THE Water Research FOUNDATION

Webcast

Leveraging Big Data and Deep Learning for the Condition Assessment of Wastewater Pipelines

November 10, 2020

Housekeeping Items

- Submit questions through the question box at any time. We will do a Q&A at the end of the webcast.
- Slides and a recording of the webcast will be available at www.waterrf.org.
- You will receive a certificate of completion at the end of the webcast.
- Survey at the end of the webcast.

Project Overview

- Principle Investigator - Dulcy Abraham, Ph.D.
- Goal to determine whether computational technologies such as deep learning and data mining can improve the consistency, accuracy, and speed of visual inspections and the evaluation of sewer pipe condition.
- An automated system was developed and evaluated detect fissures, root intrusions, and lateral connections in CCTV inspections of sewers.

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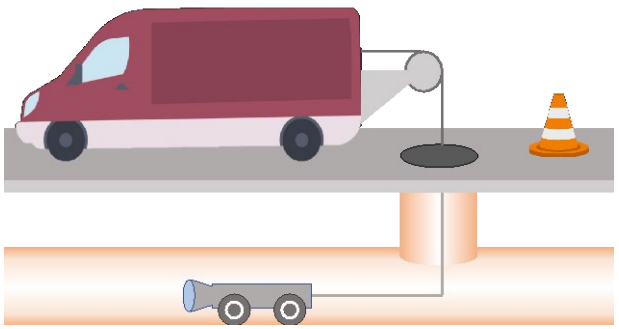
Leveraging Big Data and Deep Learning for Condition Assessment of Wastewater Pipelines

The Problem

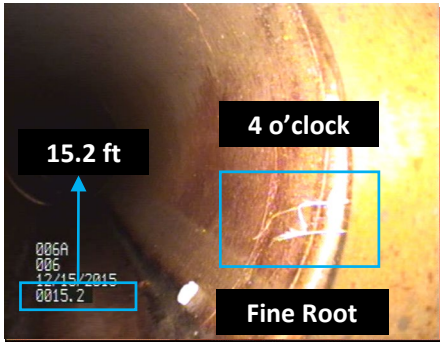
- 800,000 Miles of Public Sewage Pipes
  - 3X Distance from Earth to the Moon
- 850 Billion Gallons of Sewage Overflows
- How Can the Condition of Sewers be Assessed?
  - Rapidly, Economically, and Accurately

Sewer Condition Assessment Process

CCTV Inspections



Manual Coding



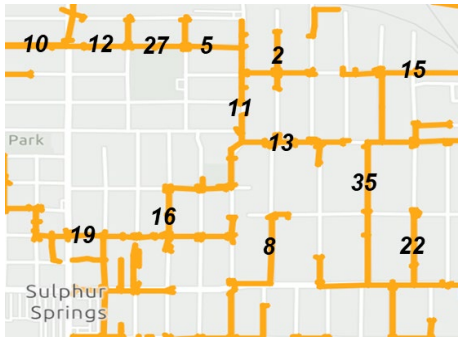
Inspection Report

Defect	Distance	Position
Fine Root	15.2 ft	4 o'clock
Spiral Crack	45.0 ft	1 o'clock
Deposit	80.0 ft	6 o'clock
Broken	100.0 ft	3 o'clock

Calculate Pipe Condition Score (NASSCO PACP)

