Deep Semantic 3D Visual Metric Reconstruction Using Wall-climbing Robot

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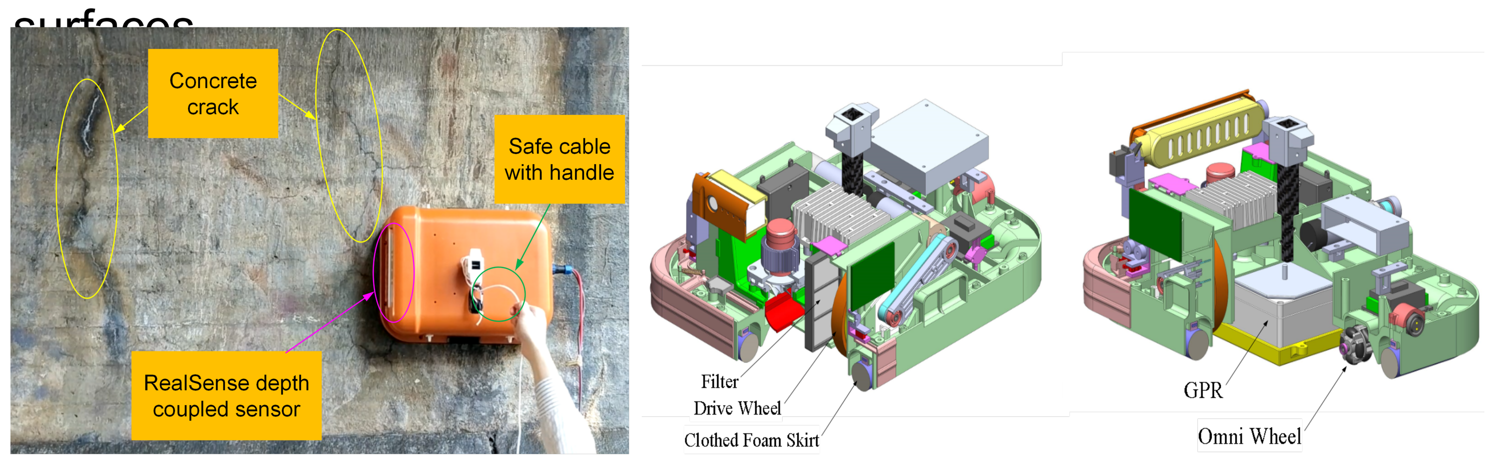
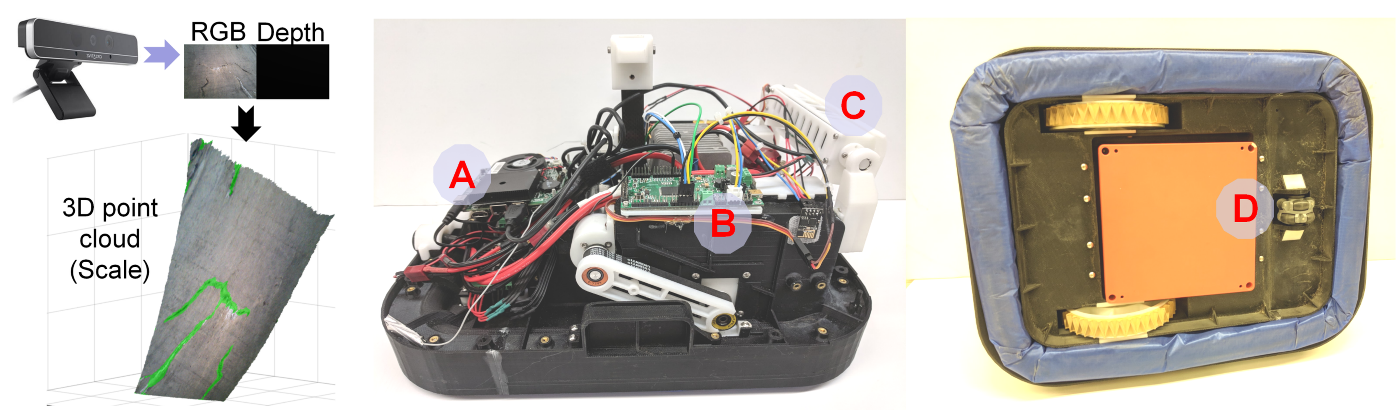
INTRODUCTION

