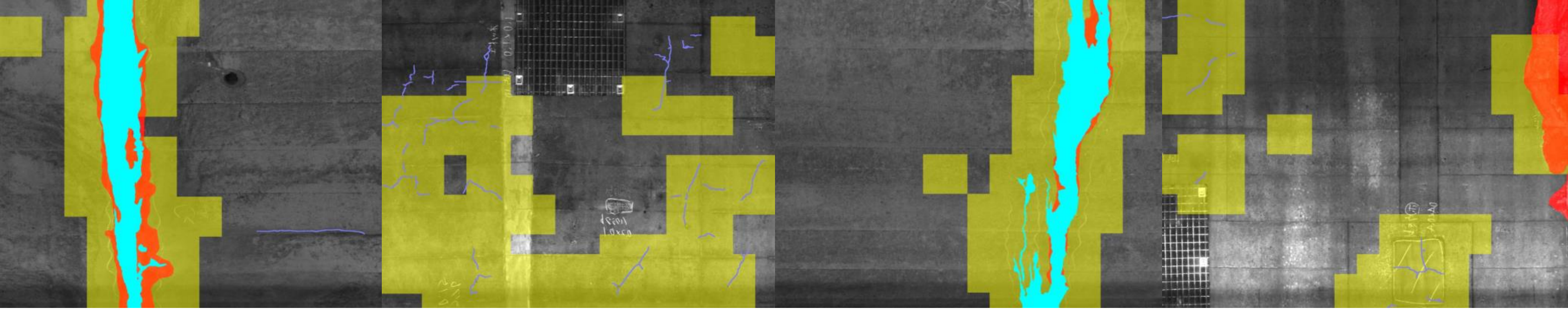

Deep Active Learning for Civil Infrastructure Defect Detection

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Mitsubishi Electric Research Laboratories (MERL)

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Chen Feng et al. International Workshop on Computing in Civil Engineering, 2017

Outline

- Importance of Defect Detection
- Previous Methods
- Problem Formulation
- Our solution
  - Deep Residual Network
  - Active Learning
- Results and Discussions

2017 INFRASTRUCTURE REPORT CARD

Bridges **C+** Roads **D** Transit **D-**

http://www.infrastructurereportcard.org/the-impact/explore-infographics/surface-transportation-infrastructure/

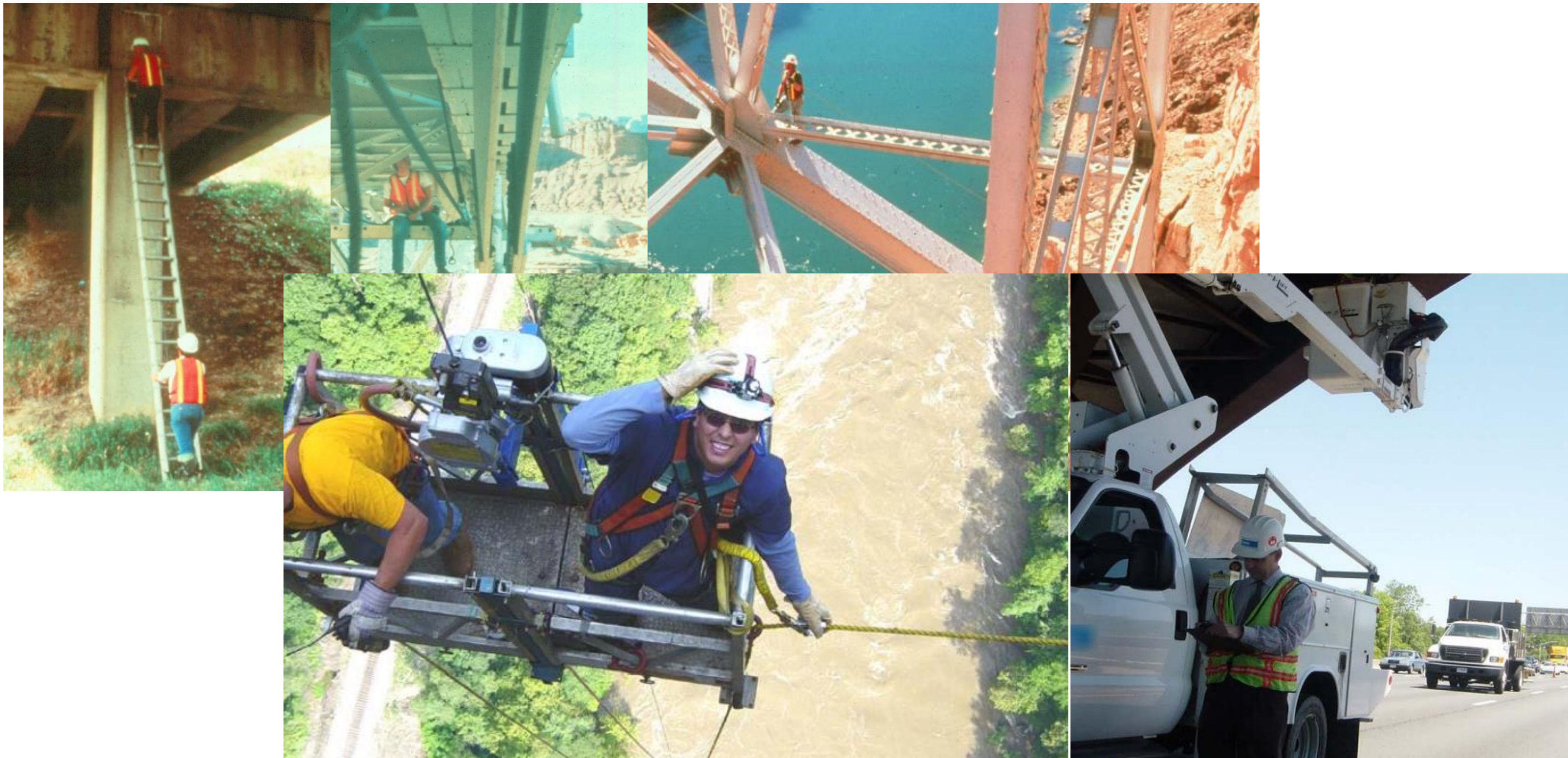
IN 2016 **56,000** OF THE NATION'S BRIDGES WERE STRUCTURALLY DEFICIENT

