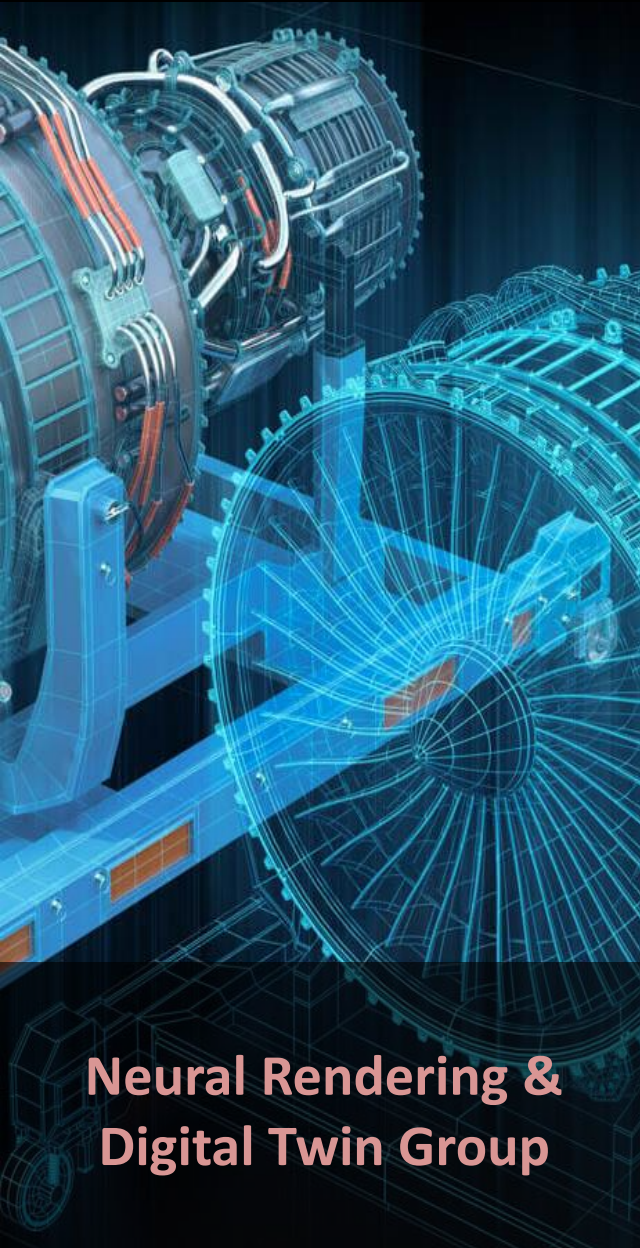
## 기계공학과(ME)



## 응용수학통계학과(AMS)



# MEIC Lab. Visual Intelligence and Representative Project



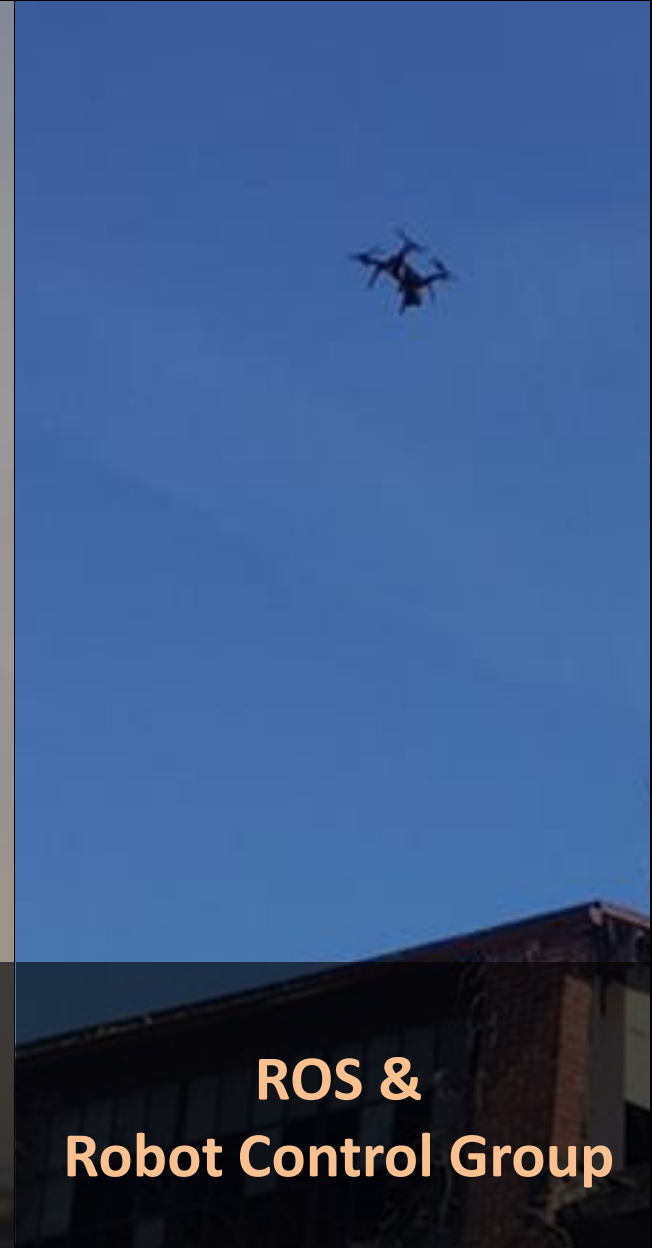
Neural Rendering &  
Digital Twin Group



Mixed Reality &  
Computer Vision Group



Deep Learning &  
EV-PHM Group



ROS &  
Robot Control Group

## Group members



Jee Won Lee,  
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Geonwoo Kim,  
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Dohyeon Lee,  
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Sanha Jang,  
BS Student  
Neural Rendering  
& RC Group

# Neural Rendering & Reality Capture Group

## TrueTwin: Hyper-Realistic 3D Reconstruction and Twining through 3D Gaussian Splatting

Audai Theinat, **Jongseong Choi** et al., (2019). Geology Explorations of Lava Tubes in the National Beds Lava Monuments. In 50th Annual Lunar and Planetary Science Conference (No. 2132, p. 3232).