Structural Score: 15

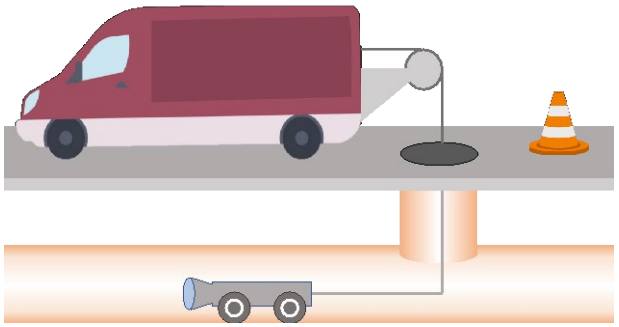
Repeat for Sewer Network



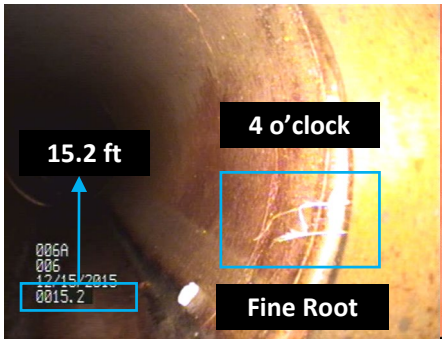
Pipe Rehabilitation Decisions

Sewer Condition Assessment Process

CCTV Inspections



Manual Coding



Inspection Report

Defect	Distance	Position
Fine Root	15.2 ft	4 o'clock
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Deposit	80.0 ft	6 o'clock
Broken	100.0 ft	3 o'clock

Slow, subjective, and prone to human error

Potential to improve the consistency and speed of inspections

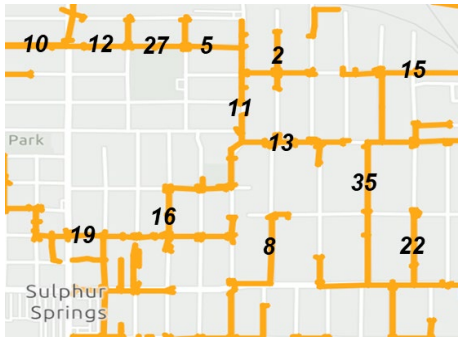
Sewer Condition Assessment Process

Big-Data Mining* – *Insights Into Sewer Deterioration

Calculate Pipe Condition Score (NASSCO PACP)

