INSPIRE

INSPECTING AND PRESERVING INFRASTRUCTURE THROUGH ROBOTIC EXPLORATION

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

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Outline

- Project Goals
- Accomplishments
  - GPR-Rover Prototypes
  - Positioning and Visualization
  - CNN-Based Visual Inspection
    - Data Set for Training
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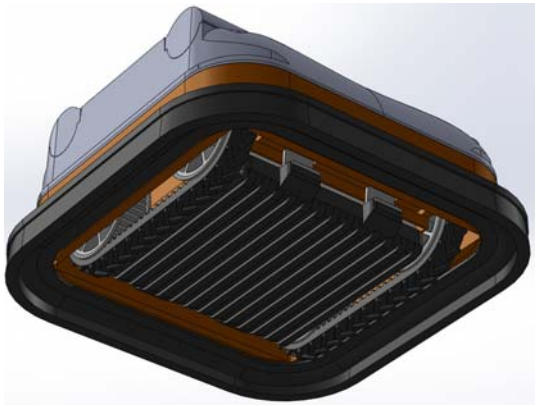
Project Goals

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**

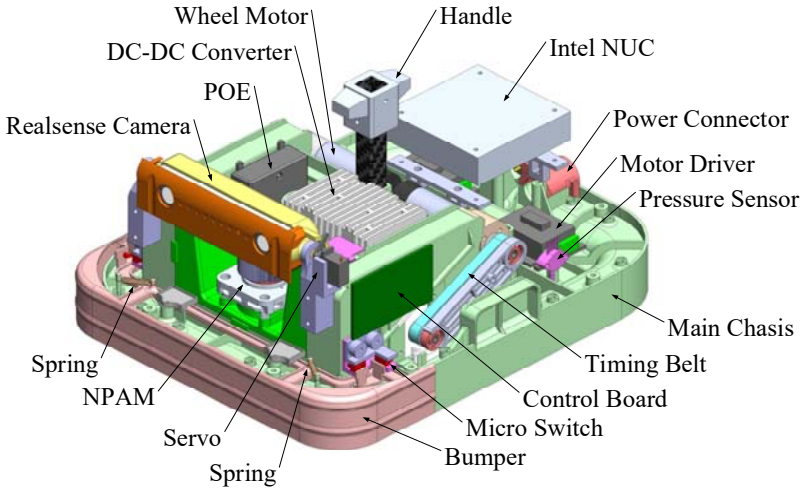


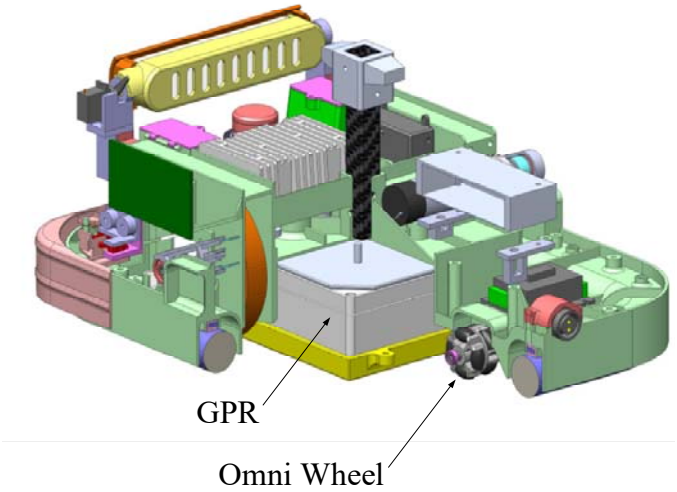
Empower GPR with vertical mobility

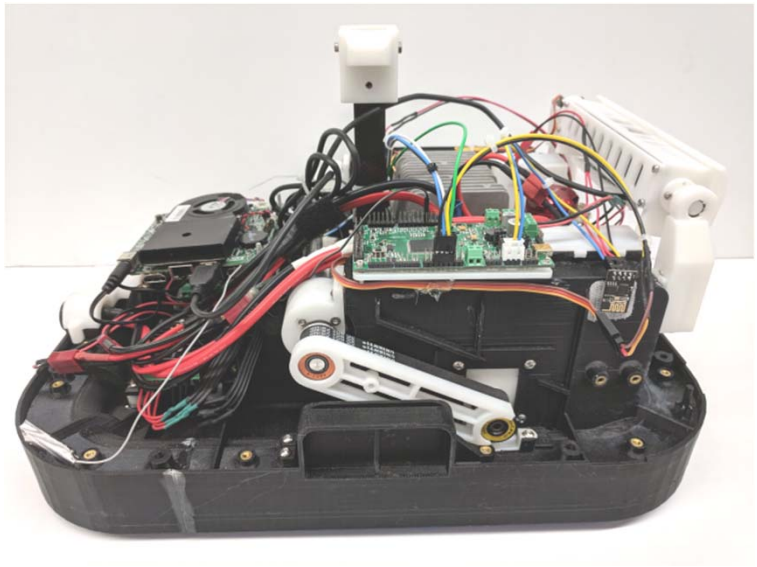
- **GPR-Rover Prototype-II**

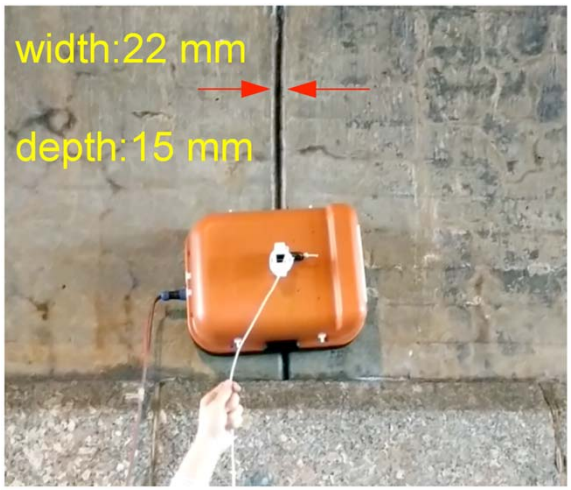
RGB-D sensor to detect surface flaws, GPR sensor on the bottom to detect sub-surface defects