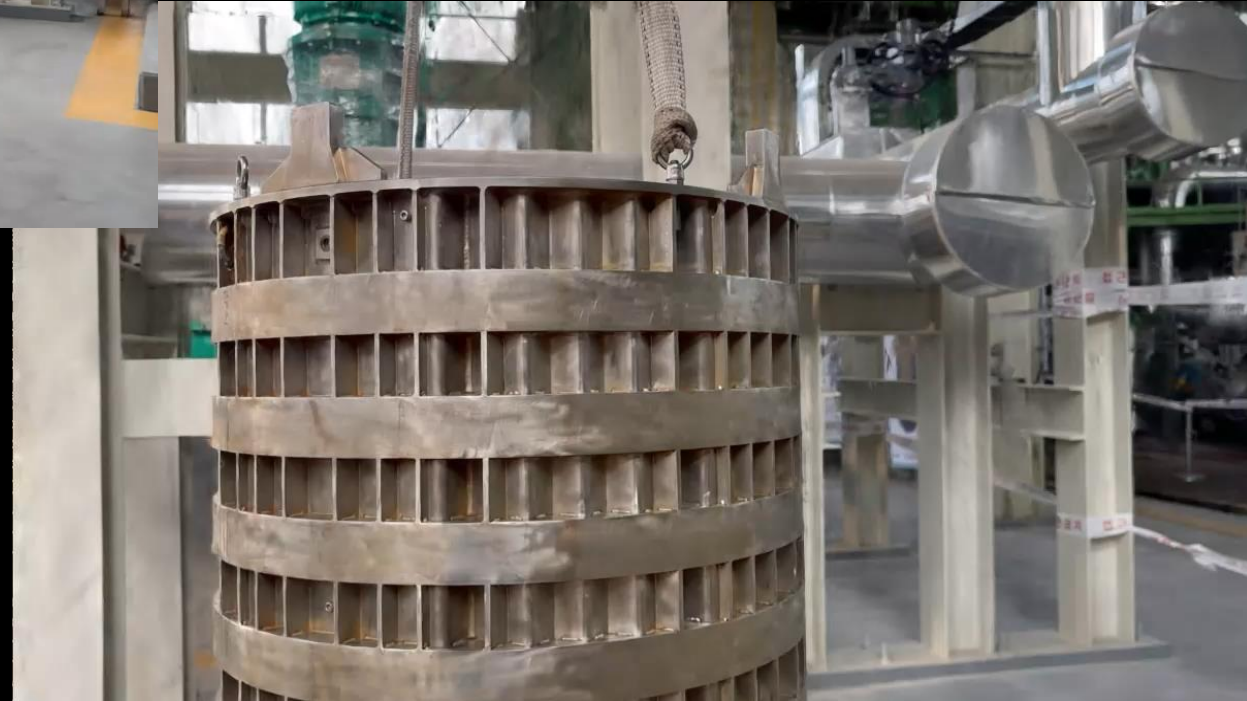
Lim, Hansol, Chang, Hanbeom, Choi, **Jongseong Brad Choi\***, and Yeum, Chul Min. (2024). LiDAR-3DGS: LiDAR Reinforced 3D Gaussian Splatting for Multimodal Radiance Field Rendering. *International Society for Photogrammetry and Remote Sensing (ISPRS)*, (Under Review)

Lee, Jee Won, Choi, **Jongseong Brad Choi\***, and Lim, Hansol. *Development of a Web-Based 3D Gaussian Splatting Platform for Remote Inspection of Maritime Ship Components*. (Under review)





## 원자로재부구조물 축소모델에 대한 시 기반 초고해상도 3D 모델링 학술용역 (2025)



# Background – Current State-of-the-Art

## History in Computer Vision for 3D Reconstruction

Early 2000s

### LiDAR Sensor-based 3D Point Clouds

Uses laser pulses to measure distances  
→ generating highly accurate  
and dense 3D point clouds



- Vulnerable to occlusion, noise, and environmental factors (rain, fog, etc.)
- Lacks inherent color & texture information, requiring additional processing for realistic visualization
- LiDAR sensor is costly

Mid 2000s

### Structure-from-Motion SfM

Reconstructs a sparse 3D point cloud from a  
sequence of overlapping 2D images by  
detecting and matching keypoints across  
frames



- Requires sufficient overlap & distinct feature detection → challenging in low-texture or highly repetitive scenes
- Produces a sparse reconstruction that often necessitates additional densification steps (MVS) for detailed modeling

2020

### Neural Radiance Field Rendering NeRF

Uses deep Neural Network to learn  
a continuous volumetric representation from  
multiple images



- Training & rendering are computationally expensive & time-consuming
- Requires expensive GPU hardware

2023

### 3D Gaussian Splatting 3DGS

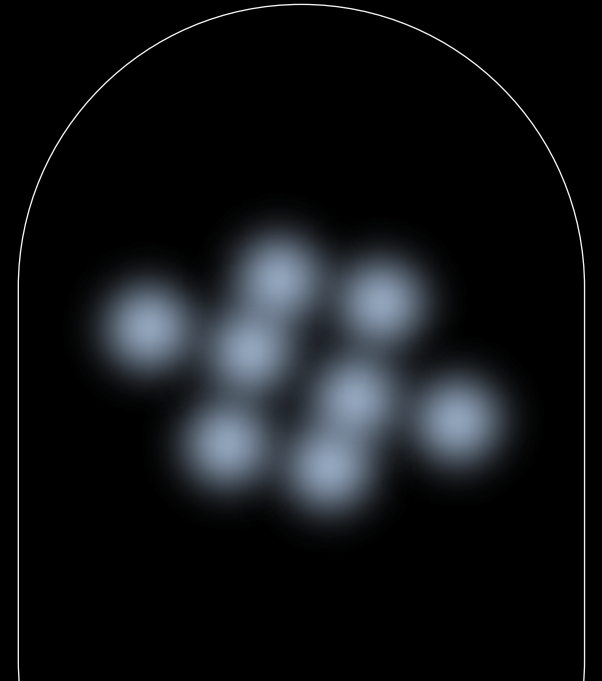
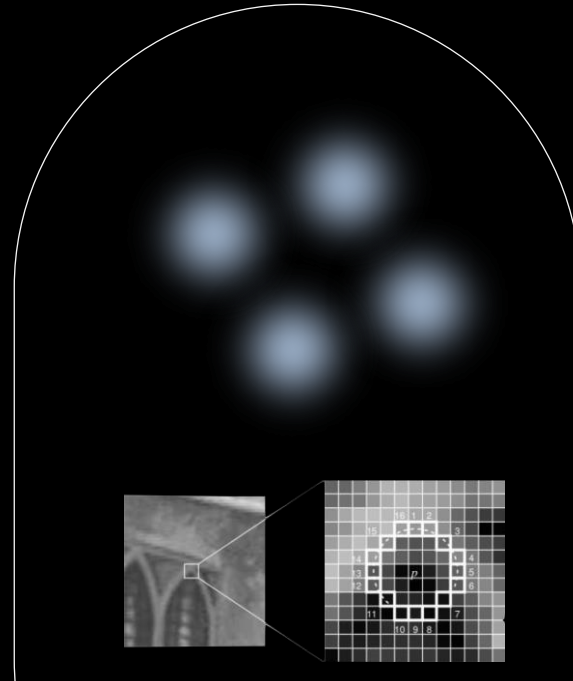
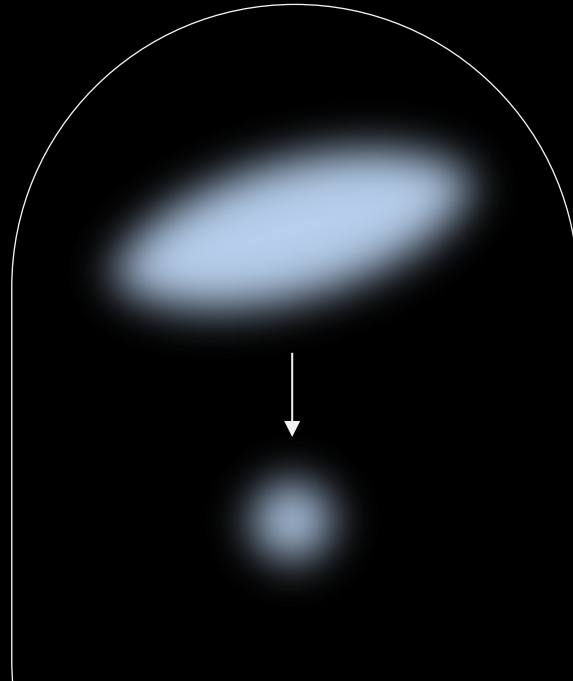
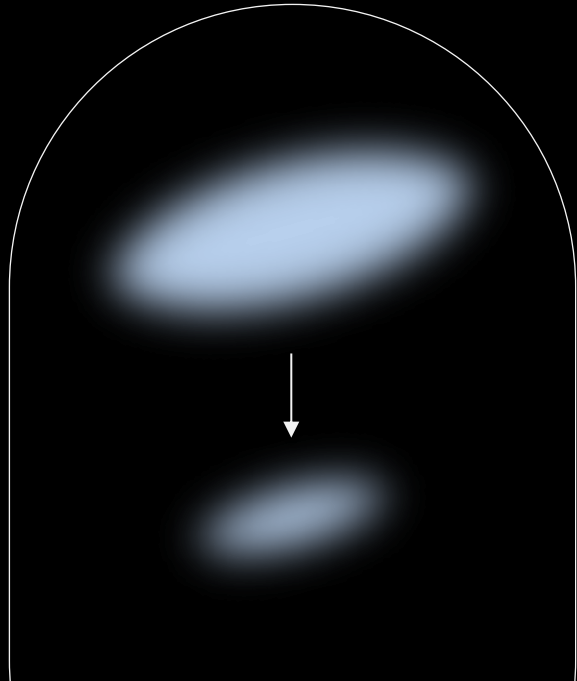
Represents scenes as collection of explicit  
Gaussian primitives, allowing for fast,  
accurate 3D reconstructions