188 MILLION TRIPS ARE TAKEN ON STRUCTURALLY DEFICIENT BRIDGES

Inspection & Maintenance: Bridge

(FHWA 2012, Bridge inspector’s reference manual)

Inspection & Maintenance: Bridge



(FHWA 2012, Bridge inspector’s reference manual)

Inspection & Maintenance: Tunnel

(FHWA 2015, Tunnel Operations, Maintenance, Inspection, and Evaluation Manual)

Inspection & Maintenance: Dam

http://www.ropeworks.com/service.htm

http://news3lv.com/news/local/gallery/hoover-dam-concrete-spillways-need-different-safety-measures-than-oroville-dam-erosion#photo-2

https://www.usbr.gov/lc/region/feature/Rope_Access_Team_130628.html

Robots are coming!

Robots are coming!

NYPA 2013

http://www.xyht.com/aerialuas/m
ulticopter-profiles/

http://echord.eu/essential_grid/arsi/

http://www.ece.rutgers.edu/node/
1135

https://ara.cse.unr.edu/?page_id=183

How to Teach Robots to Inspect?

- Challenge: large amount of data
  - Rapid and accurate decision-making
- Existing works: Supervised Learning (Koch et al. 2015)
  - Shallow methods
    - SVM, Random Forrest, etc. (Prasanna et al. 2012, 2016)
  - Deep methods (Soukup and Huber-Mork 2014; Protopapadakis and Doulamis 2015; Zhang et al. 2016)
    - Convolutional Neural Networks (CNN)

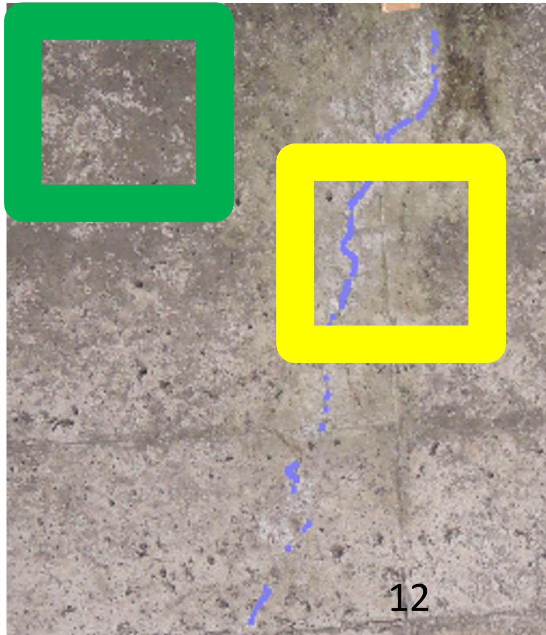
Problems of Existing Methods

- Shallow methods
  - Feature engineering
    - Hand-crafted features
    - Tedious for many tasks
    - May require expert knowledge
- Deep methods
  - Requires large amount of labeled data
    - Need time/money/experts

Our Problem Formulation

$\boldsymbol{y} = f_\theta(x)$

- Input: image patch x
- Output: defect probability $\mathbf{y} = [y_0, y_1]$
- Our contributions
  - ResNet (He et al. 2015) for four types of defect detection
  - Active learning (Settles 2010) for training, with a novel sampling strategy

