



Autonomous Wall-climbing Robots for Inspection and Maintenance of Concrete Bridges

Dr. Jizhong Xiao, Professor
The City College, City University of New York (CUNY City College)
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Outline

- ❖ **Project Goals**
- ❖ Accomplishments
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 - ❑ Positioning and Visualization
 - ❑ CNN-Based Visual Inspection
 - ✧ Data Set for Training
 - ✧ InspectionNet
- ❖ Field Test and Experiments
- ❖ Planned Activities
- ❖ Concluding Remarks

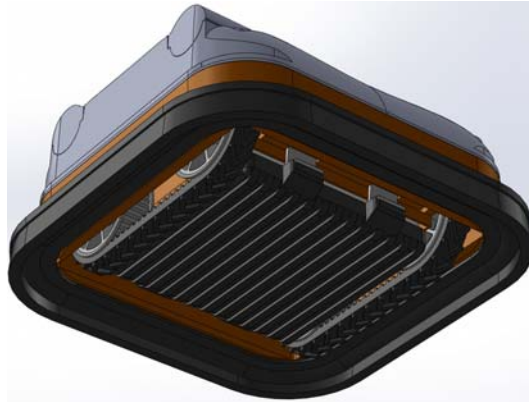
Project Goals

- 1. To develop reliable and robust robots to provide vertical mobility for field deployment and data collection on concrete structures;**