Enables real-time rendering & interactive  
visualization while preserving fine details



So does 3DGS Solve Everything  
to visualize scene for the inspectors?

# Micro-Splatting: Summary



Making gaussian splats very small

Making gaussians almost like sphere

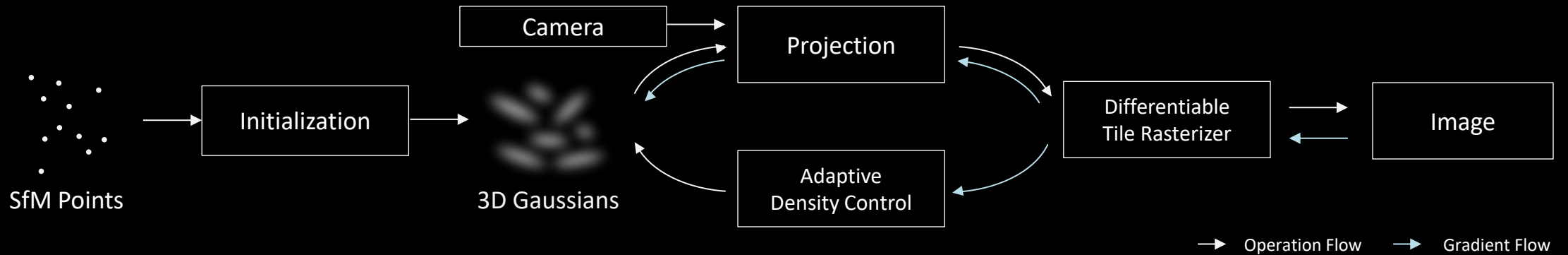
Making them small only in high gradient regions

Making sure that there are no empty spaces between the small splats

# 3D Gaussian Splatting

## Overview of 3D Gaussian Splatting

Micro-splatting follows the 3DGS pipeline but integrates a novel framework that enhances the training loop with an augmented loss, covariance-based regularization and adaptive densification



# Discussion & Limitation

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**Targeted Covariance Control:** By penalizing large or elongated Gaussians, Micro-splatting keeps each splat compact and nearly isotropic, which helps preserve sharp, high-frequency details that would otherwise be blurred away.

**Adaptive Densification:** The approach selectively splits Gaussians in high-gradient areas, increasing local splat density exactly where fine structures are needed, thus capturing textures and edges without ballooning the total point count everywhere.

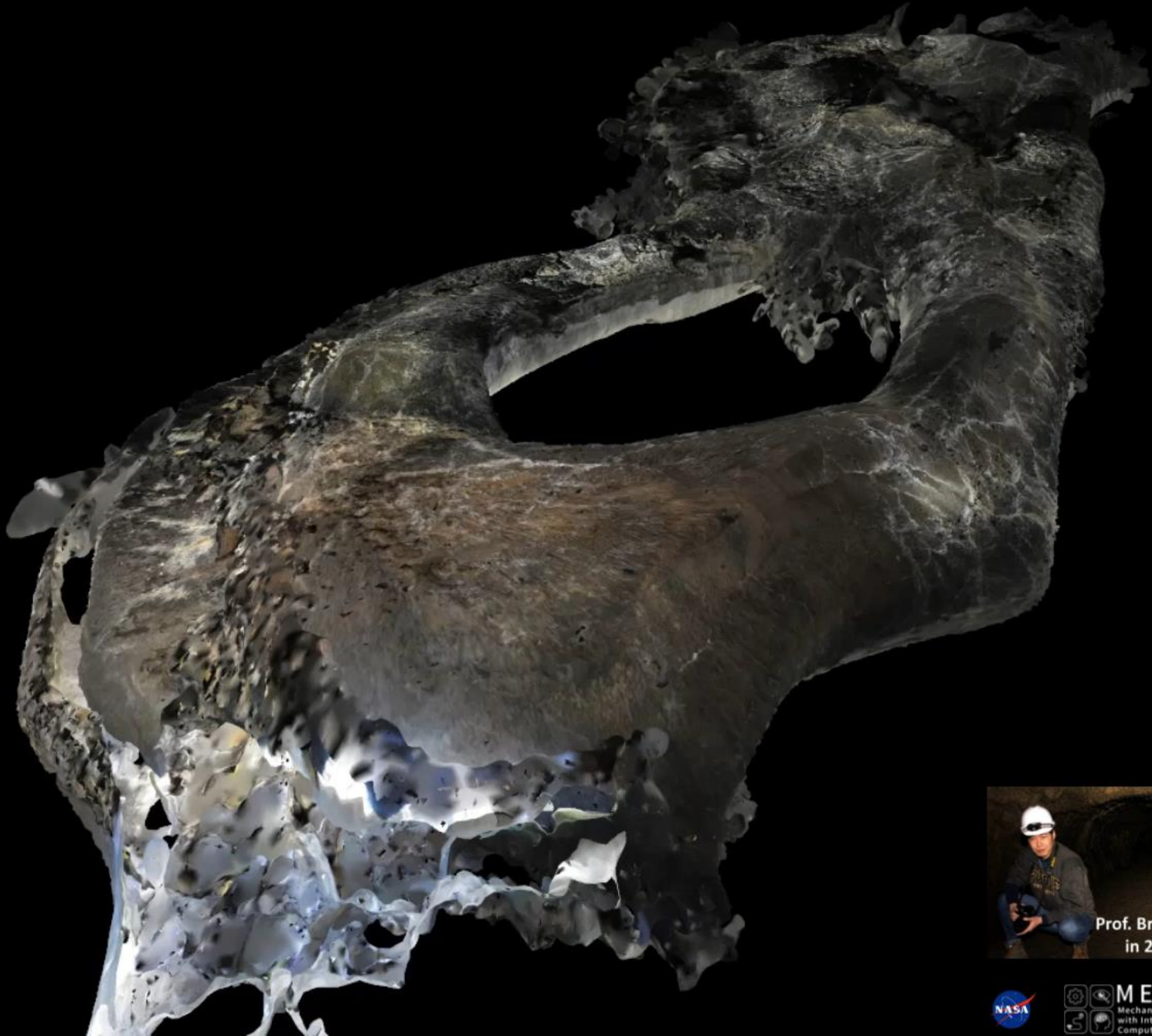
**Enhanced Loss Design:** Adding an L2 term and a covariance penalty to the baseline L1 + SSIM framework provides stronger local gradient signals and explicitly discourages overly large splats, leading to sharper reconstructions while retaining real-time rendering performance.