This project introduces an inspection method using a deep neural network to detect the crack and spalling defects of concrete structures performed by a wall-climbing robot. First, we create a pixel-level semantic dataset which includes 820 labeled images. Second, we propose an inspection method to obtain 3D metric measurement by using an RGB-D camera-based visual simultaneous localization and mapping (SLAM), which is able to generate pose coupled key-frames with depth information. Therefore, the semantic inspection results can be registered in the concrete structure 3D model for condition assessment and monitoring. Third, we present our new generation wall-climbing robot to perform the inspection task on both horizontal and vertical surfaces.

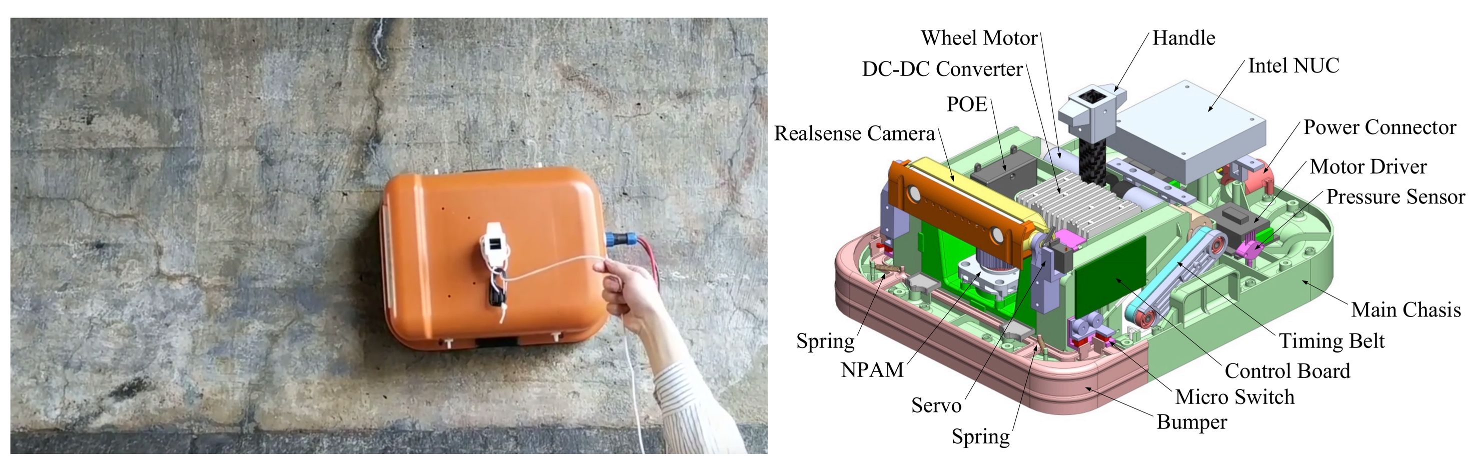




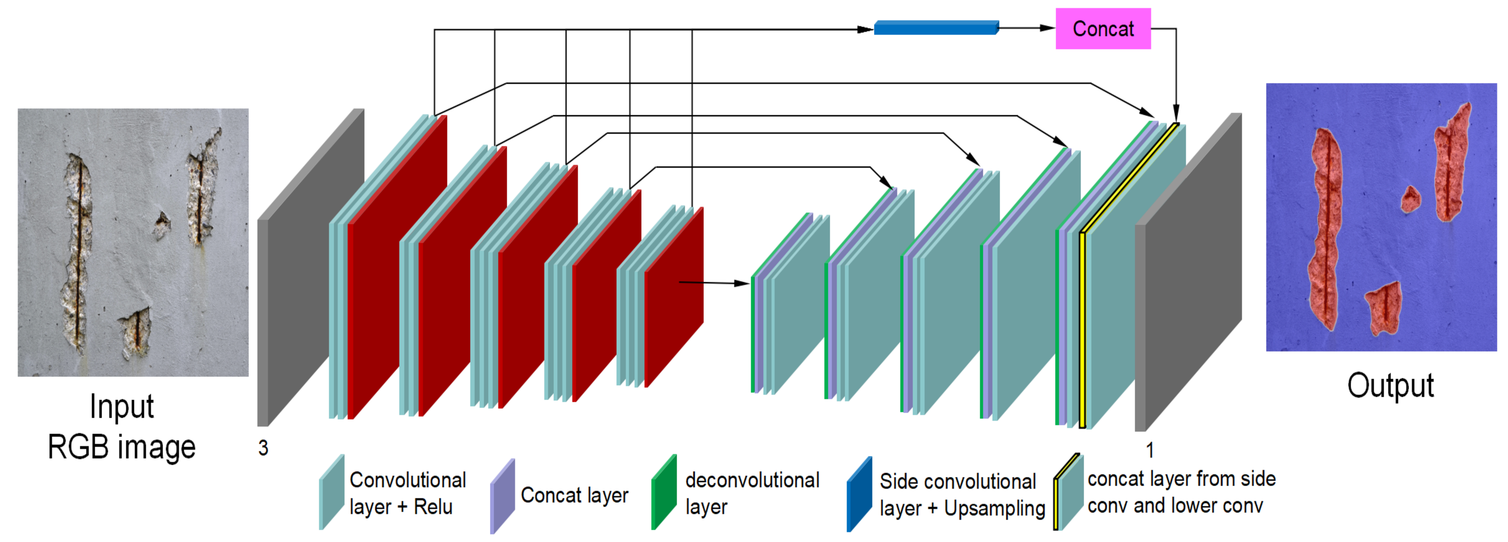
Wall-climbing robot acts as a mobile platform carrying two inspection sensors: a RGBD cameras and a Ground Penetration Radar.

METHODS

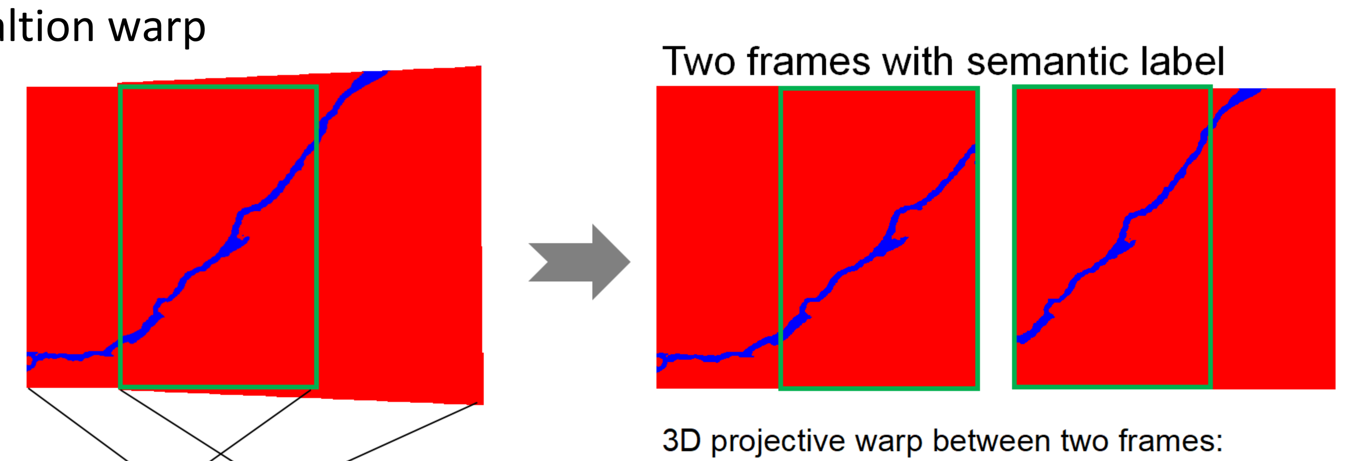
Robot: For the robot, the drive train consists of two drive wheels in the rear and one omni-direction wheel in the front. The drive wheel is covered with soft rubber tread to increase the friction force between the wheel and the wall. A RealSense RGB-D Camera is mounted on the robot, and it can be driven by a servo to change view angle.Components such as POE module, motor driver, wheel motor, DC-DC converter, digital signal processing (DSP) control board and Intel NUC board are installed on the top of the chassis.