- 2. To develop NDE methods and integrate them in the rover to detect surface flaws and subsurface defects;**
- 3. To develop image processing algorithms and innovative methods for accurate positioning of flaws;**
- 4. To empower the rovers with rich knowledge and intelligence to automate the bridge inspection process with minimal human intervention.**



Accomplishments

- GPR-Rover Prototype-I



Empower
GPR with
vertical
mobility

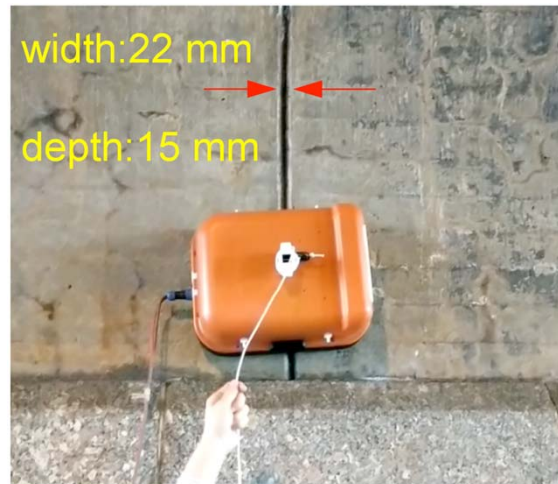
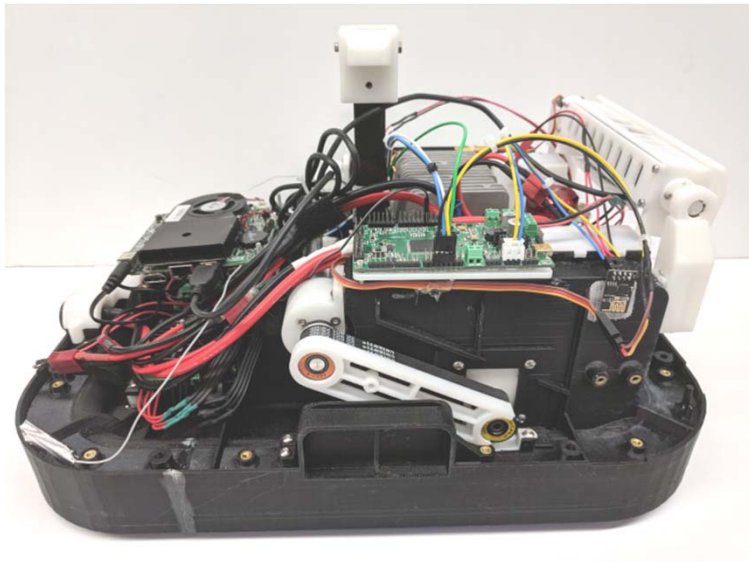
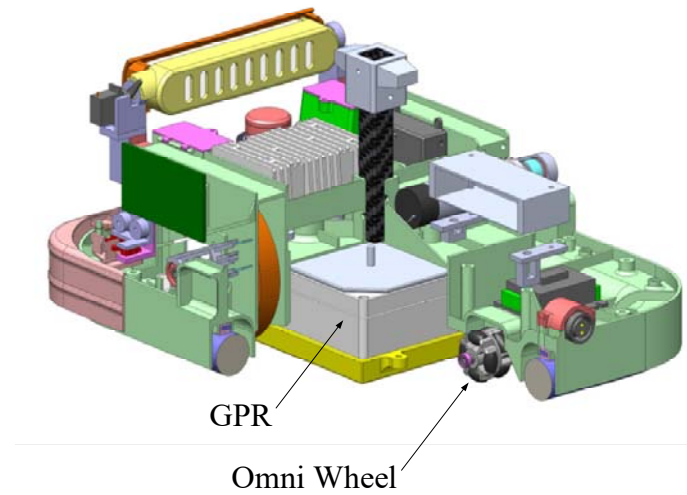
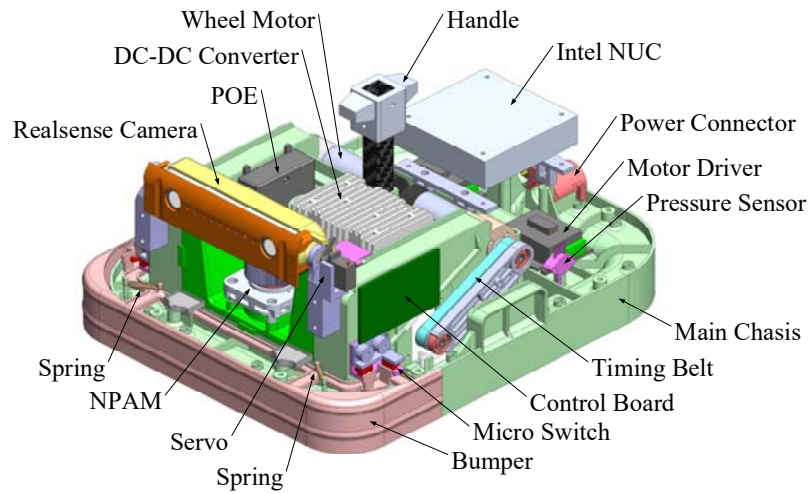