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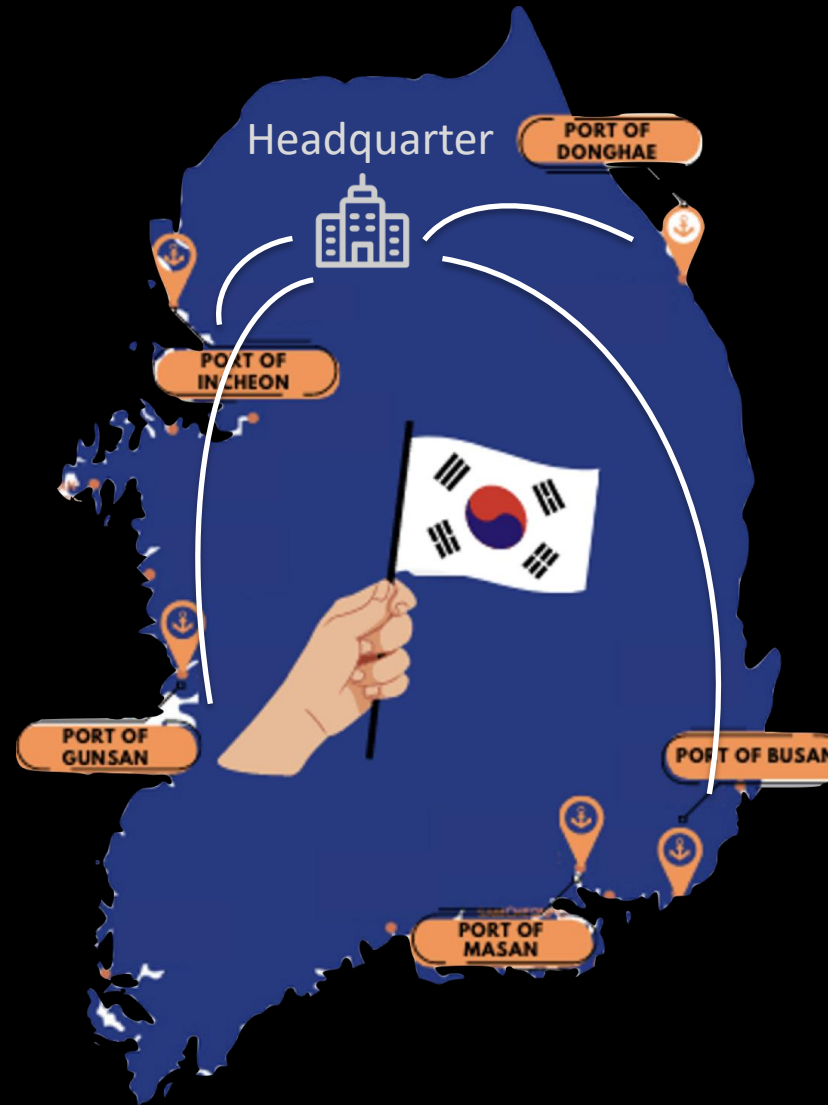
- Adaptive splitting process can introduce additional computational overhead if thresholds are not optimally set.
- The method's performance is sensitive to the quality of the initial point cloud from COLMAP, so noisy or incomplete data may degrade results.
- Tradeoff of retaining quality and accuracy of the model and FPS exists.