GPR-Rover Prototype-II





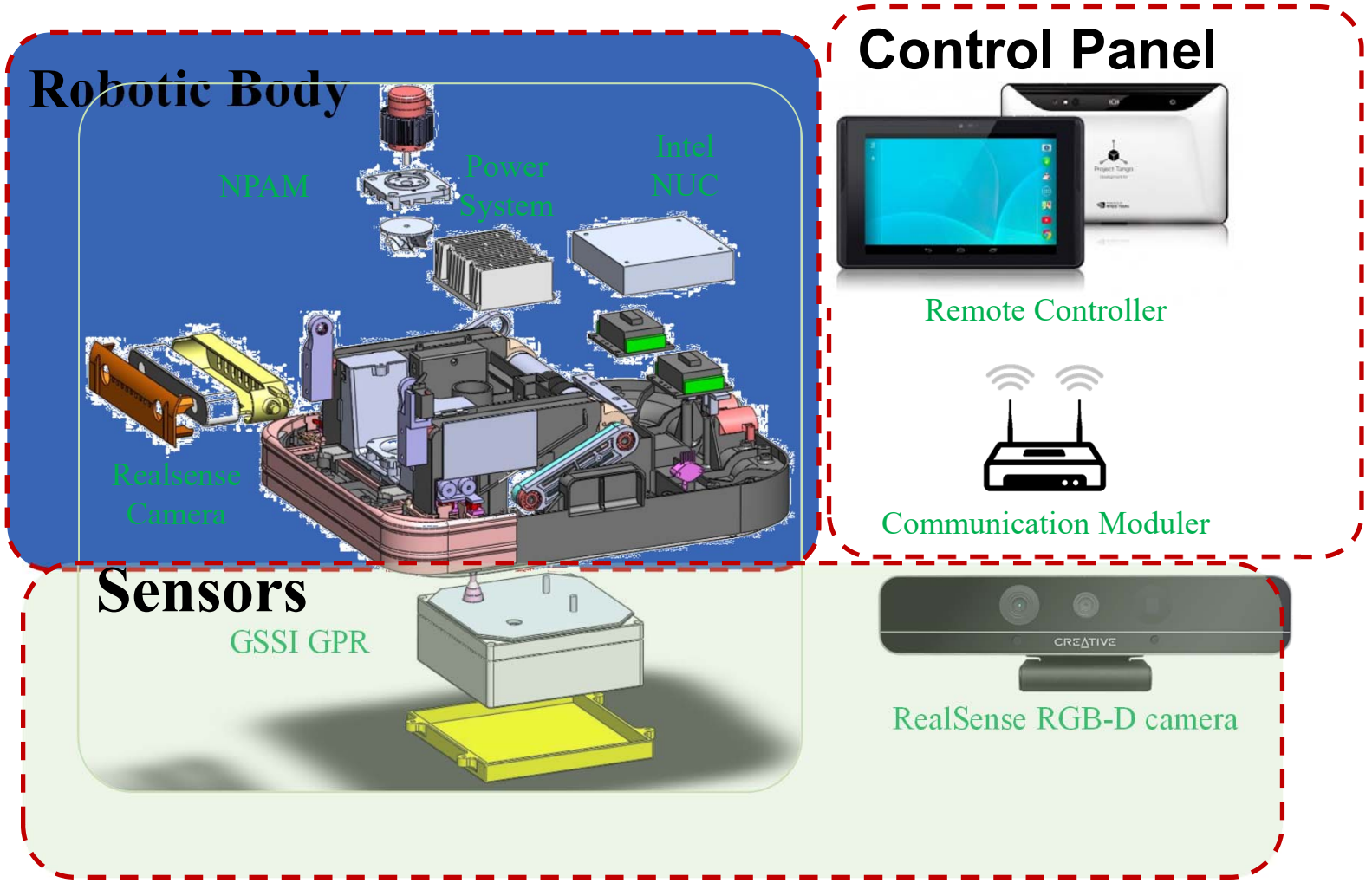




(*a*)Under - bridge area test

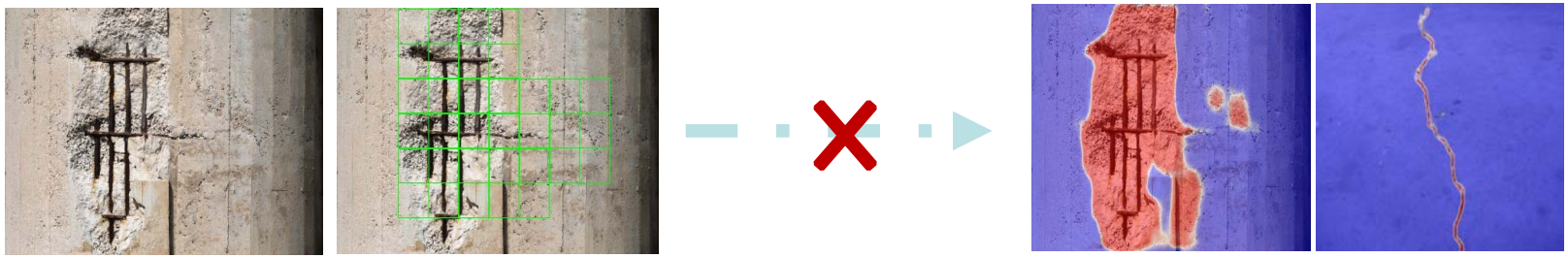
(*b*)Test at CCNY

System Architecture