Structural Score: 15

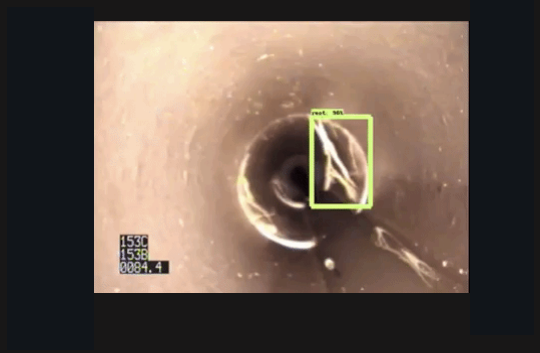
Repeat for Sewer Network

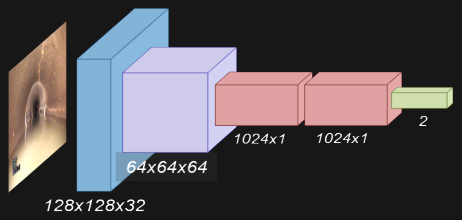


Pipe Rehabilitation Decisions

Objective 1

Automated Inspection Coding

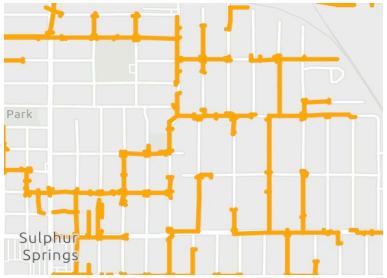


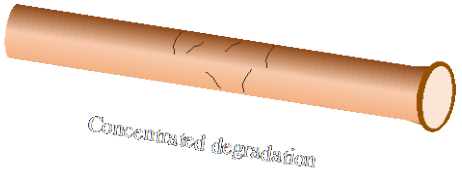


State-of-the-Art Deep Learning

Objective 2

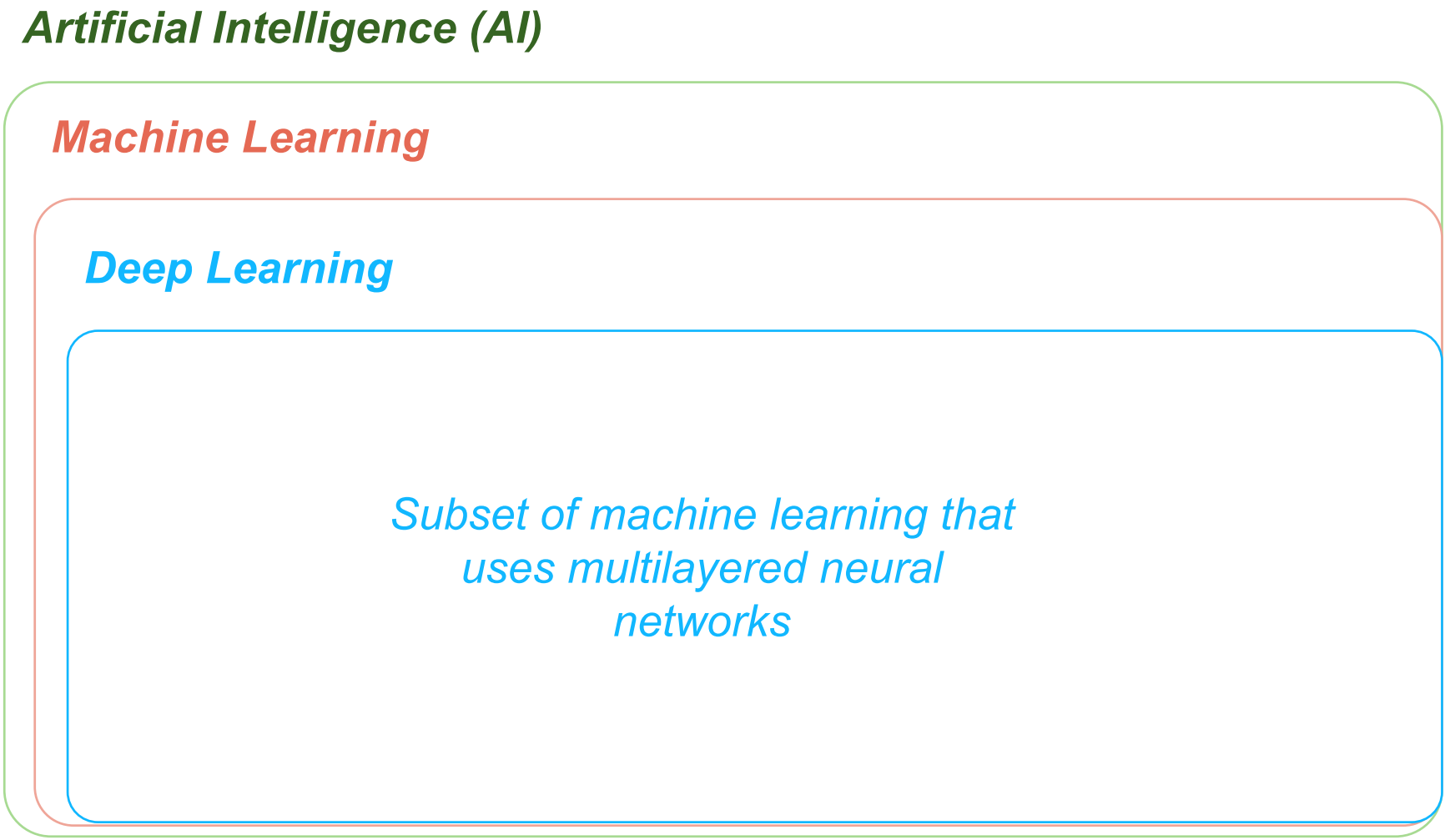
Predictive Analytics for Sewer Failure





Big-Data Mining of Sewer Condition History

Terminology



Terminology

Language

Machine Translation

English:
Have a nice day

Hindi:
आपका दिन शुभ हो

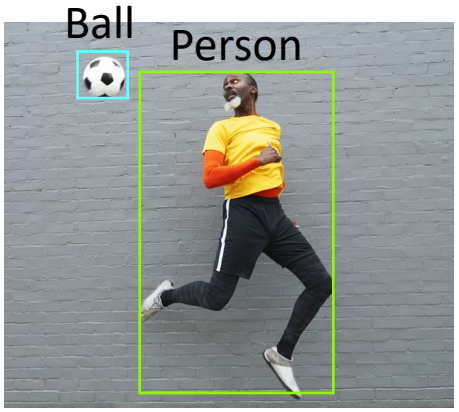
Audio

Virtual Assistant

What's the weather like?