# Neural Rendering & Digital Twin Group Applications



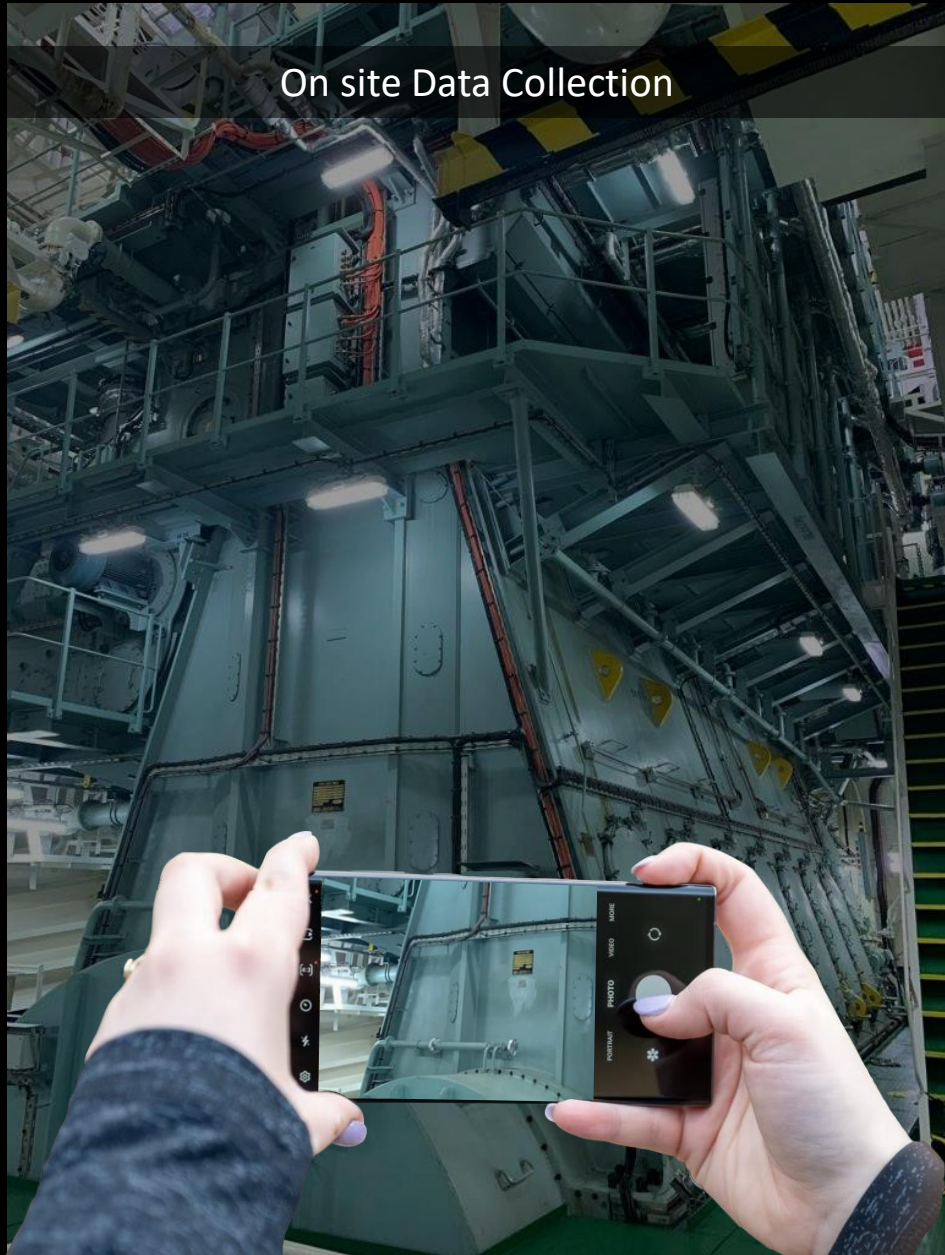
## Main Ports in South Korea



But not only this, but the challenges of inspection exists not only in dangerous working environment.

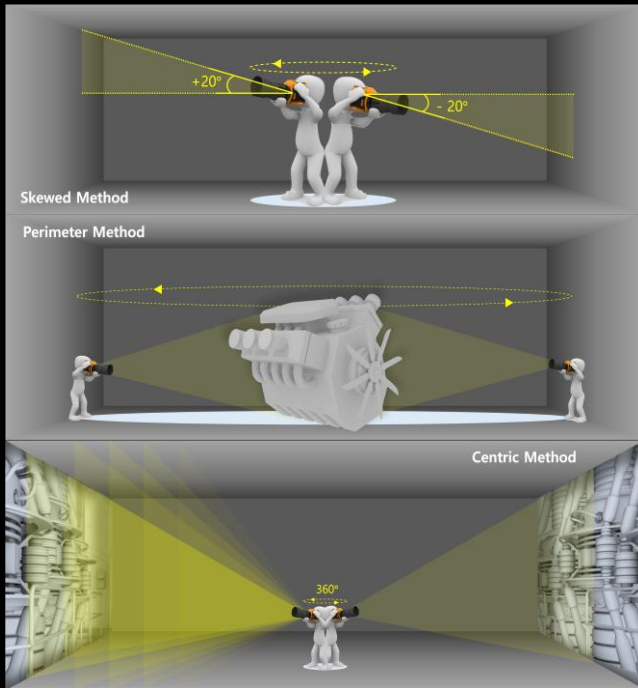
In the case of ship engine room inspection where frequent and regular inspection is necessary, as the ports are far away from the headquarter, it is physically hard to be present very frequently.

# Motivation



# Methodology – Data Collection

## Data Collection Strategy



Developed based on meticulous calculation of the Field of View, target structure or scene's character, and camera specification

Single equation gives inspectors the exact camera-tilt required given object distance, scene height, and overlap percentage to guarantee sufficient image overlap



### Angle of View, AoV

angular extent of the scene visible to the camera

$$AoV = 2 \arctan\left(\frac{s}{2f}\right)$$

### Field of View, FoV

actual physical area captured at a given distance  $d$

$$FoV = 2 \cdot d \cdot \tan\left(\frac{AoV}{2}\right)$$

### Vertical Field of View, VFOV

critical when calculating the tilting angle required to capture overlapping portions of the scene

$$VFOV = 2 \arctan\left(\frac{h}{2f}\right)$$

### Scene Height, $h_{sc}$

for sufficient overlap

$$h_{sc} = 2 \cdot d \cdot \tan\left(\frac{VFOV}{2}\right)$$

### Tilting Angle, $\theta_{sc}$

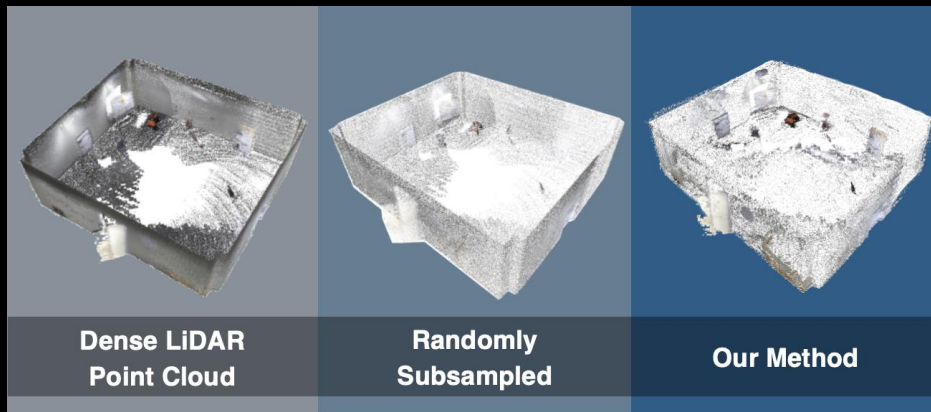
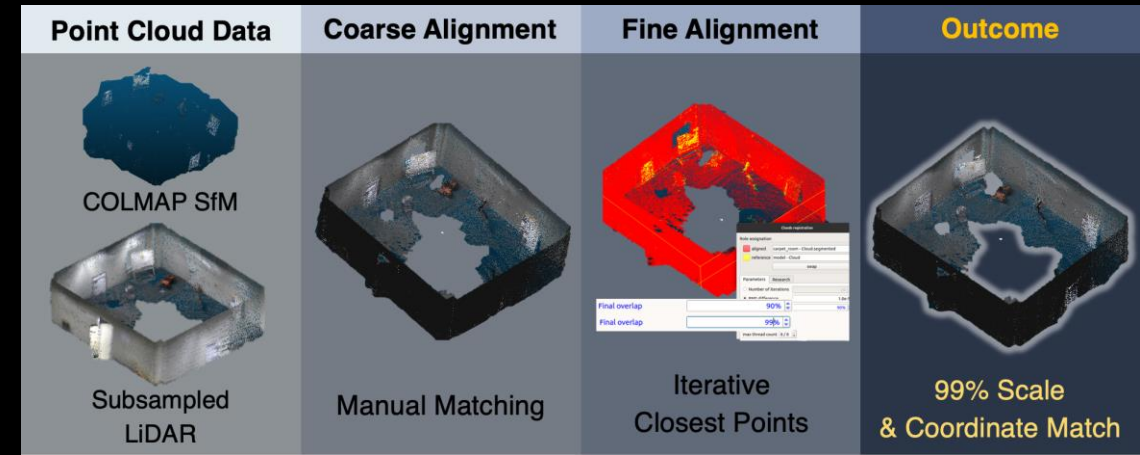
for sufficient overlap