Visual Inspepction: In order to perform pixel-level segmentation for concrete defects, we first propose a fully convolutional neural network for crack and spalling semantic segmentation. Then, the detection results are registered in the 3D model to obtain metric information such as size and area. To the best of our knowledge, this is the first time for visual inspection registered on the 3D model for complete semantic visualization and SHM diagnosis.

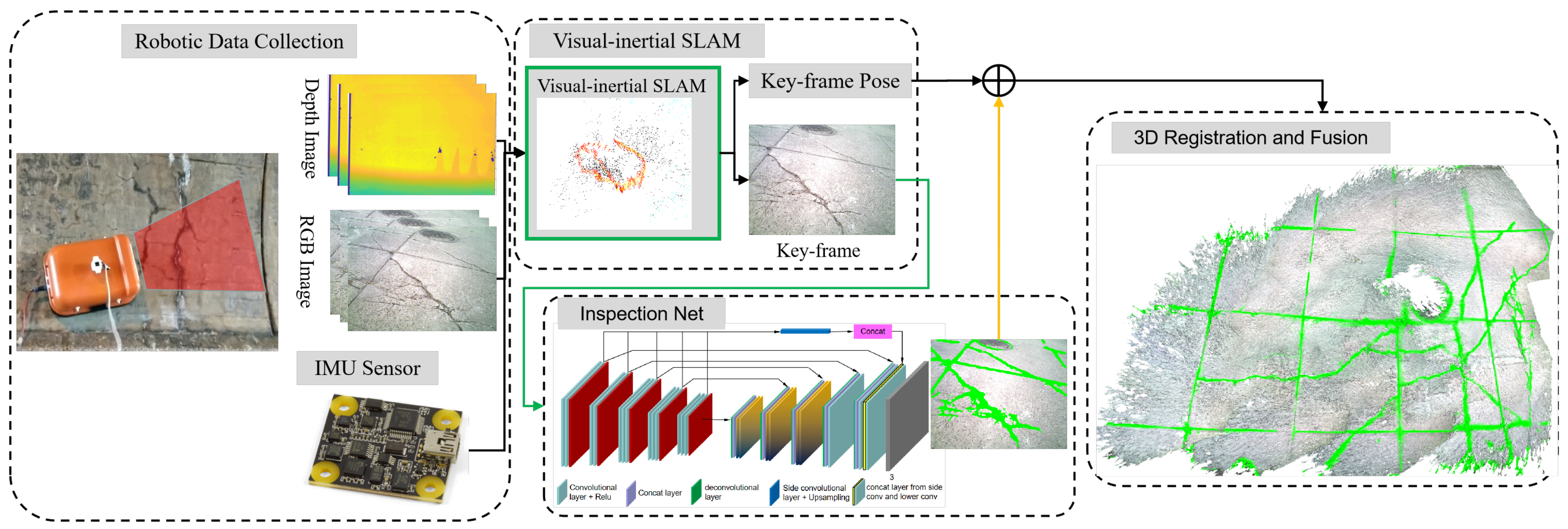


3D Spatial and Semantic Fusion: CRF to perform fusion of consective frames with localtion warp