- GPR-Rover Prototype-II

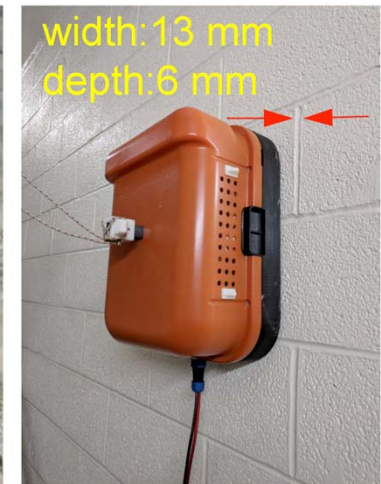
RGB-D sensor to detect
surface flaws, GPR sensor
on the bottom to detect
sub-surface defects



GPR-Rover Prototype-II



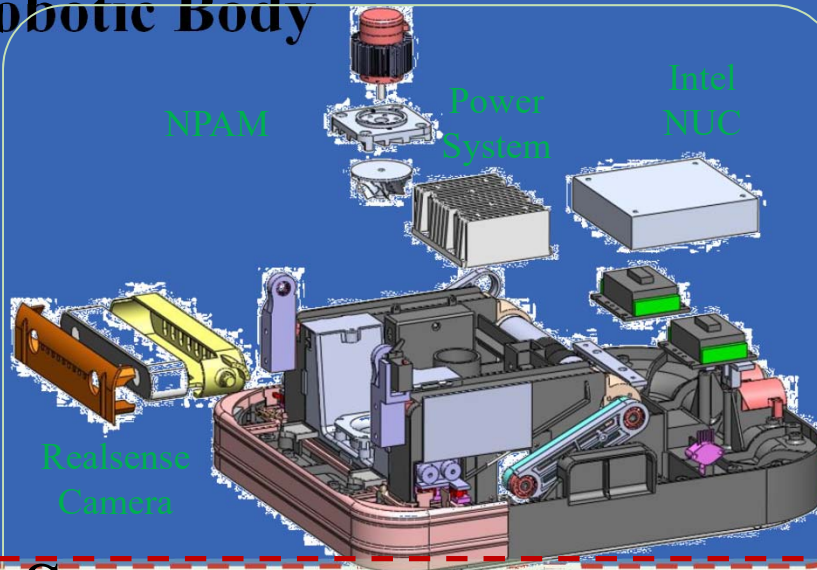
(a) Under - bridge area test



(b) Test at CCNY

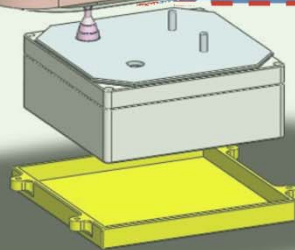
System Architecture

Robotic Body



Sensors

GSSI GPR



Control Panel



Remote Controller



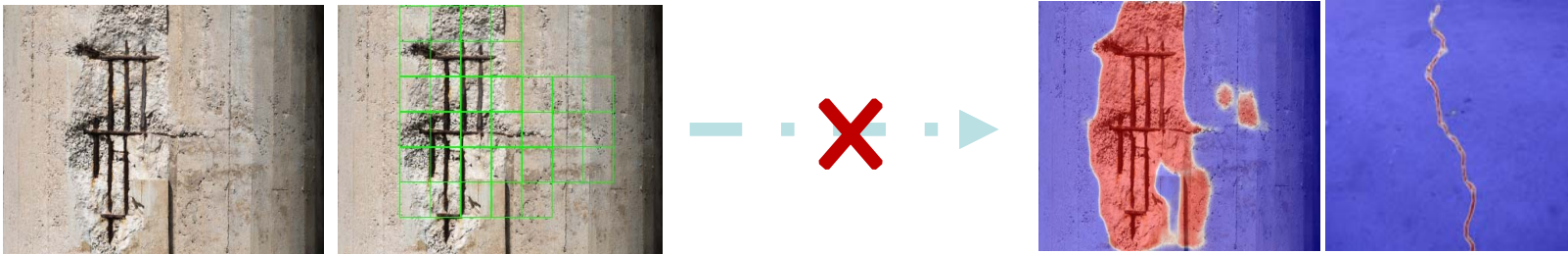
Communication Moduler



RealSense RGB-D camera

Visual Inspection Problems

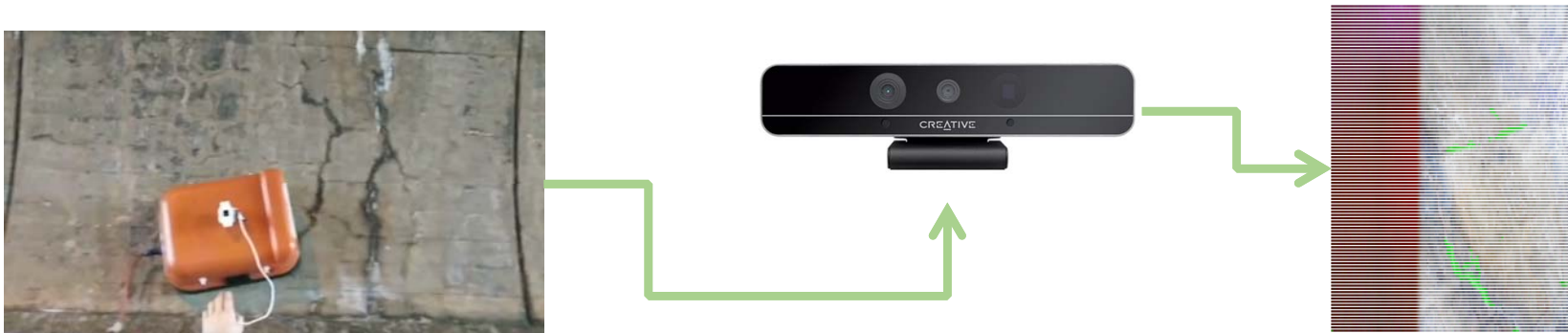
Problem 1: Lack of Accurate detection and pixel-level measurement



Problem 2: No Dataset available for learning purpose



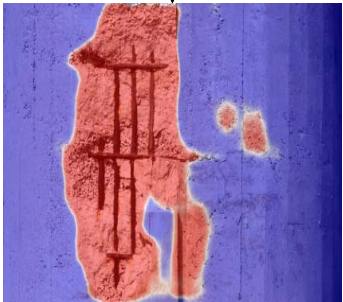
Problem 3: Lack of a robotic approach for automatic data-collection and positioning