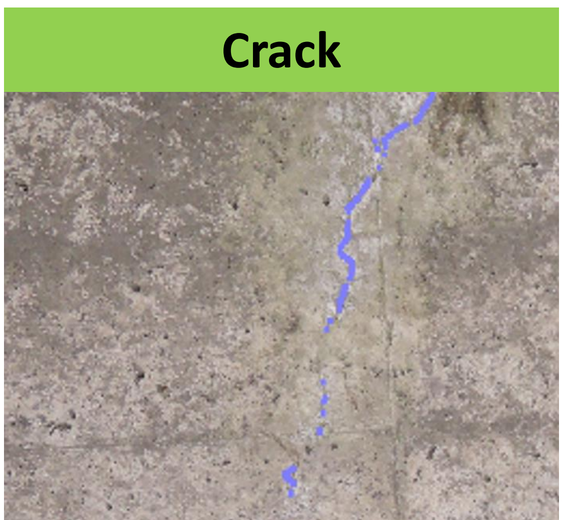


Deep Residual Learning

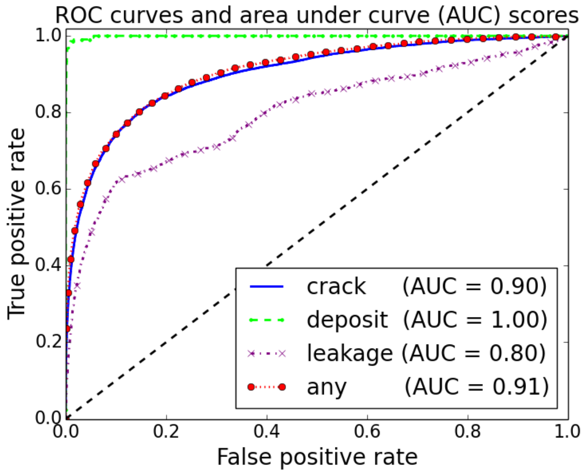
- ResNet as the classifier $\boldsymbol{y} = f_{\theta}(x)$
  - $\boldsymbol{z}_1 = f_{\theta_1}(x) + x$, …., $\boldsymbol{z_n} = f_{\theta_n}(\boldsymbol{z}_{n-1}) + \boldsymbol{z}_{n-1}$
  - $\boldsymbol{y} = f_{\theta_{n+1}}(\boldsymbol{z}_n) + \boldsymbol{z}_n$
  - Efficient learning of a deeper network (30+ layers)
- Loss Function: weighted cross-entropy loss
  - $E = \frac{-1}{N} \sum_{n=1}^{N} w\,(l_n) log\left(y_{n,l_n}\right)$
  - Handle unbalanced positive-negative ratio

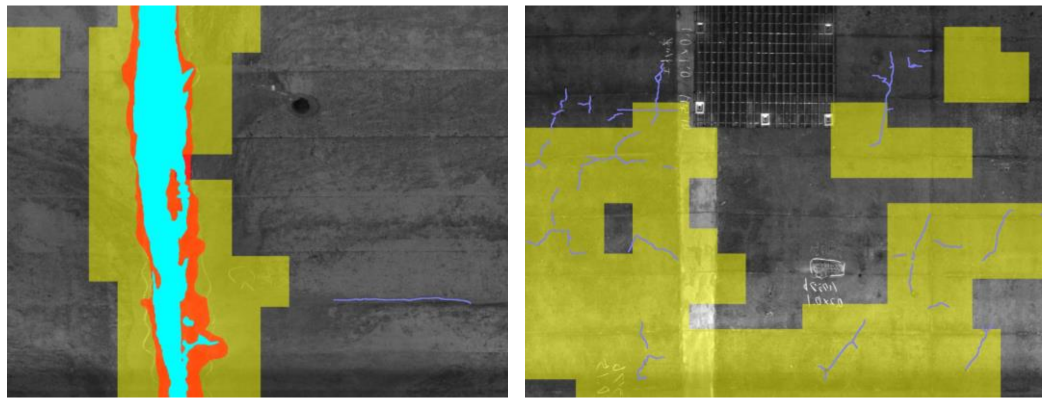
Experiments

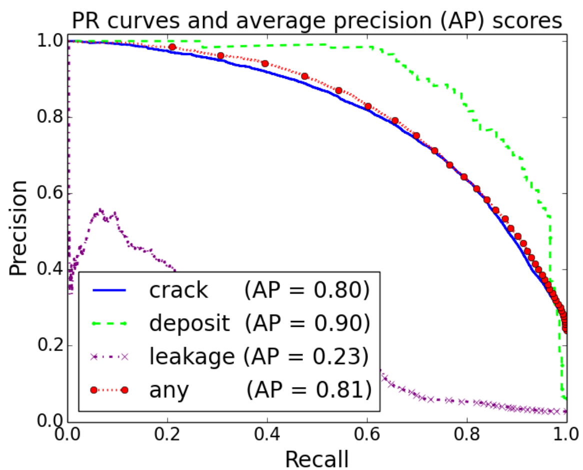
- Experimental Dataset: 289440 patches
  - Train : validation : test = 3 : 1 : 1
  - Train four classifiers