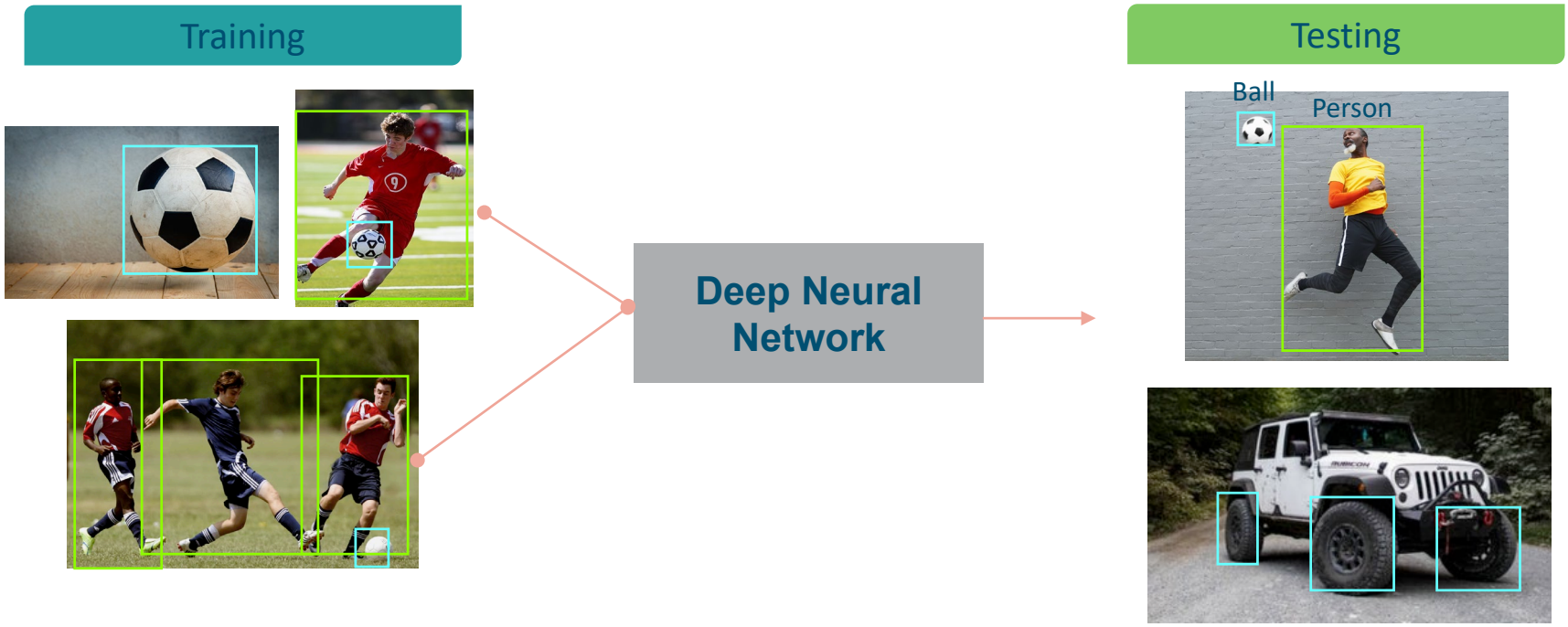
Vision

Object Detection



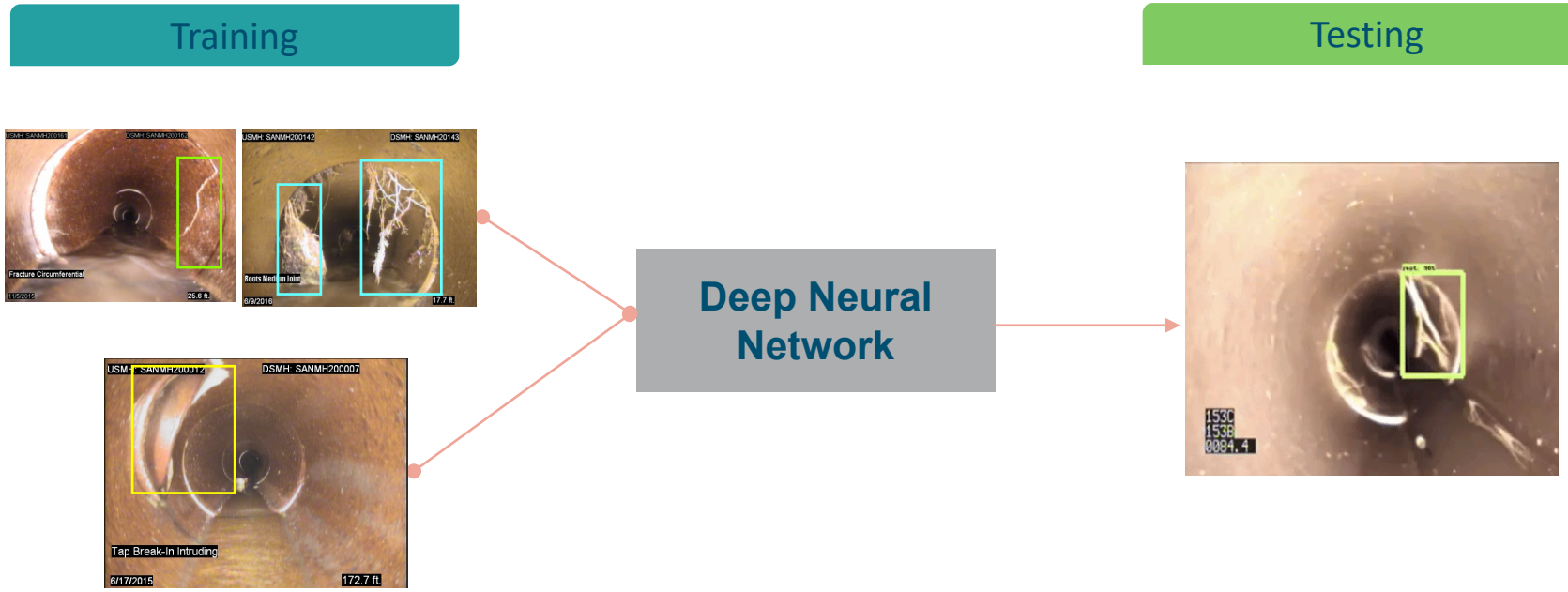
We use object detection extensively for automated CCTV coding

How to Implement Object Detection?



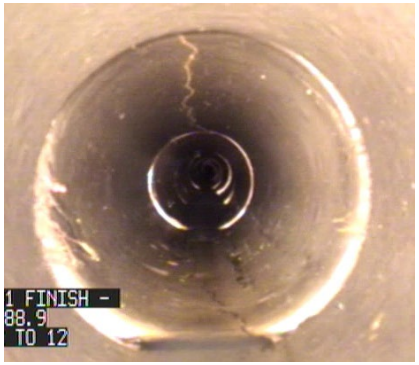
Important to provide a diverse set of training images

How to Implement Object Detection?