Health Monitoring and Visualization



region level accuracy



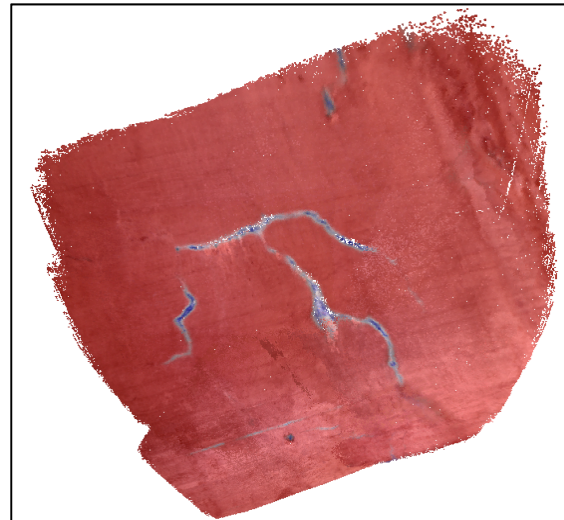
pixel level accuracy

❖ Desired Features:

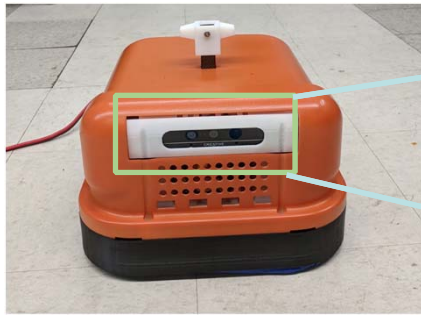
- ❑ Perform pixel-level segmentation
- ❑ Register to 3D Map for visualization

❖ Issues:

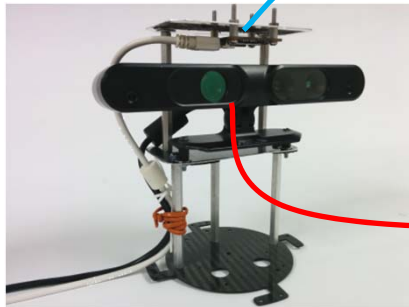
- ❑ Accurate Positioning
- ❑ 3D Reconstruction



Visual Odometry for Positioning



Indirect Kalman:

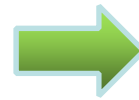


Feature with
covariance

Trifocal tensor for
feature estimation

IMU to propagate

Update error to correct
the nominal state

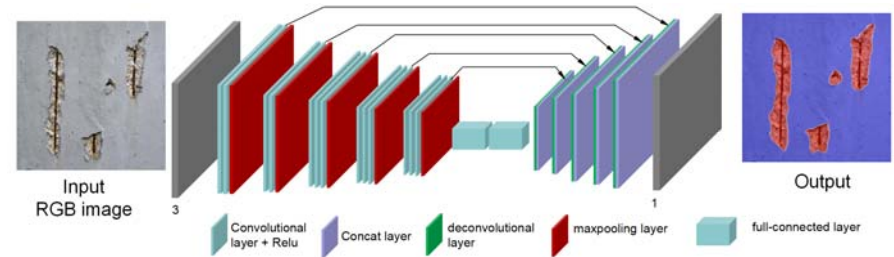


Detection and 3D Registration

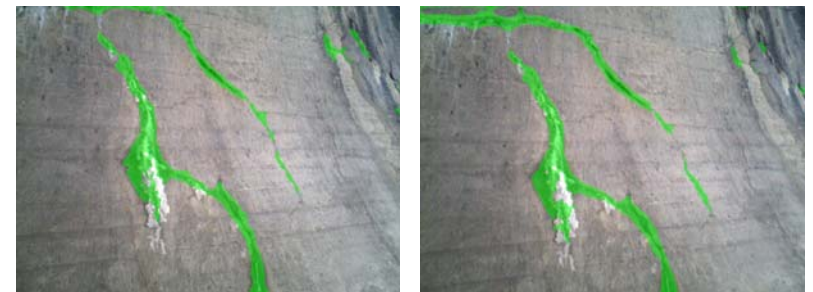
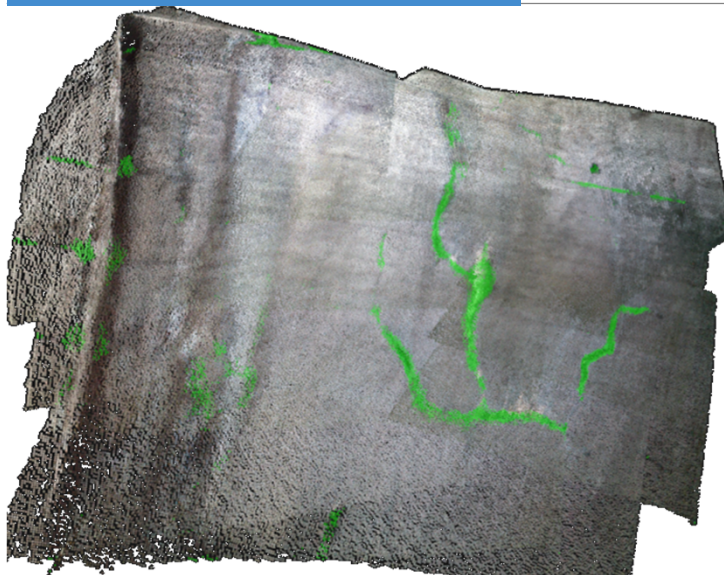
3D Registration:



InspectionNet for Pixel-level Detection



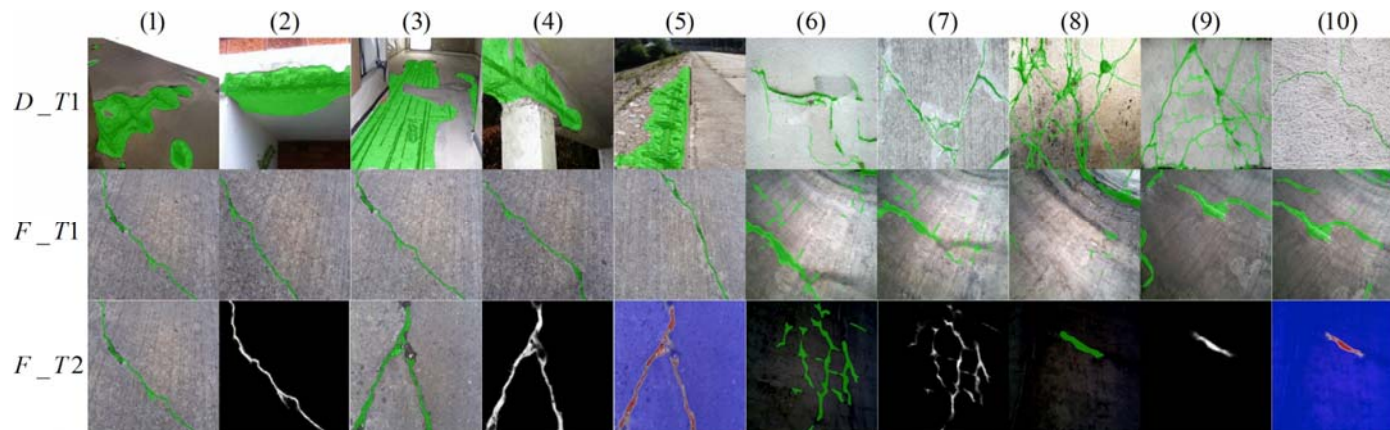
3D Reconstructed Map



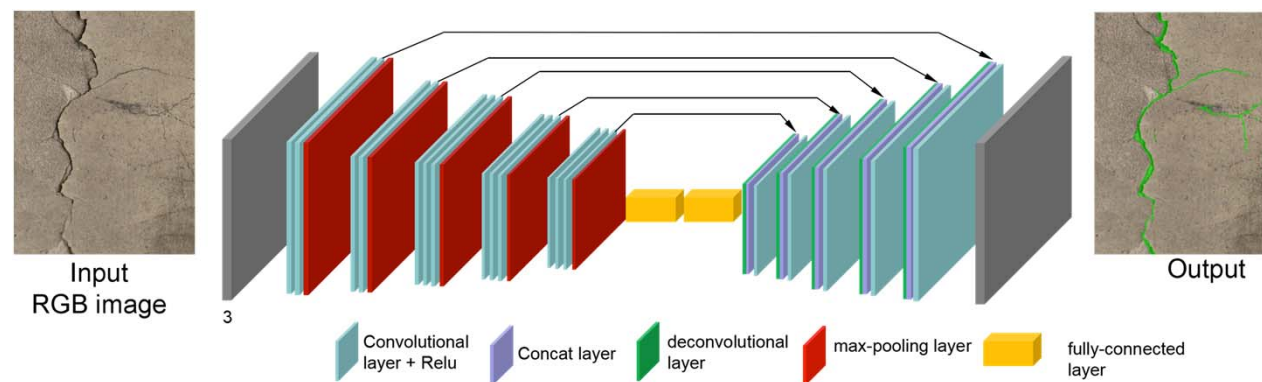
Segmentation Mask over defects

Accomplishments

- Create a Concrete Structure Spalling and Cracks (CSSC) database with 820 labeled images