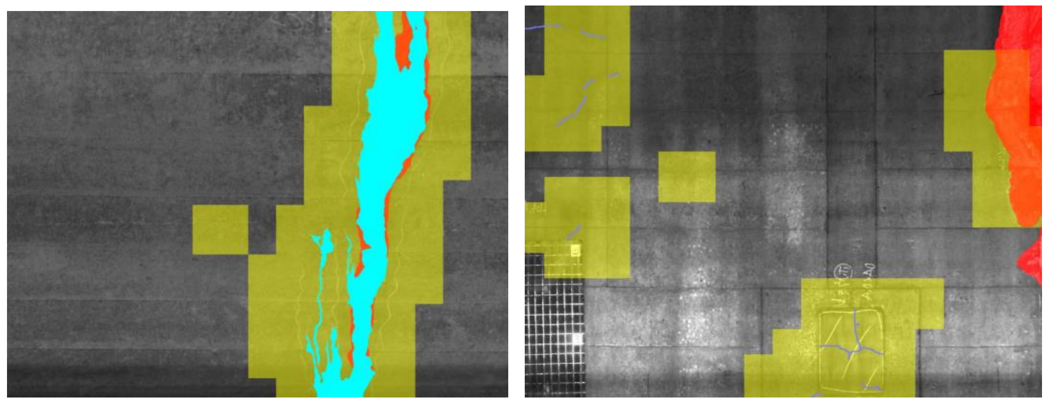


Defect Detection Results



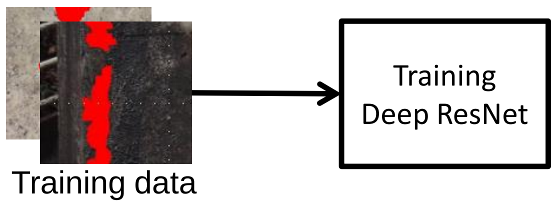






Active Learning (AL)

- Data annotation for supervised learning
  - Tedious/expensive/qualified annotator
- AL: aims for the most efficient data annotation
  - Fewer data to achieve same accuracy



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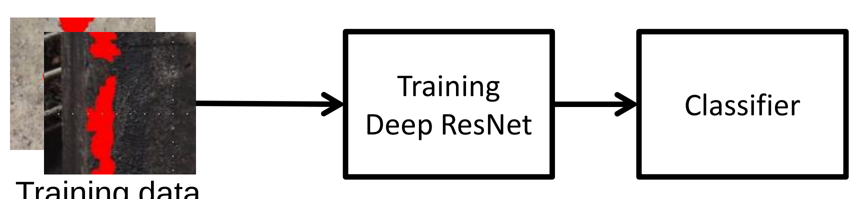

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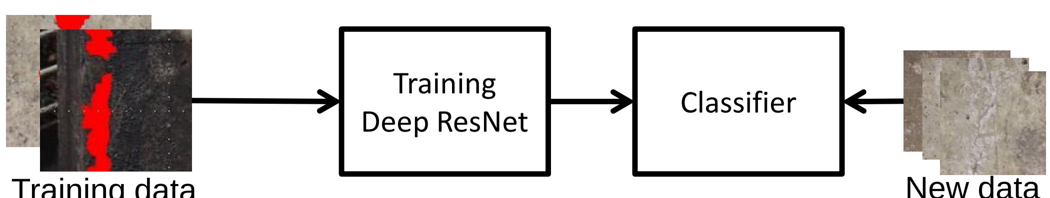

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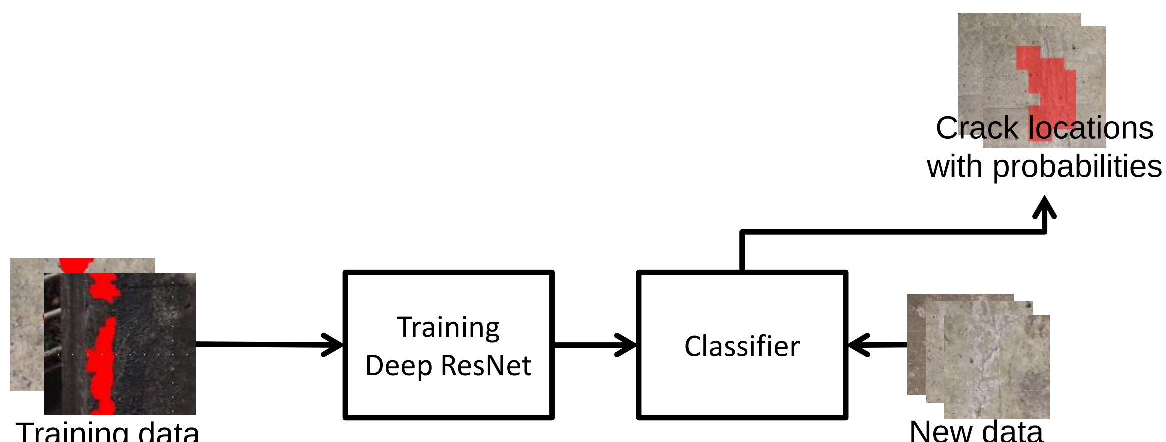