$$\theta_{sc} = \arctan\left(\frac{(1 - 0.01X) \cdot h_{sc}}{d}\right)$$

where  $X\%$  is the desired overlap percentage

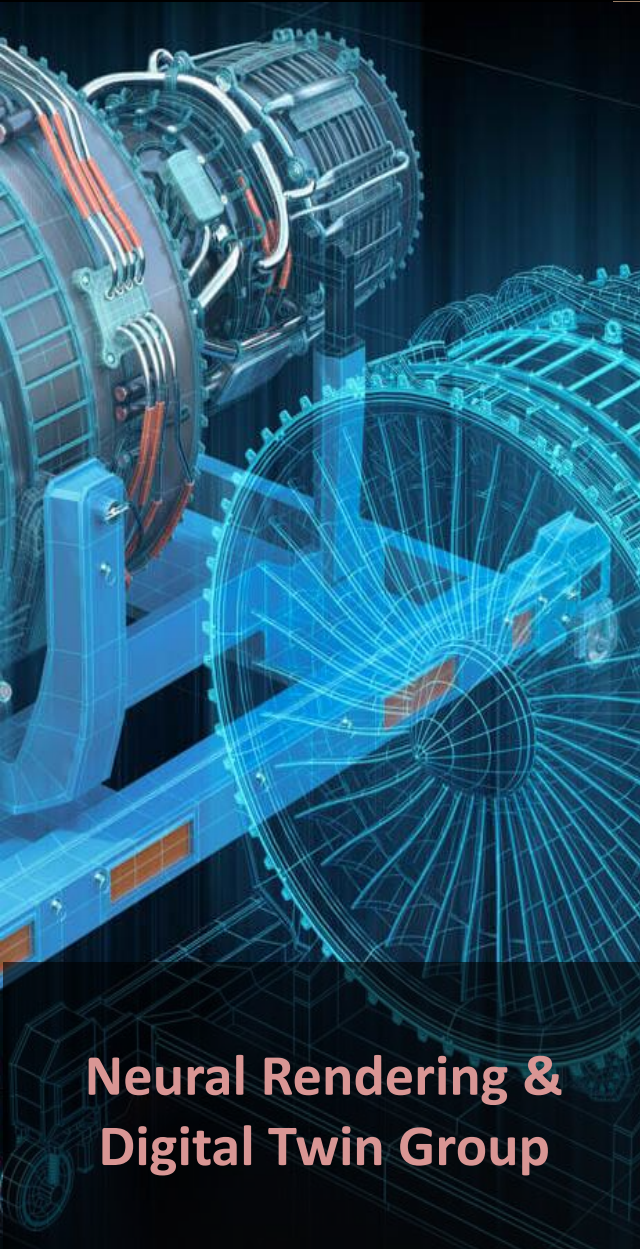


## LiDAR-3DGS: LiDAR Reinforced 3D Gaussian Splatting for Multimodal Radiance Field Rendering (2025 – Current)



	PSNR	Relative Increase in %	SSIM	Relative Increase in %
3DGS [2]	29.77	-	0.960	-
NeRF [1]	31.23	4.904%	0.958	-0.208%
Mip-Splatting [28]	34.56	16.09%	0.979	1.979%
MipNeRF [29]	34.51	15.92%	0.973	1.354%
Plenoxels [30]	30.34	1.915%	0.955	-0.521%
TensorRF [31]	30.60	2.788%	0.956	-0.417%
Instant-NGP [32]	31.20	4.803%	0.959	-0.102%
Tri-MipRF [33]	34.36	15.42%	0.974	1.458%
<b>LiDAR-3DGS (ours)</b>	-	<b>7.064%</b>	-	<b>0.564%</b>

# MEIC Lab. Research Groups and Representative Project



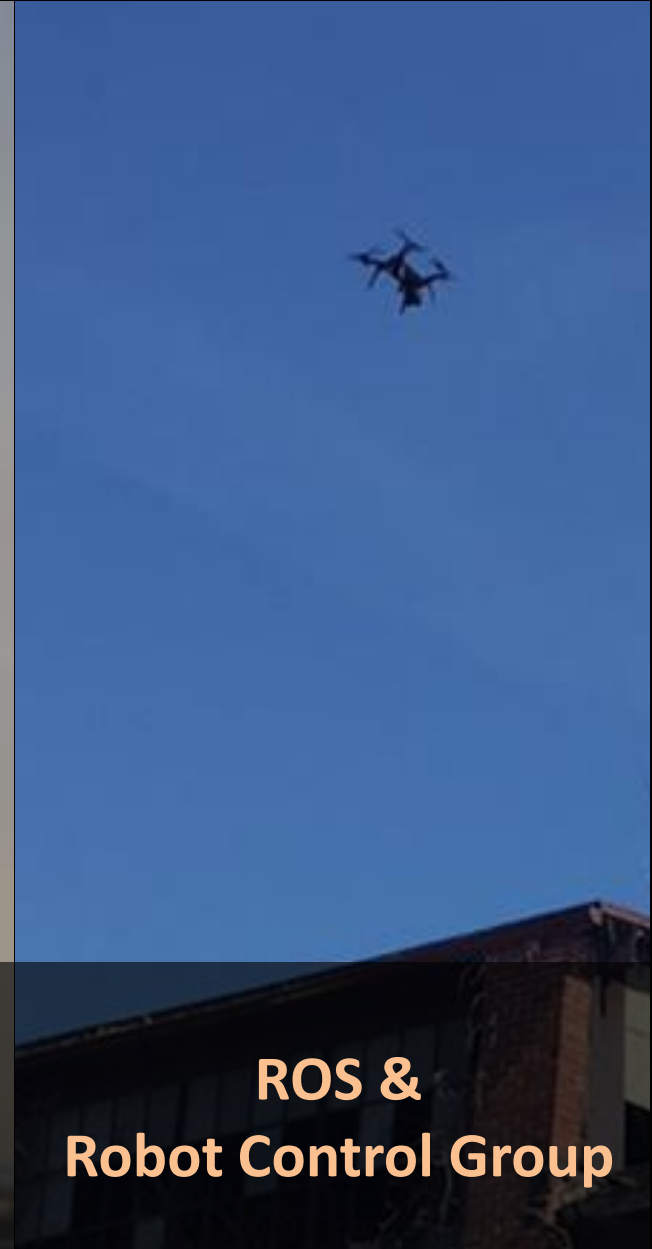
Neural Rendering &  
Digital Twin Group



Mixed Reality &  
Computer Vision Group



Deep Learning &  
EV-PHM Group



ROS &  
Robot Control Group

## Group members



Joanthan Boyack,  
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& AR Group



Hanbeom Chang,  
MS Student  
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& AR Group



Hyeoji Chang,  
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Visual Analytics  
& AR Group



Sungwook Choi,  
BS Student  
Visual Analytics  
& AR Group



Eunha Choi,  
BS Student  
Visual Analytics  
& AR Group

# Mixed Reality & Computer Vision Group

## DCRM: Distributed Collaborative Remote Assessment Metaverse (Collab. w. U. Waterloo)

**Jongseong Choi**, Chul Min Yeum\*, Shirley J. Dyke, Mohammad R. Jahanshahi (2018). Computer-Aided Approach for Rapid Post-Event Visual Evaluation of a Building Façade. *Sensors*, 18(9), 3017. [DOI: 10.3390/s18093017](https://doi.org/10.3390/s18093017).