$$I_j(u,v)=\pi(\Im, Depth(\Im), T_{ij})$$

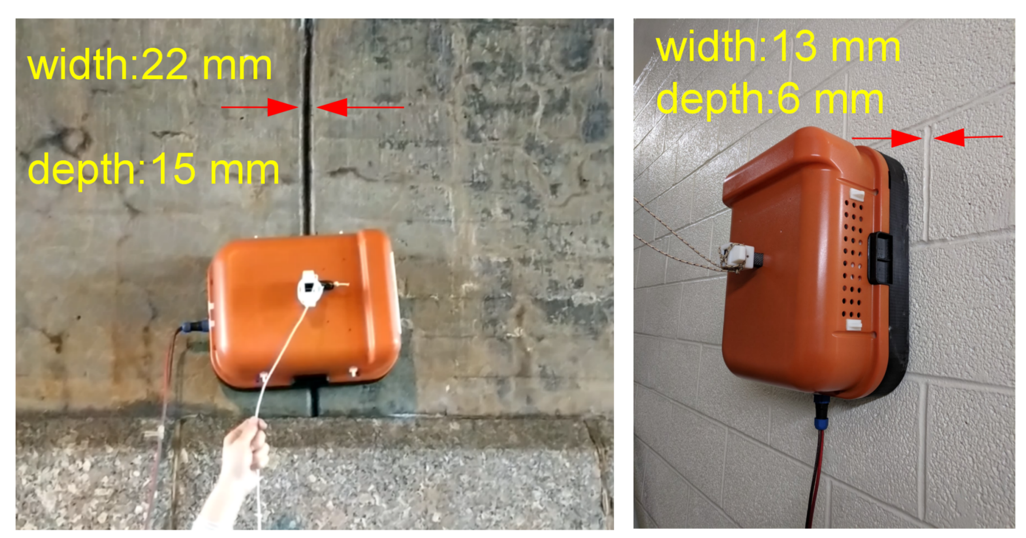
Inspection Robot System Architecture: The whole system consists of four modules: robotic data collection, visual-inertial SLAM, InspectionNet neural network model, and 3D registration and map fusion modules.