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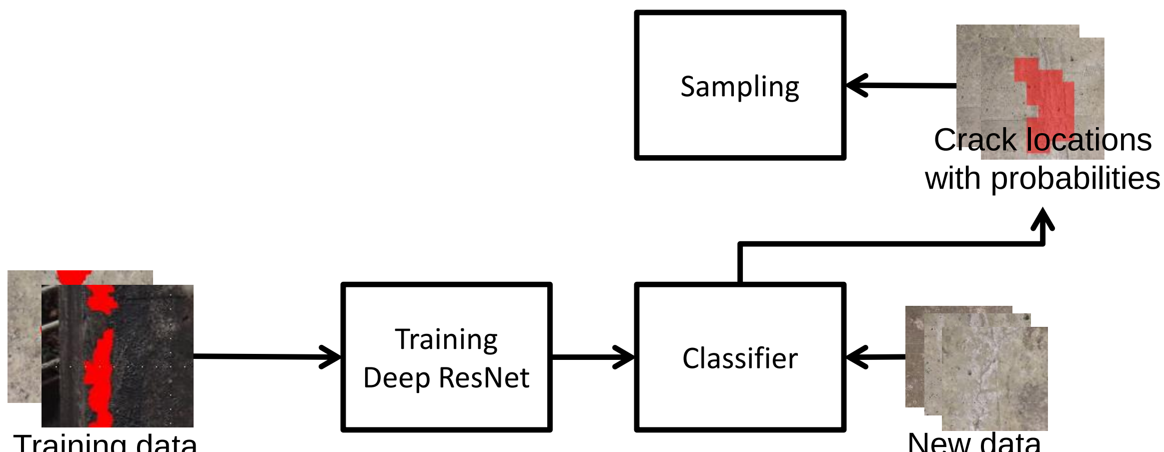

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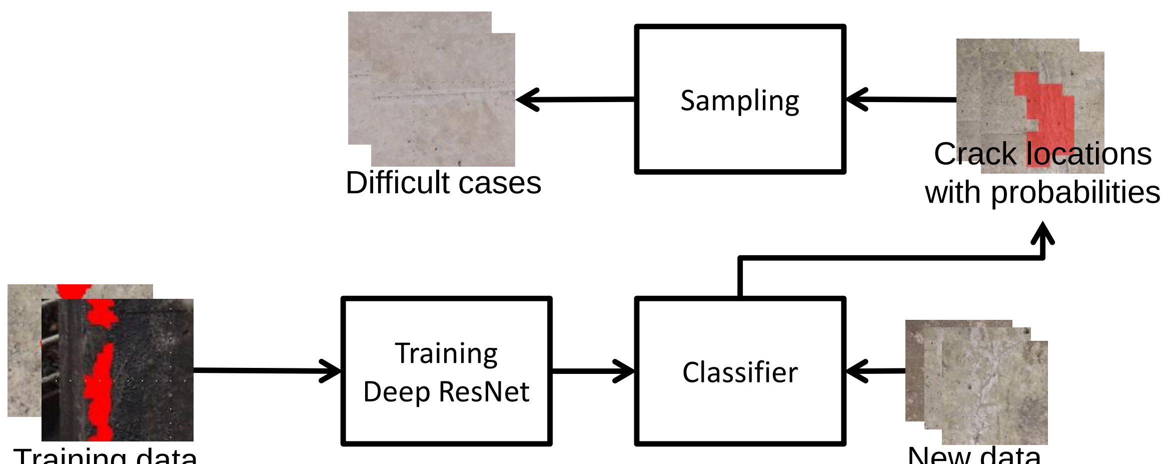