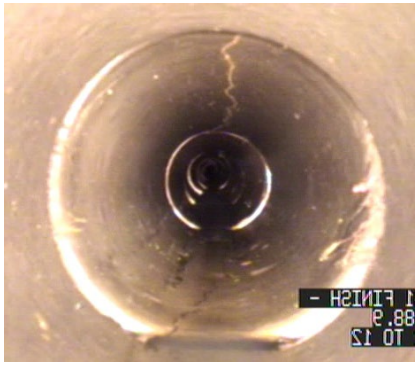


Need for diversity in training images

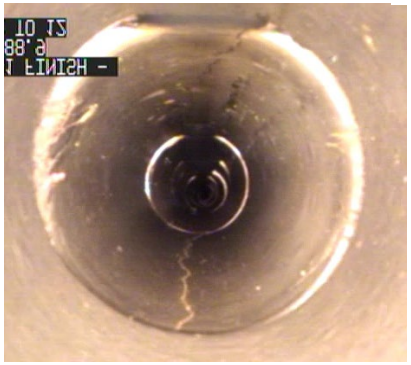
Data Augmentation



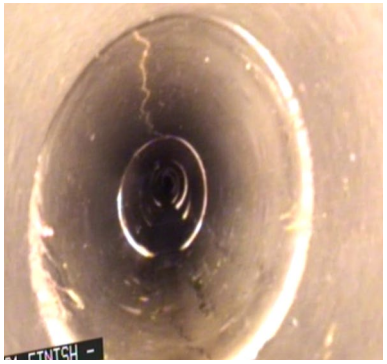
Original Image



Horizontal Flip



Vertical Flip



Rotation

Adds Variation to the Training Images

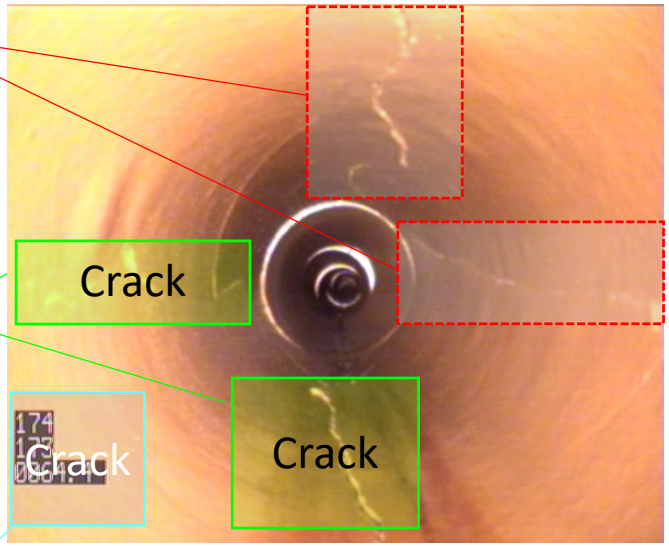
Evaluating Accuracy

False Negative (FN)

"AI missed a defect"

True Positive (TP)

"AI correctly detected a defect"



False Positive (FP)

"AI predicted a defect which did not exist"

Recall

$$\frac{TP}{Total\ Number\ of\ Defects}$$

$$\frac{2}{4} = 50\%$$

Precision

$$\frac{TP}{TP + FP}$$

$$\frac{2}{3} = 67\%$$

Accuracy Metrics

Recall

High Recall => Fewer Missed Defects

90% => 1 out of 10 defects are missed

Precision

High Precision => Fewer False Positives

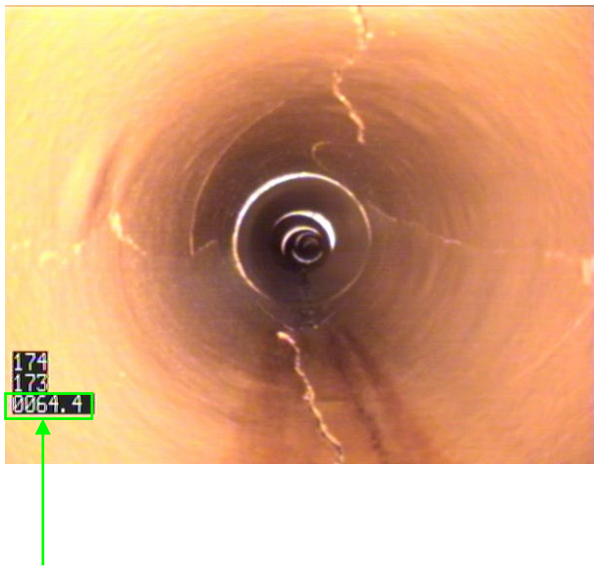
90% => 1 false positive for every 10 defects the AI correctly identifies