RESULTS

Successful demo at Manhattan 155 Tunnel and Indoor, and robot payload test

Robot climbing capability test

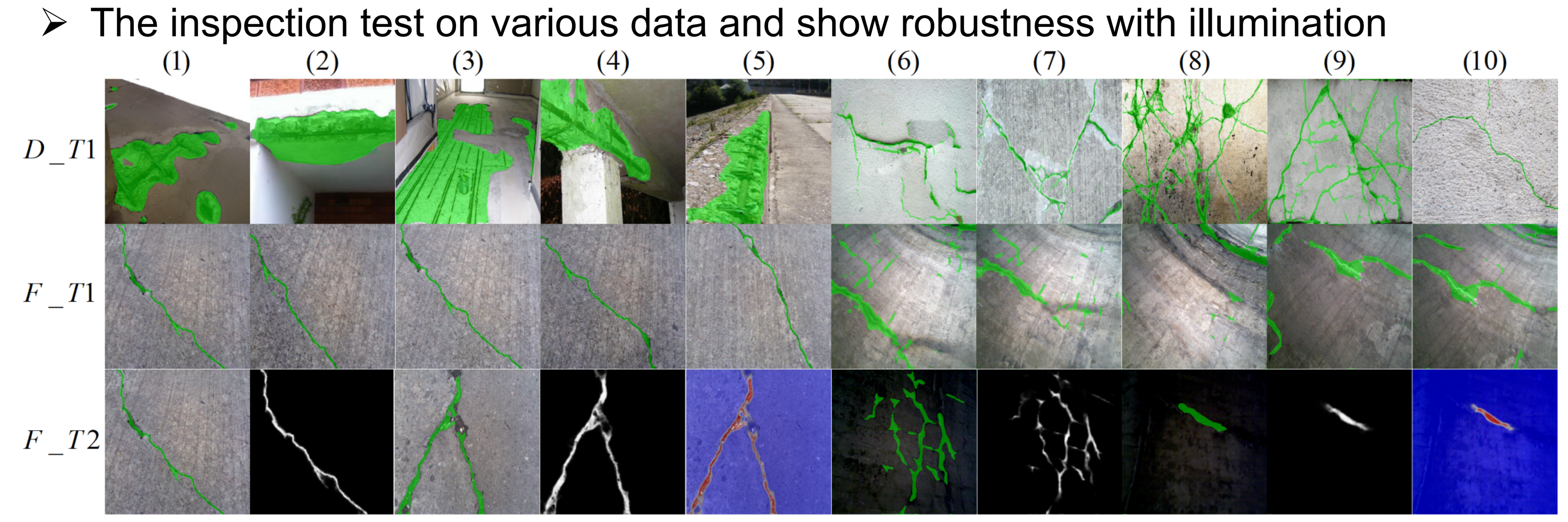


(a) Under-bridge area test (b) Test at CCNY

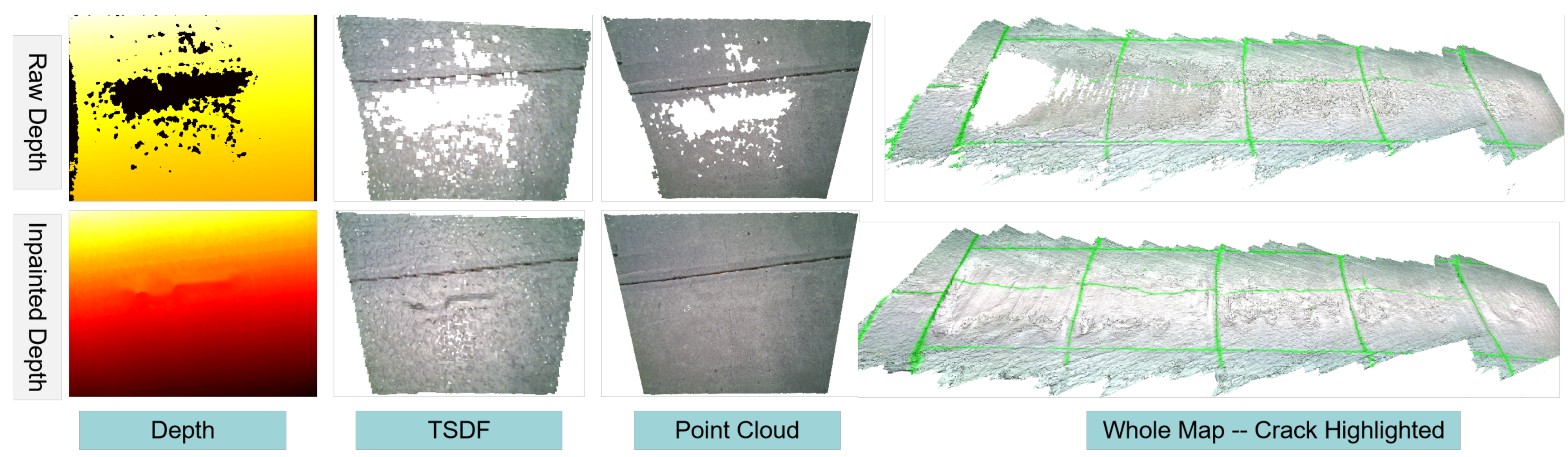
➢ Our neural network training performance:

	InspectionNet		VGG-Unet		FCN-8s	
	Crack	Spalling	Crack	Spalling	Crack	Spalling
E_MaxF1	82.40	88.64	76.76	88.72	-	88.68
E_AP	83.59	91.69	80.96	91.71	-	91.54
T_MaxF1	60.60	96.69	58.89	96.79	-	96.64
T_AP	55.70	93.81	55.70	93.94	-	93.78
T_BAP	98.00	95.00	94.00	95.00	-	94.5
AF	8.02	6.53	6.48	6.78	-	6.48