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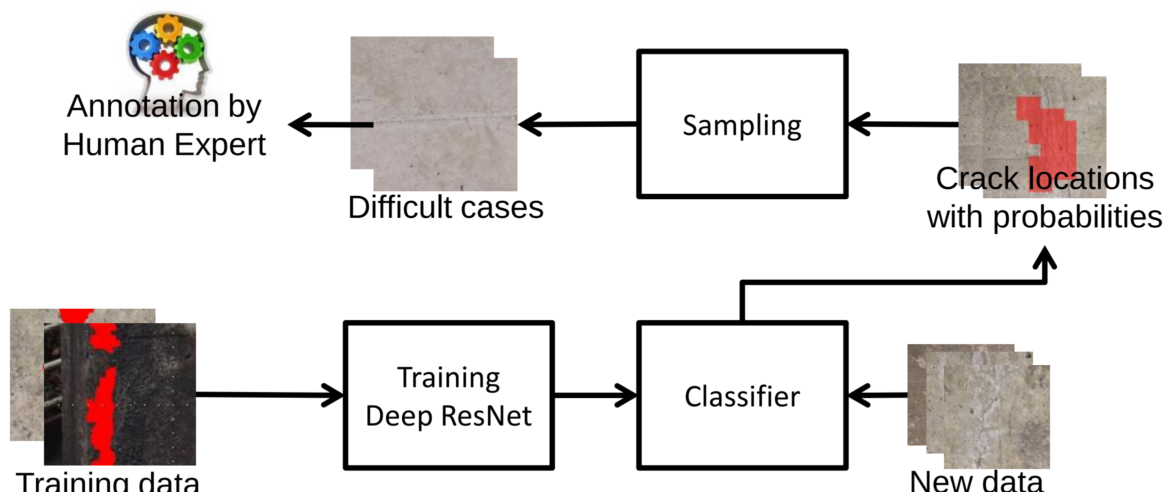

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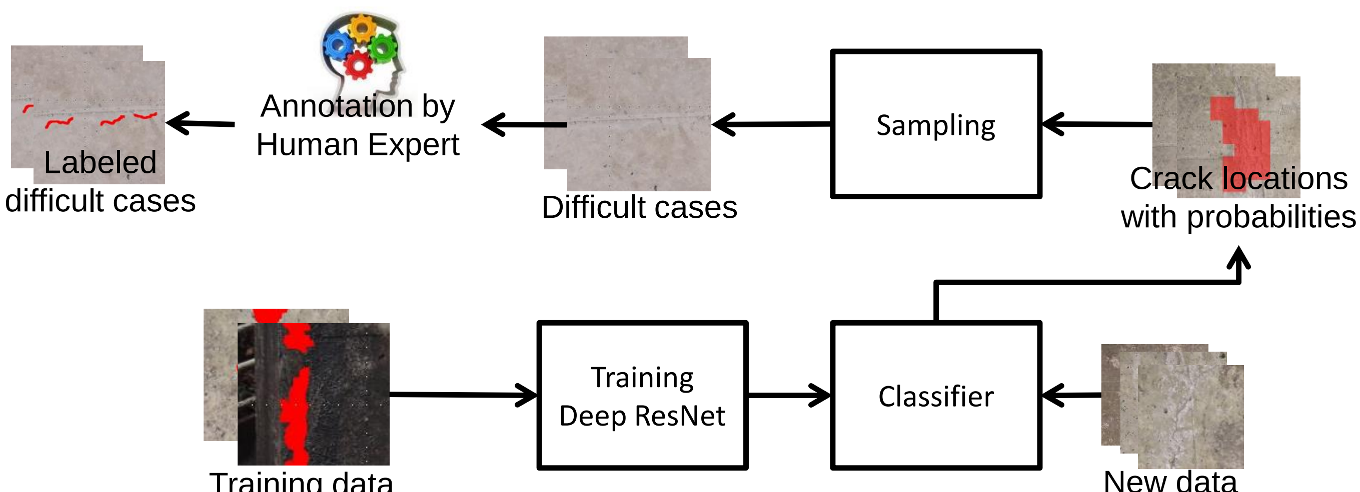