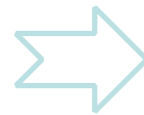
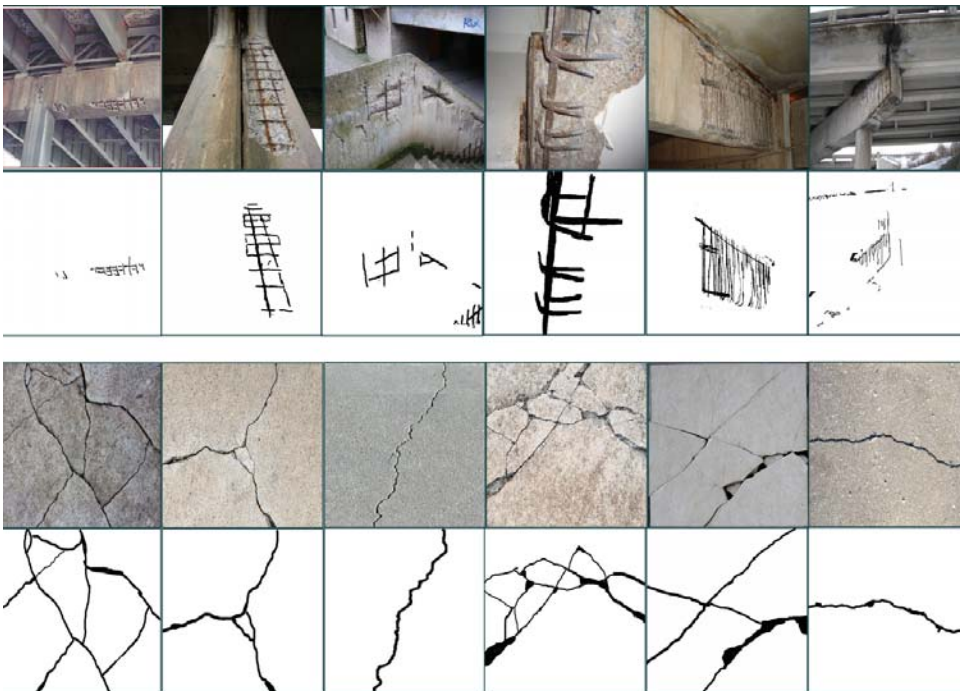


- Develop InspectionNET for surface flaw detection and measurement.



Data Set Preparation

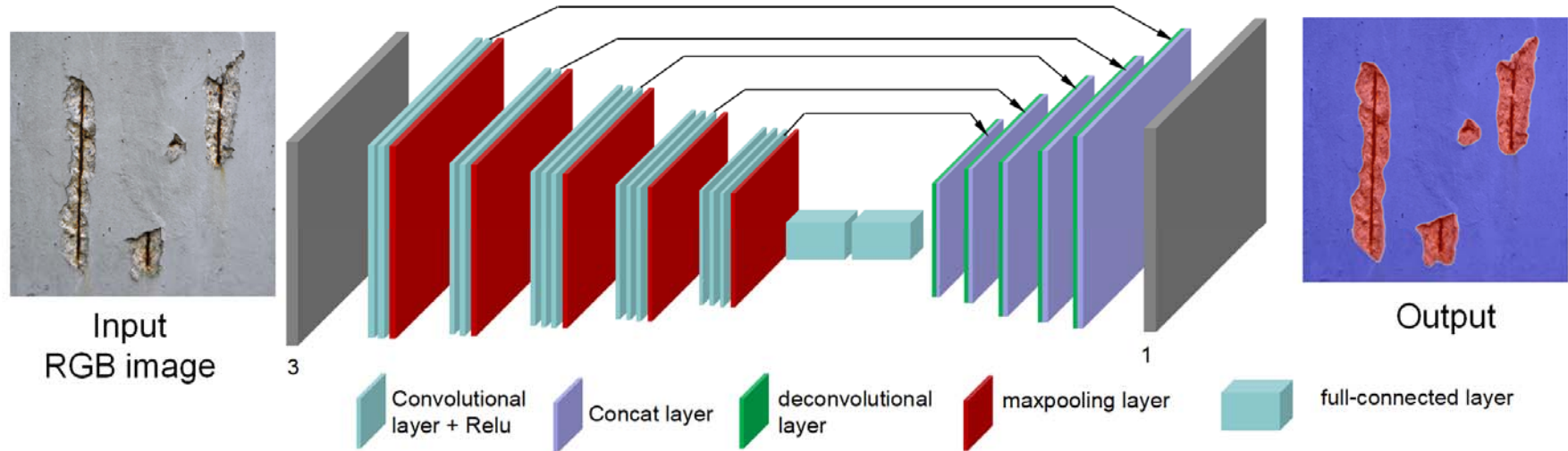
- ❖ Data Collection:
 - Real pictures; Web search (**Google, Yahoo, Bing, flicker**)
- ❖ Labeling:
 - Most manually; Pay attention to information you want



