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

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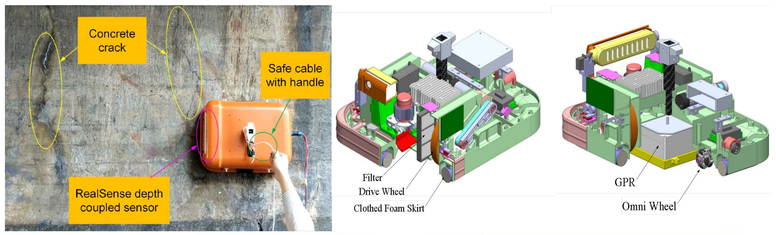
INTRODUCTION

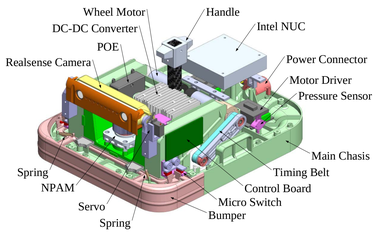
This project introduces an inspection method using a deep neural network to detect the crack and spalling defects on concrete structures performed by a wall-climbing robot. First, we create a pixel-level semantic dataset which includes 820 labeled images. Second, we propose an inspection method to obtain 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.



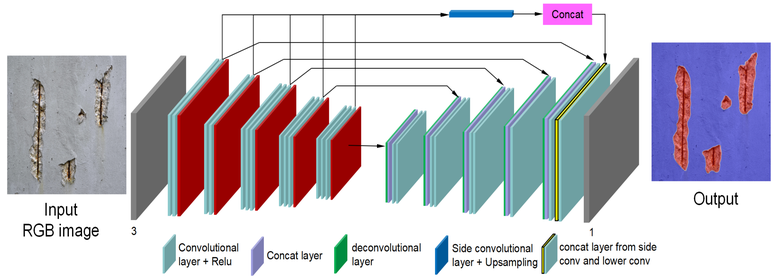
Wall-climbing robot acts as a mobile platform carrying two inspection sensors: a RGBD cameras and a Ground Penetration Radar.

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.

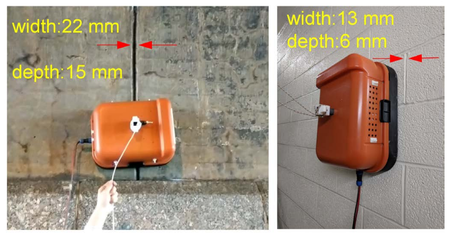


- **Visual Inspepction**: In order to perform pixel-level segmentation for concrete defects, we first propose a fully convolutional neural network for crack and spalling semantic segmentation. Then, the detection results are registered in the 3D model to obtain metric information such as size and area. 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.



RESULTS

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

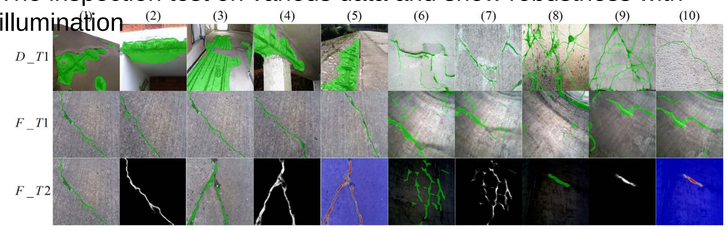


(a)Under-bridge area test

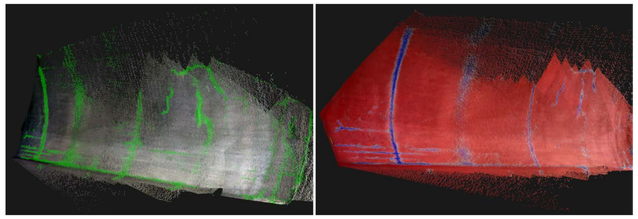
(b)Test at CCNY

Adhesive motor speed (percentage %)	15	20	25	30	35	40	45	50
Ground pull-up adhesive force (Kg)	4.62	5.62	8.22	11.02	16.42	24.5	28.95	31.62
Vertical pull-down load adhesive force (Kg)	N/A	1.3	4.5	6.4	8.0	9.7	10.4	10.5

The inspection test on various data and show robustness with illumination

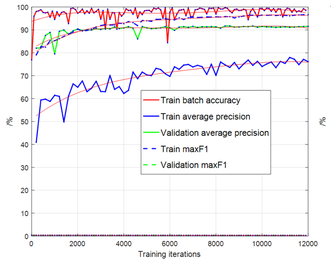


3D semantic reconstruction with crack labelled cracks

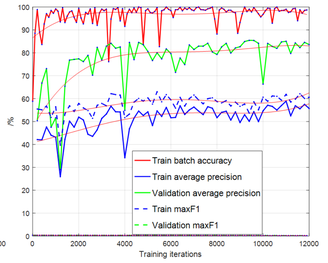


(a)Semantic defects labled point cloud map (b) Heat map like point cloud map

Our neural network training performance:



(a)Training with partial dataset



(b)Training with complete dataset

CONCLUSIONS

We introduced a new generation wall-climbing robot system for concrete structure visual inspection. The robot can carry as much as 30 kg payload. A state-of-the-art CSSC dataset with pixel-level labeling and an InspectionNet network were designed for semantic segmentation. Furthermore, based on our design on the visual odometry positioning and 3D reconstruction, the detected results were registered in the 3D model to provide metric information for concrete structure condition assessment. The 3D reconstruction accuracy can be 2% on average.

REFERENCE

[1]Yang, L., Li, B., Li, W., Jiang, B., & Xiao, J. (2018). Semantic Metric 3D Reconstruction for Concrete Inspection. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops (pp. 1543-1551).
[2]Yangí, L., Yang, G., Liu, Z., Chang, Y., Jiang, B., Awad, Y., & Xiao, J. (2018, May). Wall-climbing robot for visual and GPR inspection. In 2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA). IEEE.

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