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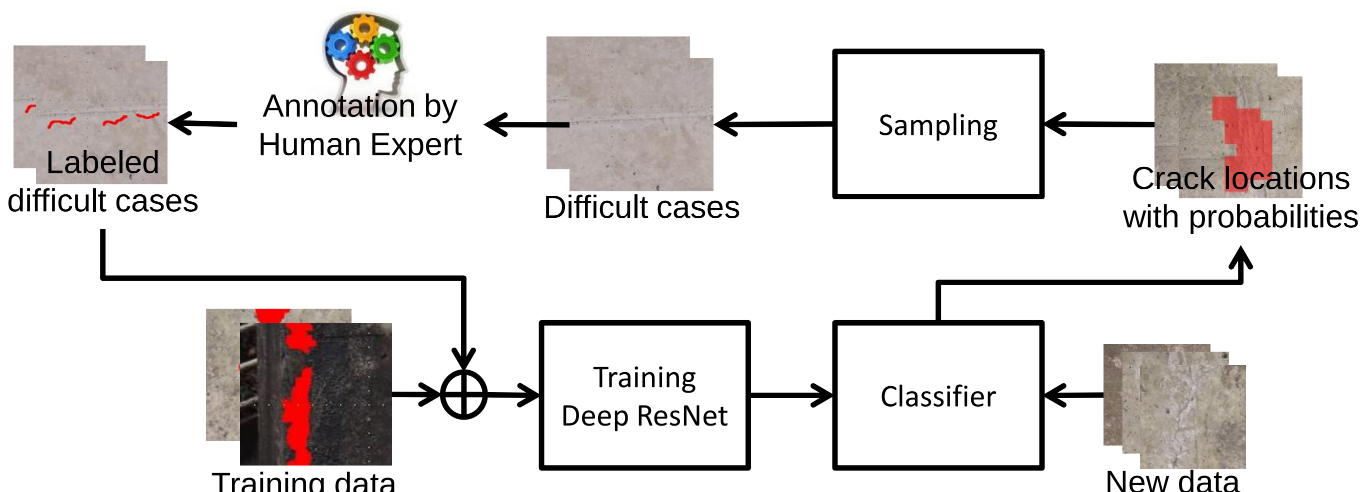
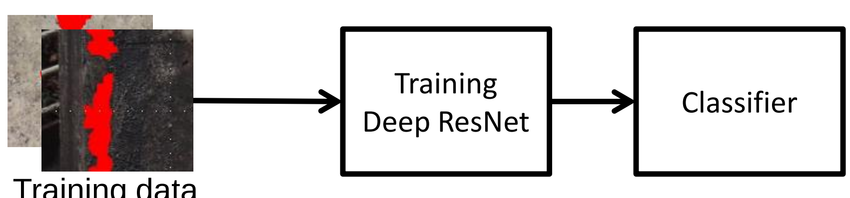
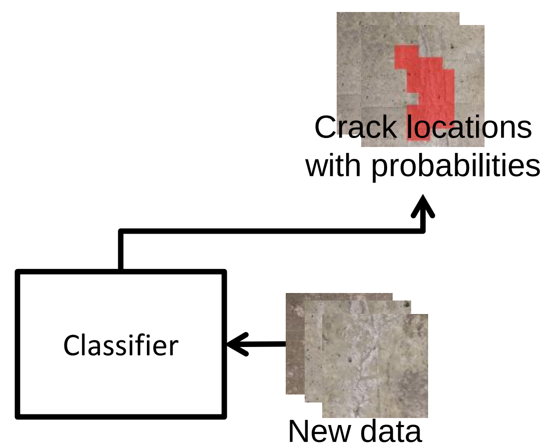


AL Analogy: Initial Training



AL Analogy: Trial and Error



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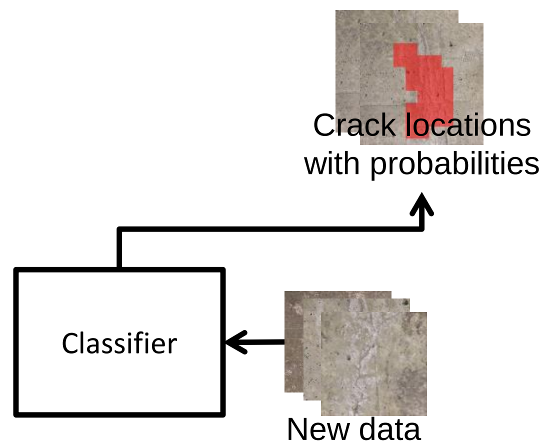

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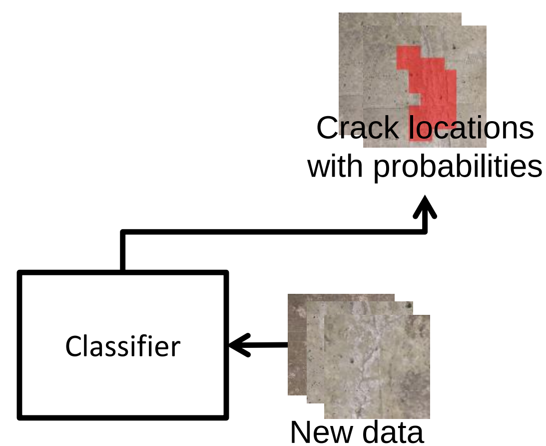