Evaluation

Evaluated on 10 CCTV Videos of Vitrified Clay Pipe from Alabama and Ohio

Recall 90%
Precision 50%

Localization of Observations



1. *On-screen text recognition*
2. *Distance files from inspection crawler*

Desired Output

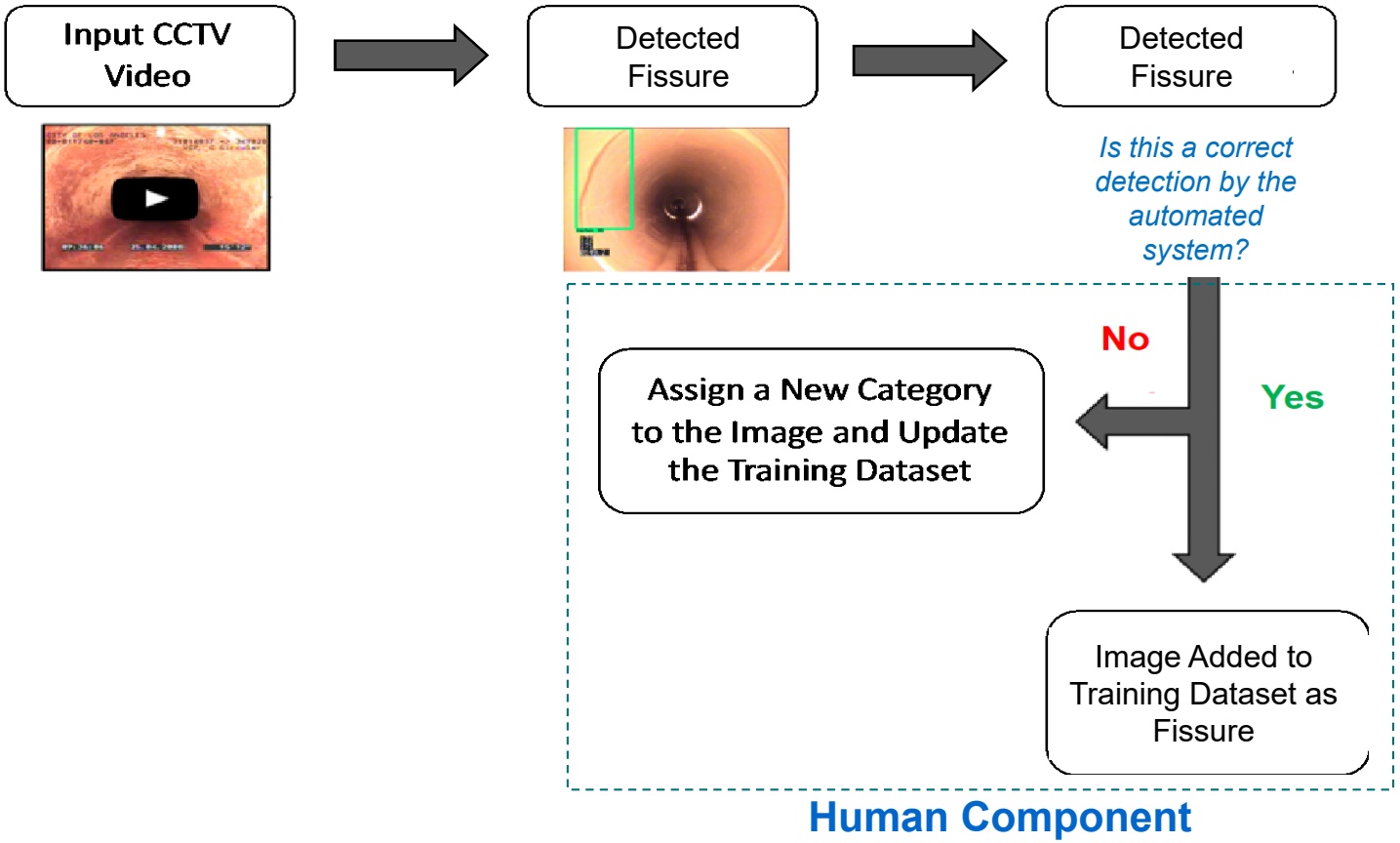
Type: Longitudinal Crack

Distance: 64.4

Circumferential Position: 3, 6, 9, and 12 o'clock

Time	Distance	Observation
1 sec	0 ft	-
2 sec	1 ft	-
3 sec	1 ft	-
4 sec	2 ft	Crack
5 sec	2 ft	Crack
6 sec	3 ft	-
7 sec	3 ft	-
8 sec	3 ft	-