For Training



InspectionNet for Segmentation



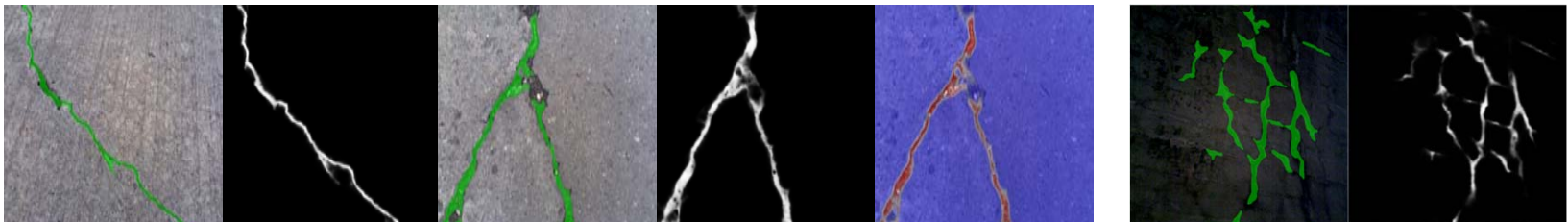
Item	Concrete Crack				Concrete Spalling			
	max F1	Ave Prec.	min Entropy	min Loss	max F1	Ave Prec.	min Entropy	min Loss
(CN) Training	79.59	91.66	0.048	0.3152	96.63	93.77	0.0128	0.388
(CN)Test	74.98	76.41	-	-	95.80	93.88	-	-
(FCN-8s) Training	7.33	3.81	-	-	96.37	94.039	0.09	0.43

CNN for detection

Crack and Spalling segmentation based on test dataset



The white and black probability distribution & **Dark illuminance case**



CNN for detection -- Experiment



The City College
of New York



U.S. Department
of Transportation
Federal Highway
Administration

Deep Neural Network based Visual Inspection with 3D Metric Measurement of Concrete Defects using Wall-climbing Robot