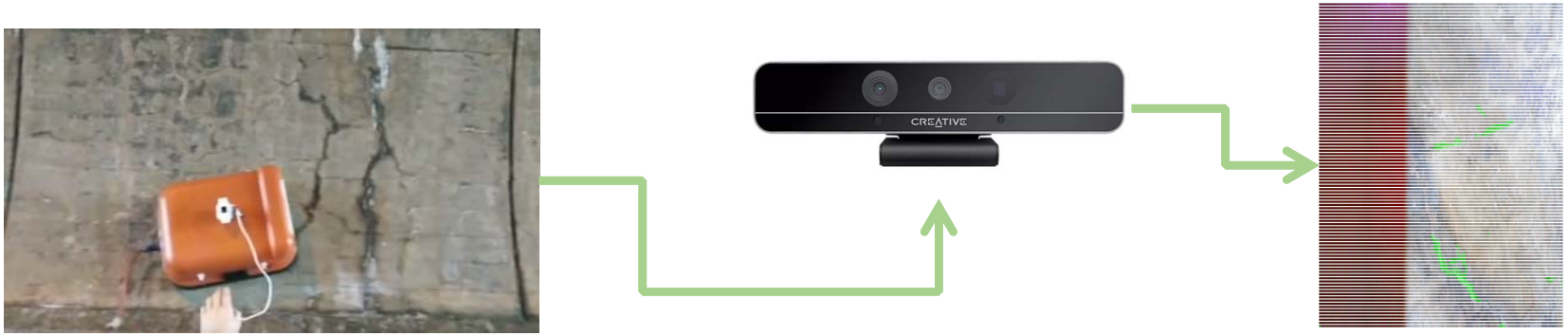
Visual Inspection Problems

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



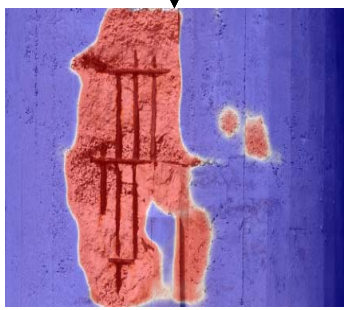
Problem 2: No Dataset available for learning purpose