**Jongseong Choi\***, et al., Automated Graffiti Detection: A Novel Approach to Maintaining Historical Architecture in Communities, *Applied Sciences*, [DOI: 10.3390/app12062983](https://doi.org/10.3390/app12062983)

**Jongseong Choi\*** & Shirley Dyke (2020). CrowdLIM: Crowdsourcing to enable lifecycle infrastructure management. *Computers in Industry*, 115, 103185. [DOI: 10.1016/j.compind.2019.103185](https://doi.org/10.1016/j.compind.2019.103185)

Benjamin Wogen, **Jongseong Choi\*** et al. (2024). Automated Bridge Inspection Image Retrieval Based on Deep Similarity Learning and GPS. *Journal of Structural Engineering*, 150(3), 04023238. [DOI: 10.1061/JSENDH.STENG-12639](https://doi.org/10.1061/JSENDH.STENG-12639)

Lisette Iturburu, **Jongseong Choi\*** et al. (2024). Building pose detection for the characterization of reinforced concrete buildings. *The Structural Design of Tall and Special Buildings*, 33(13), e2120. [DOI: 10.1002/tal.2120](https://doi.org/10.1002/tal.2120)

Hanbeom Chang, Chul Min Yeum, and **Jongseong Choi\***, (2024). 3D Reconstruction by Looking: Instantaneous Visualization of Point Cloud on an MR Device. *IEEE Robot Intelligence Technology and Application*. (under review)