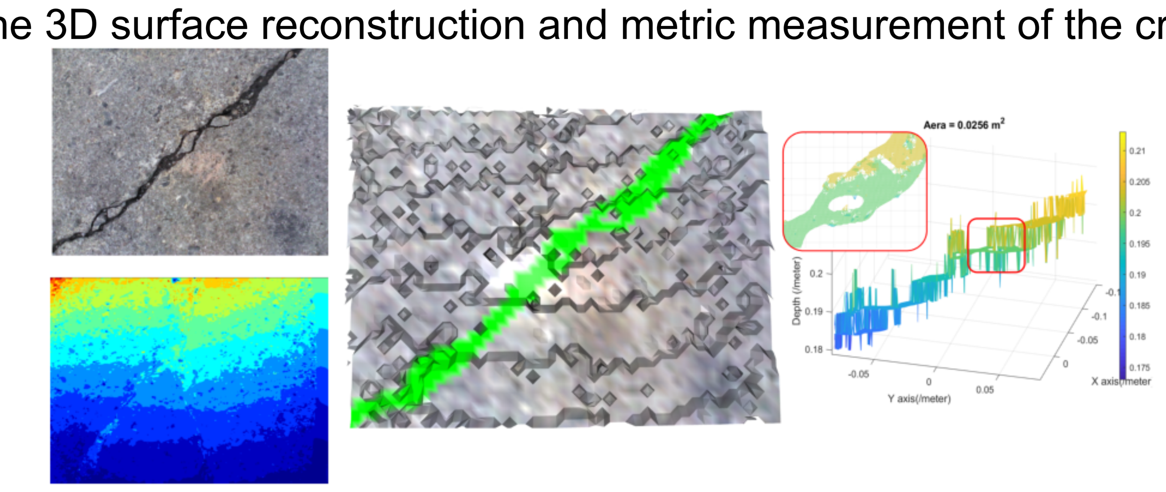
➢ The inspection test on various data and show robustness with illumination



➢ The 3D reconstruction result compared with raw depth data using depth completion

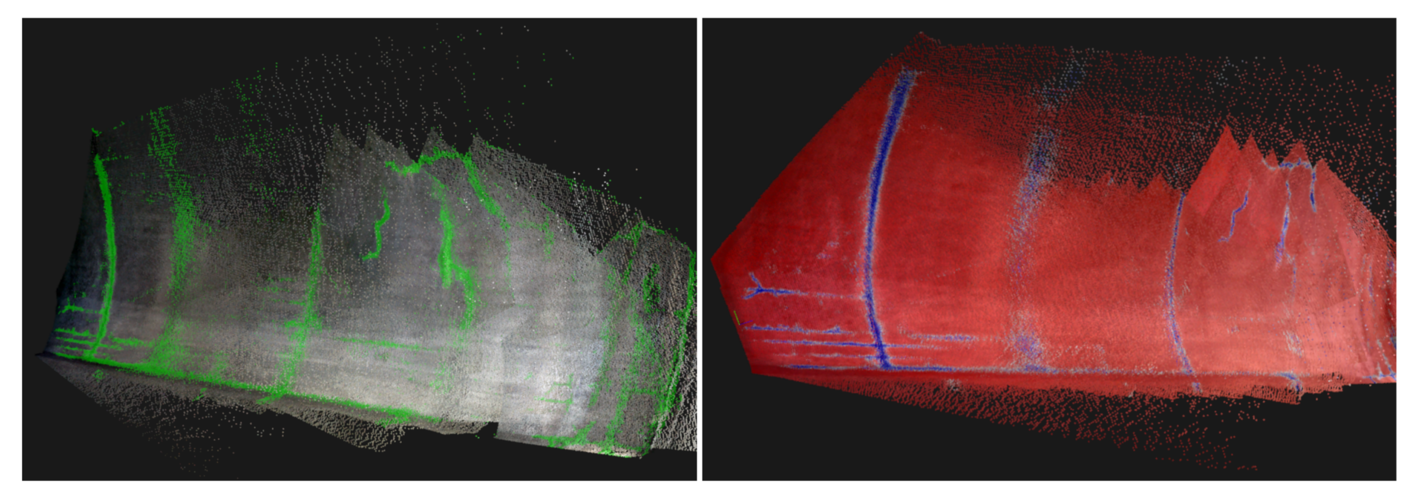


➢ The 3D surface reconstruction and metric measurement of the crack



Raw Depth + RGB Surface Reconstruction Metric Measurement

➢ 3D semantic reconstruction with crack labelled cracks



(a)Semantic defects labled point cloud map (b) Heat map like point cloud map

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