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



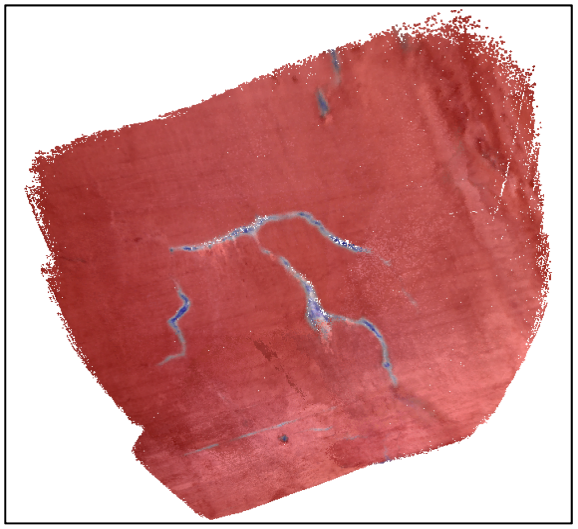
Health Monitoring and Visualization

region level accuracy

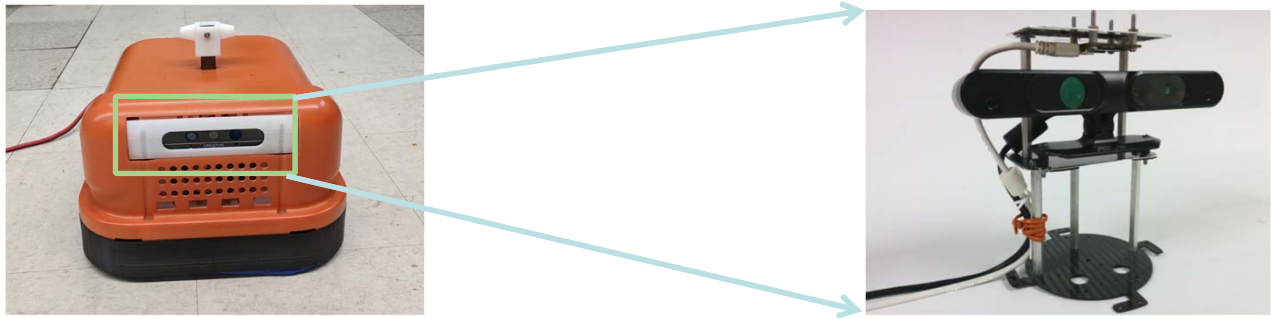


pixel level accuracy

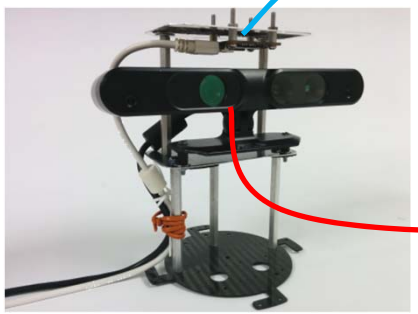
- Desired Features:
  - Perform pixel-level segmenation
  - Register to 3D Map for visualiztion
- Issues:
  - Accurate Positioning
  - 3D Reconstruction



Visual Odomotry for Positioning



Indirect Kalman:



Feature with covariance

Trifocal tensor for feature estimation

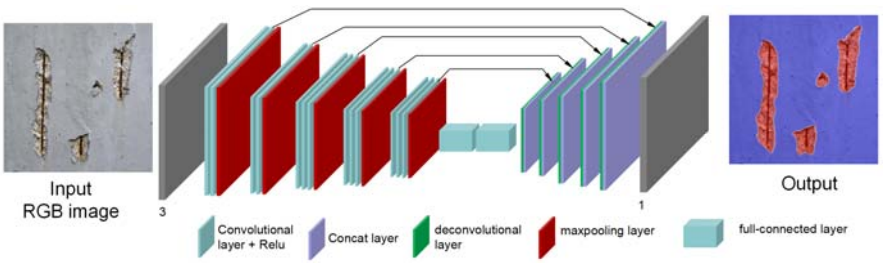
IMU to propergate

Update error to correct the nomial state

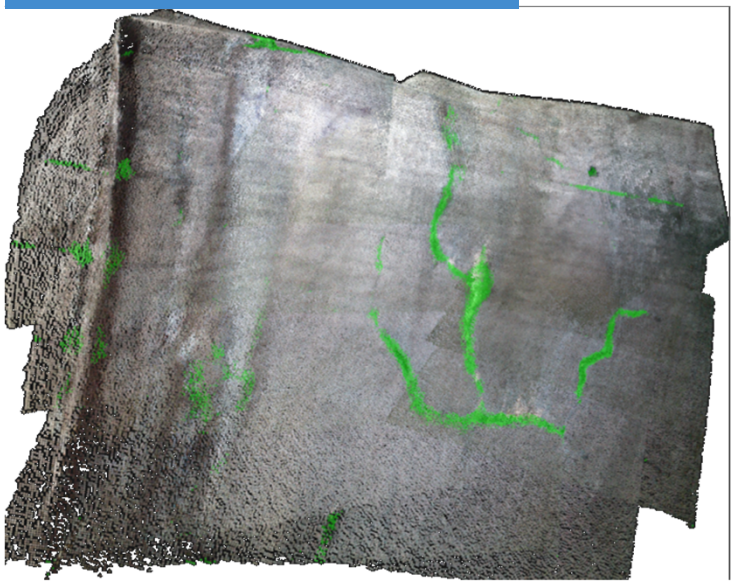
Detection and 3D Registration

3D Registeration:

InspectionNet for Pixel-level Detection



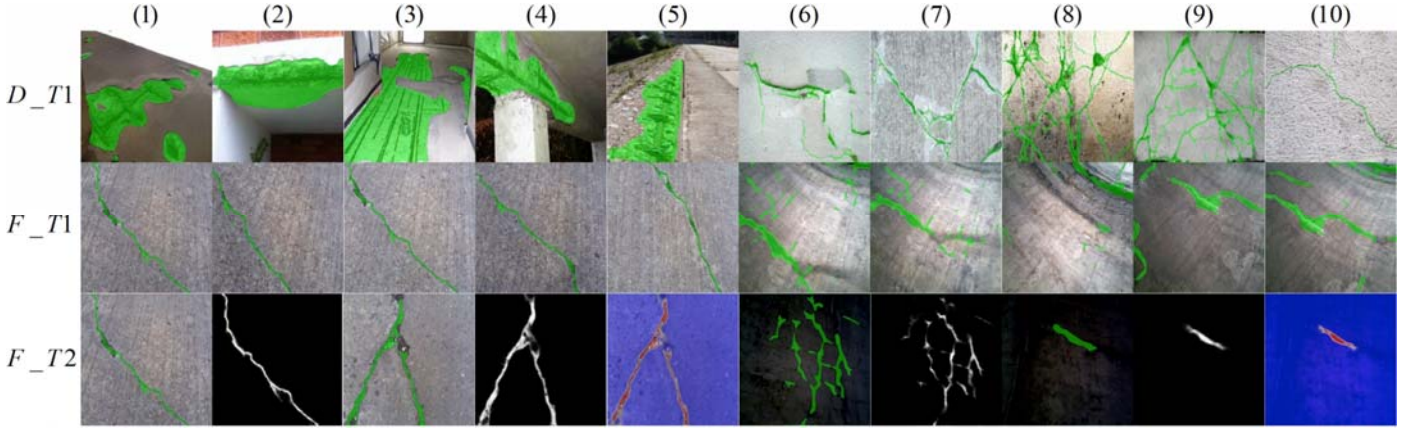
3D Reconstructed Map



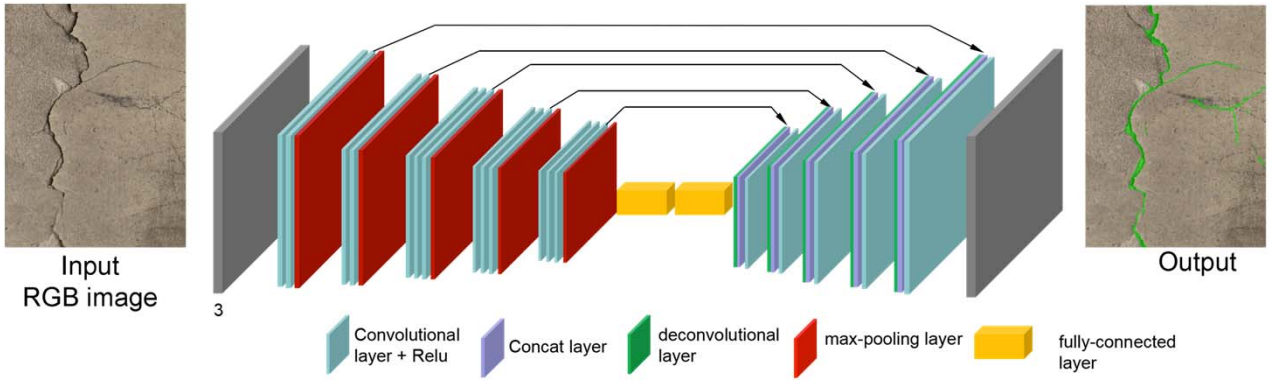
Segmentation Mask over defects

Accomplishments

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

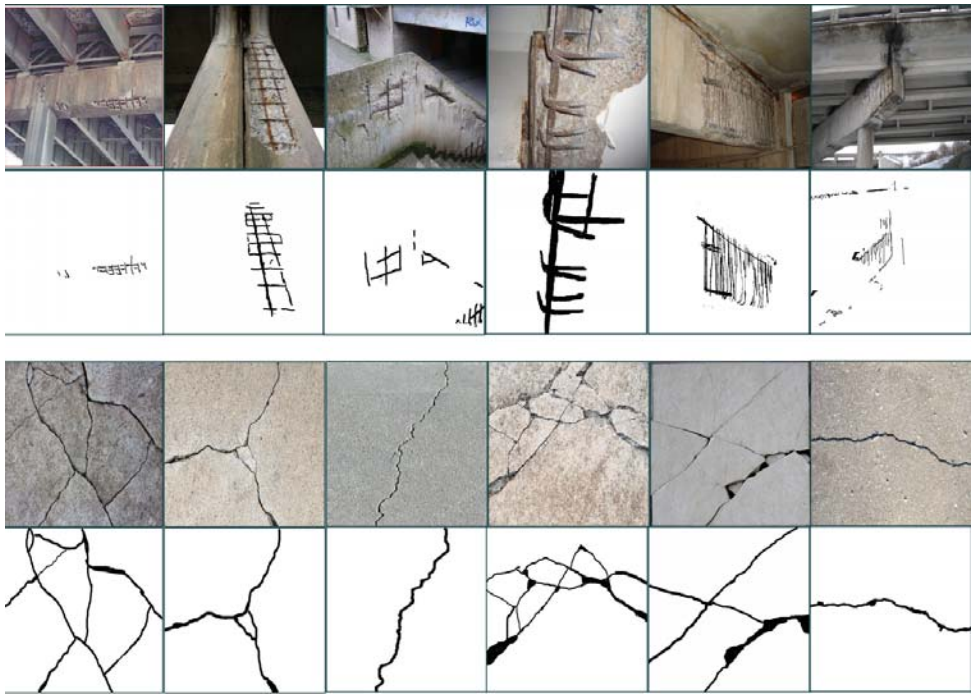


- Develop InspectionNET for surface flaw detection and measurement.