## CrowdLIM: Crowdsourcing to Enable Lifecycle Infrastructure Management (2017 – 2019)



Pictures



Point Cloud &  
Camera Locations and Parameters

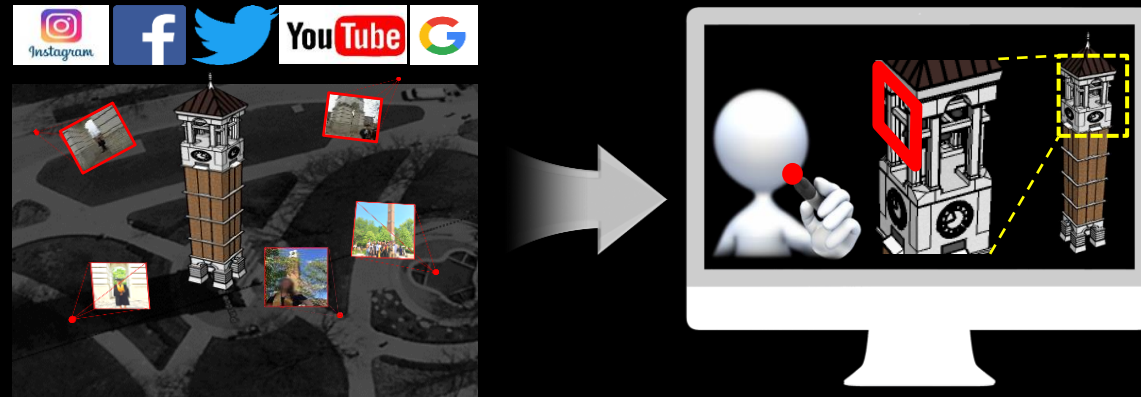


## STORM: Safeguarding Cultural Heritage through Technical and Organisational Resources Management (2018-2022)

### Crowdsourcing to Enable Lifecycle Infrastructure Assessment

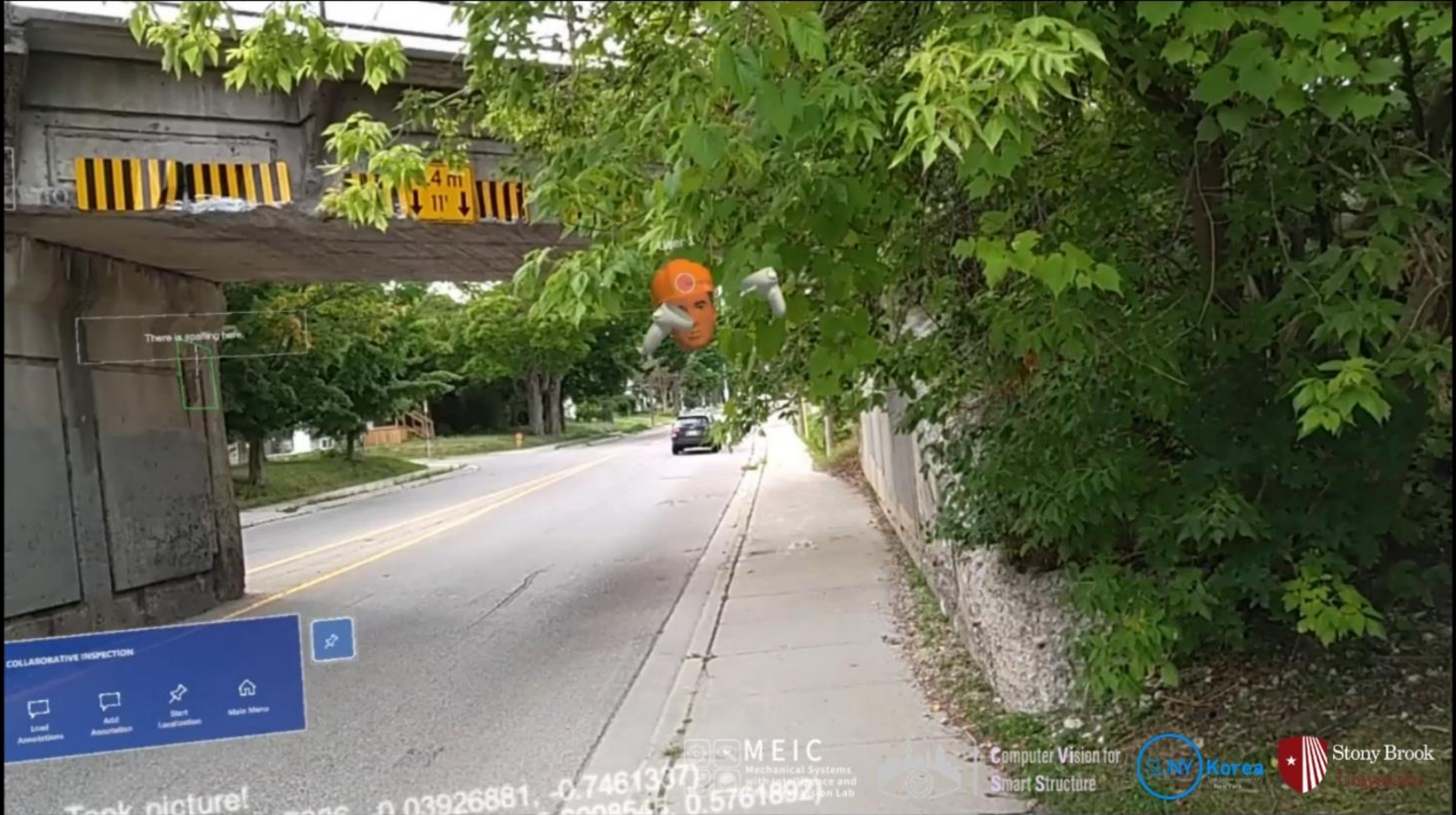


### Cultural Heritage Assessment enabled by Crowdsourcing



# Mixed Reality & Computer Vision Group

## DCRM: Distributed Collaborative Remote Assessment Metaverse (2022 - Current) (1)

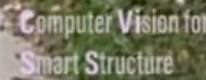


COLLABORATIVE INSPECTION

- Live Annotations
- Add Annotations
- Start Localization
- Main Menu

Take picture!

03926881, -0.7461357  
6098543, 0.5761892



## DCRM: Distributed Collaborative Remote Assessment Metaverse (2022 - Current) (2)



### Collaboration between On- and Off-site Users



#### VR Remote User:

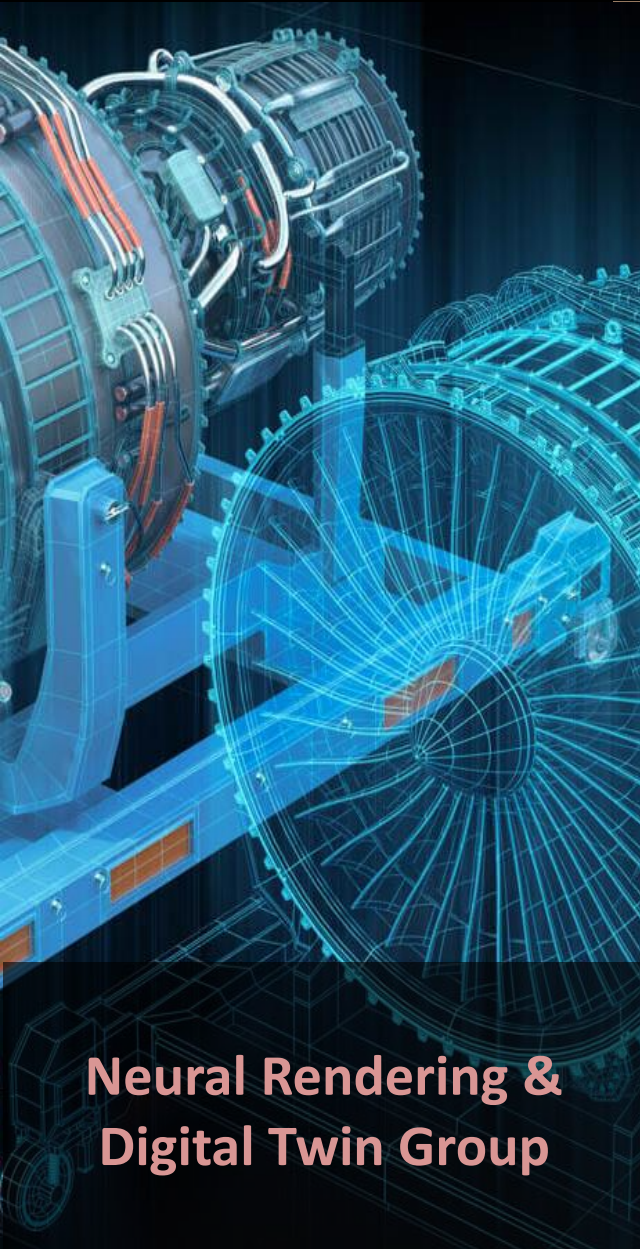
View 3D prebuilt map using VR headset  
VR user interacts with AR users remotely



#### AR On-site User:

AR headset is automatically localized to 3d map  
AR user interacts with remote VR users in real-time

# MEIC Lab. Research Groups and Representative Project



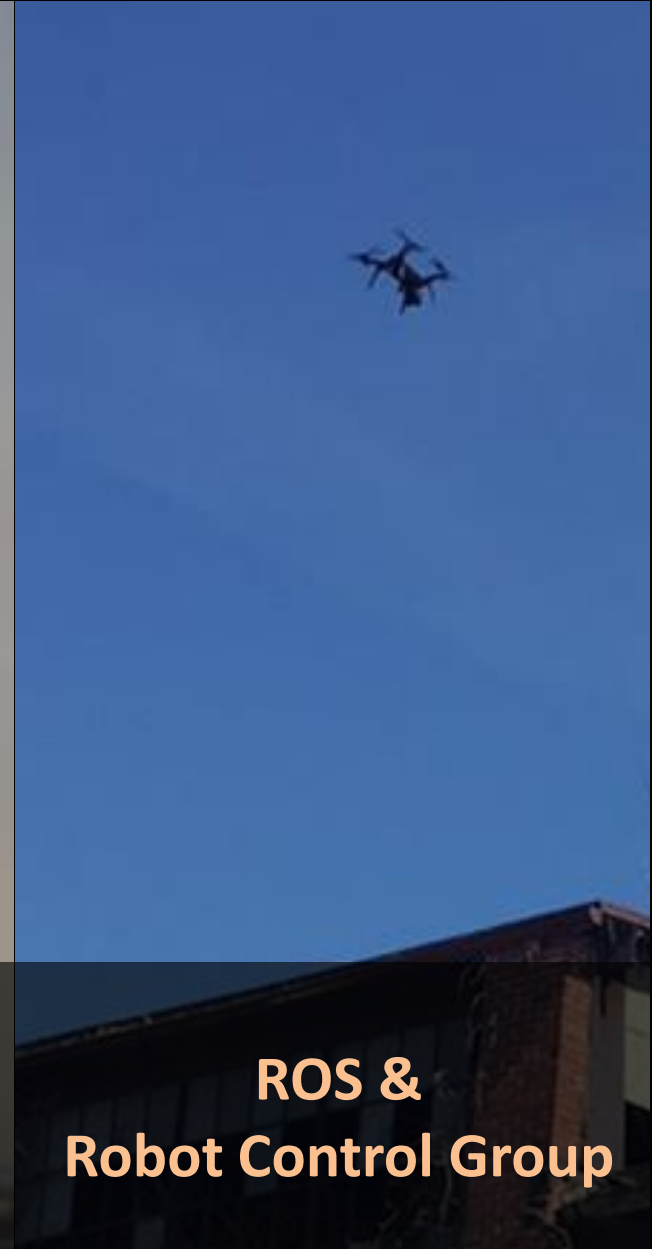
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Digital Twin Group



Mixed Reality &  
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