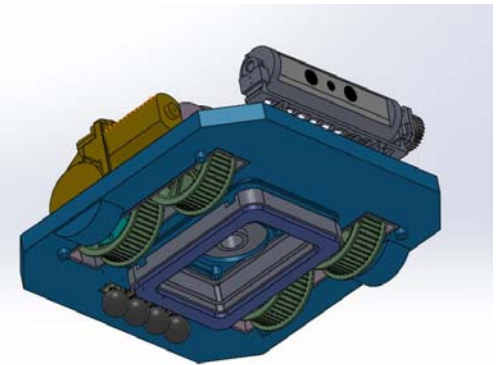
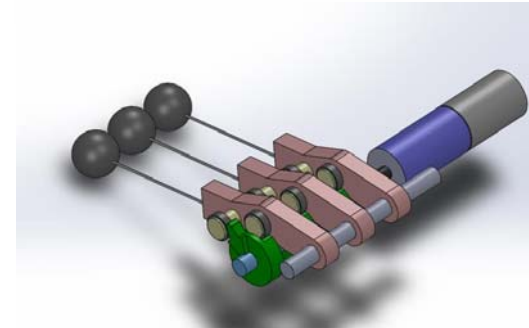
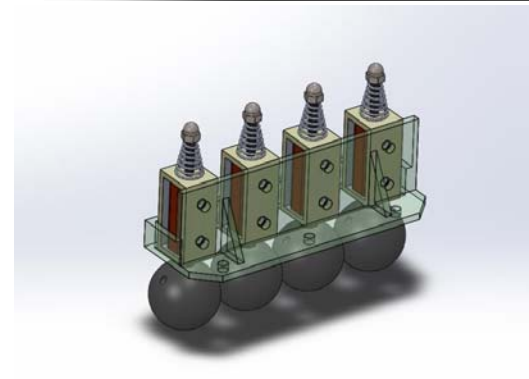
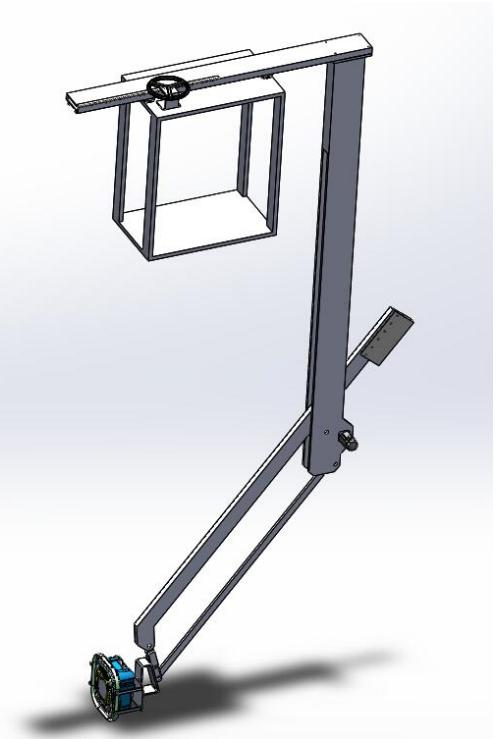
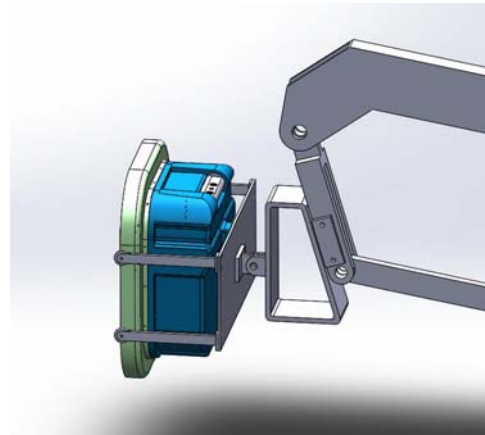
Liang Yang, Bing Li, Guoyong Yang,
Yong Chang, Zhaoming Liu, Biao Jiang, Jizhong Xiao



Robotics Lab
The Electrical Engineering Department
The City College of New York
Feb. 25 2018

PLANNED ACTIVITIES:

- Develop a robotic delivery system to reach the bridge pillar from the deck.
- Develop Impact sounding mechanism and data analysis methods.
- Develop multi-chamber wall-climbing robot to cross over deep groves



Concluding Remarks

- GPR-Rovers provide vertical mobility to ease the data collection process in difficult-to-access places;
- Use RGB-D camera to detect surface flaws, GPR to detect subsurface defects, impact sounding to detect delamination;
- Develop image processing and visual odometry algorithms for accurate positioning of flaws;
- Propose CNN-based machine learning algorithms and dataset for surface flaw detection and measurement.

Products

- PCT/US17/40621, filed on July 3, 2017, “Robotic Device for Providing Vertical Mobility”, Inventors: Jizhong Xiao, Kenshin Ushiroda, Guoyong Yang, SaiadiVishnu Saniegepalli, Provisional US patent application: US62/357, 607. Priority claim filing date: July 01, 2016, Ownership: InnovBot (50%) and CUNY (50%)
- B. Li, K. Ushiroda, L. Yang, Q. Song, J. Xiao*. “Wall-Climbing Robot for Non-Destructive Evaluation using Impact-Echo and Metric Learning SVM”, International Journal of Intelligent Robotics and Applications, 2017.
- Deep Neural Network based Visual Inspection with 3D Metric Measurement of Concrete Defects using Wall-climbing Robot, submitted R&A Letter
- Liang Yang, Guoyong Yang, Zhaoming Liu, Yong Chang, Biao Jiang, Youssef Awad, and Jizhong Xiao, “Wall-Climbing Robot for Visual and GPR Inspection”, The 13th IEEE Int. Conf. on Industrial Electronics and Applications (ICIEA 2018).
- Contribute an article “Autonomous Wall-Climbing Robots to Inspect Concrete Bridges” to INSPIRE Center News Letter

Acknowledgement

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