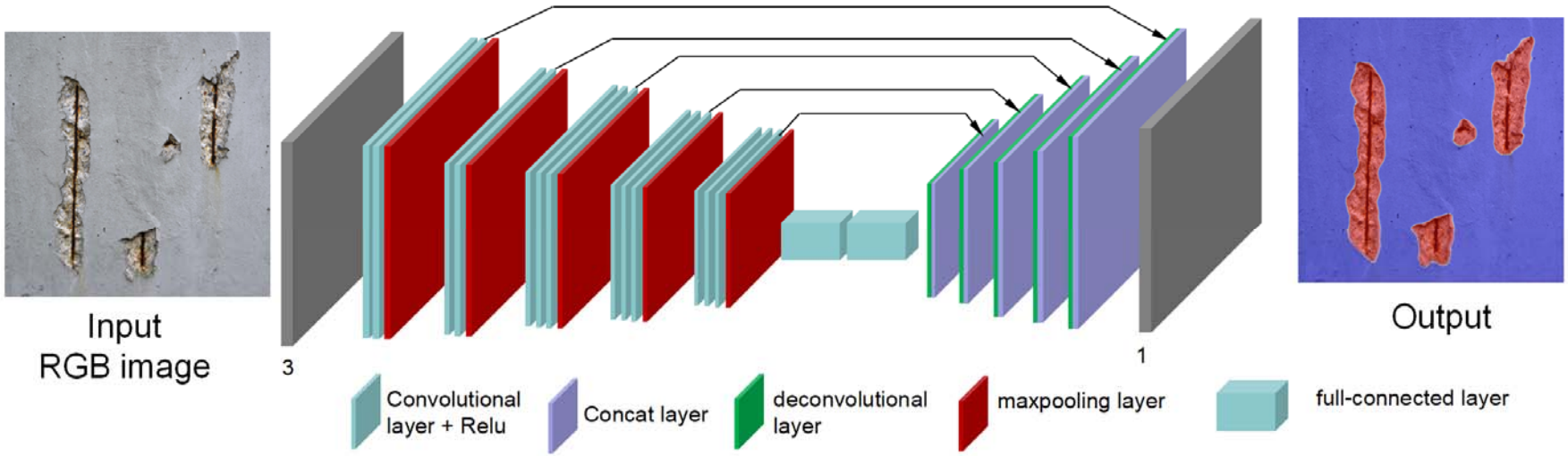
Data Set Preparation

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



For Training

InspectionNet for Segmentation

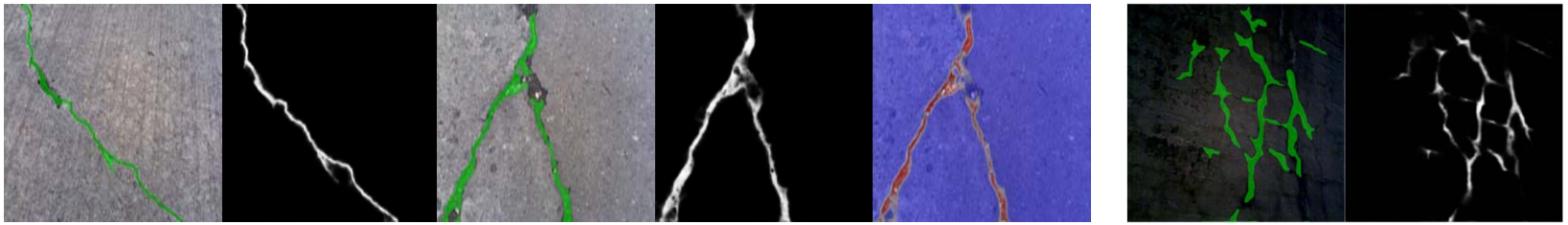


	Concrete Crack				Concrete Spalling			
Item	max F1	Ave Prec.	min Entropy	min Loss	max F1	Ave Prec.	min Entropy	min Loss
(CN) Training	79.59	91.66	0.048	0.3152	96.63	93.77	0.0128	0.388
(CN)Test	74.98	76.41	-	-	95.80	93.88	-	-
(FCN-8s) Training	7.33	3.81	-	-	96.37	94.039	0.09	0.43