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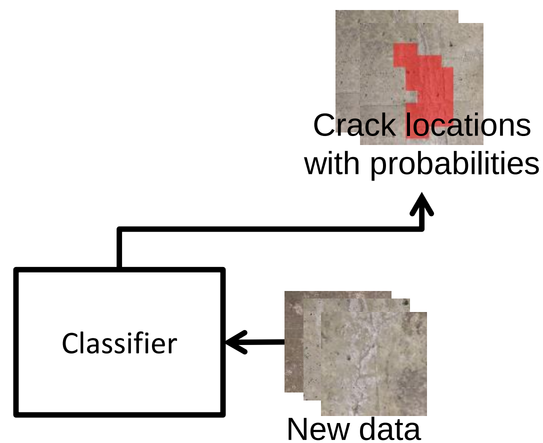
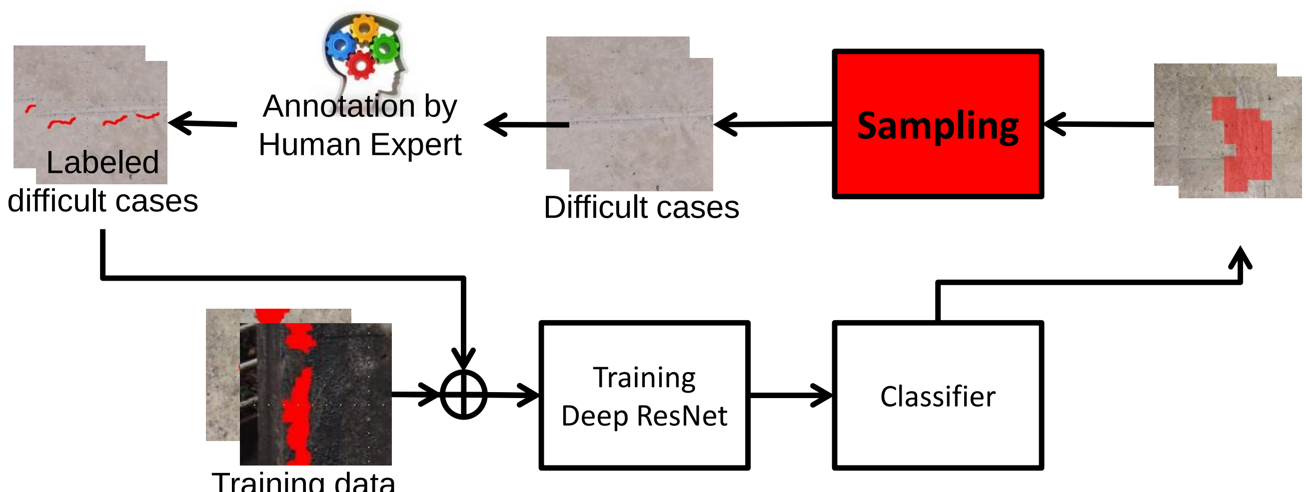
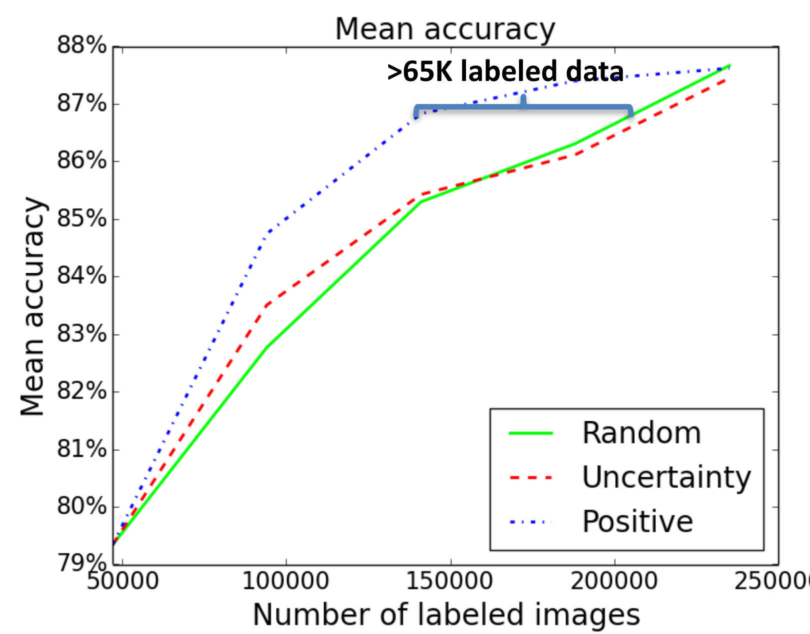


AL Analogy: Selected Feedbacks



Active Learning Results

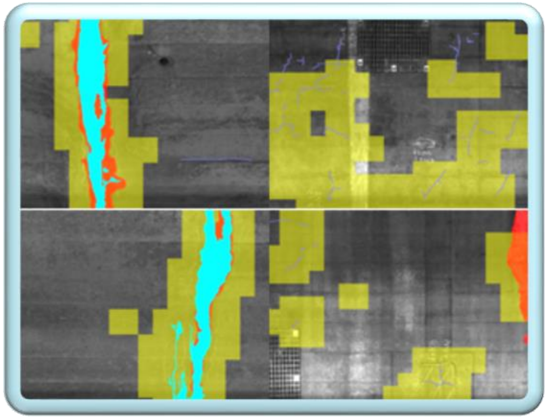
- Positive AL
  - "Robot says this is defect, can you verify it?"
- Uncertainty AL
  - "Robot is not sure…"
- Test AL on "any" detector
  - "train+validation"
  - Positive AL saves 30%



Recap: Deep Active Learning

- Defect detection is important for civil infrastructure
- Deep Learning avoids explicit feature engineering
  - Need more data
- ResNet allows deeper networks for higher accuracy
- Active learning samples most informative data to improve classifier
  - Positive sampling strategy for defect detection

Thank you! Questions?



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