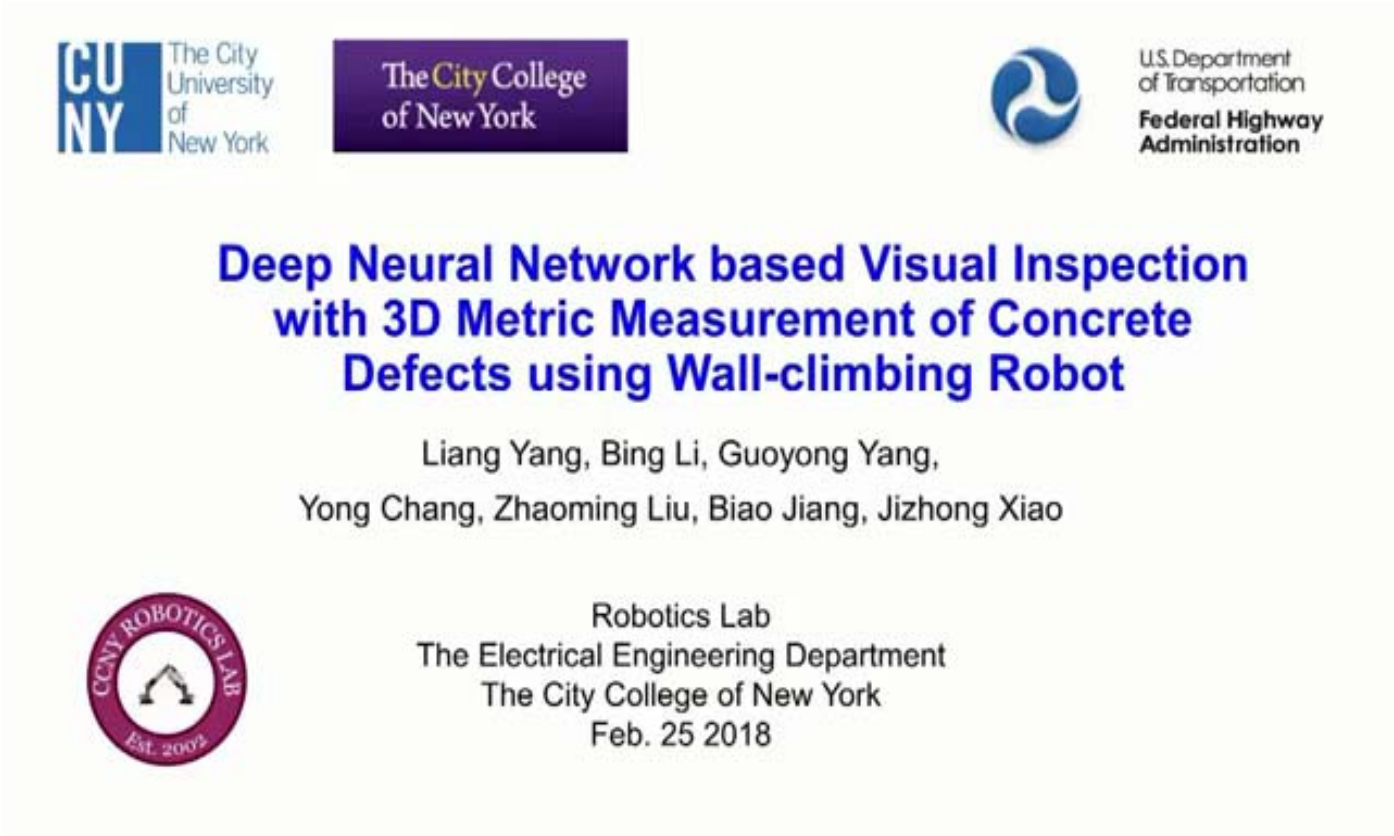
CNN for detection

Crack and Spalling segmentation based on test dataset

The white and black probability distribution & Dark illuminance case

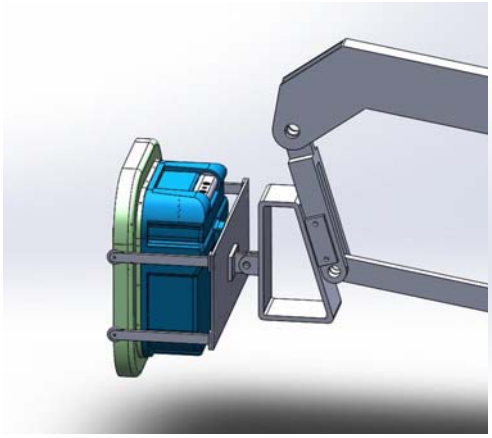


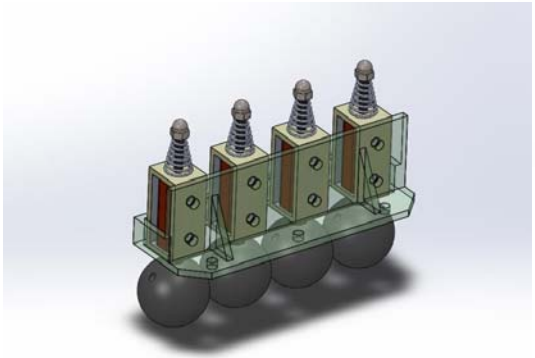
CNN for detection -- Experiment

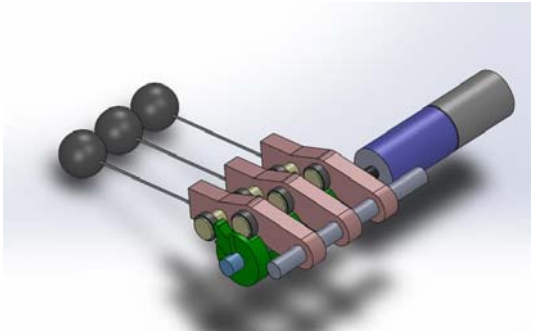


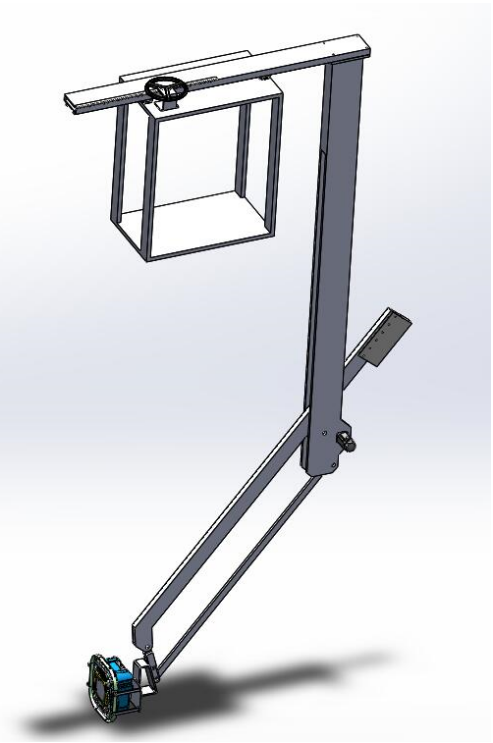
PLANNED ACTIVITIES:

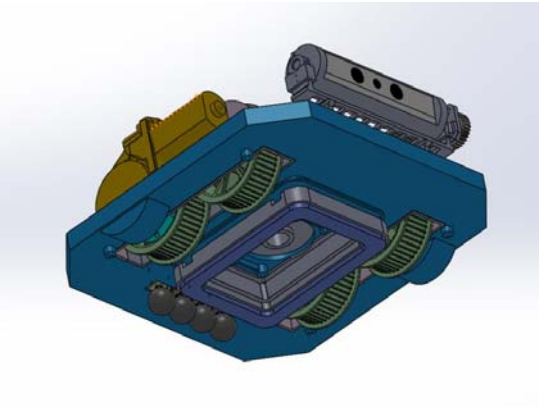
- Develop a robotic delivery system to reach the bridge pillar from the deck.
- Develop Impact sounding mechanism and data analysis methods.
- Develop multi-chamber wall-climbing robot to cross over deep groves











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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