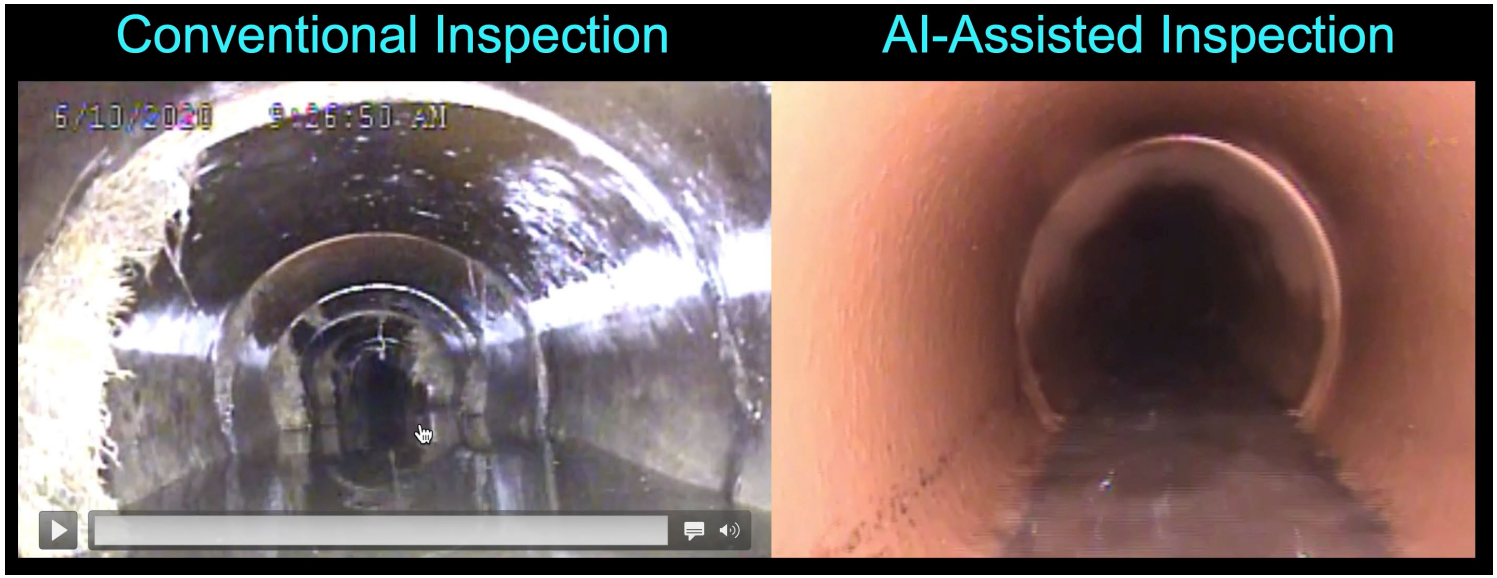
AI-Assisted Coding



Benefits of AI-Assisted Coding

Avoid time spent stopping and coding observations

Inspect in the field, code in the office (using AI)



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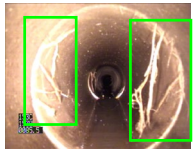
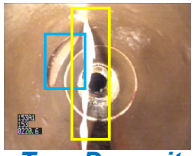
Extending the Work – Levels of Automation

Level 2. Multi-Classification

Detect the position and extent of multiple instances of deterioration indicators



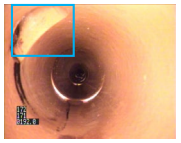
Roots



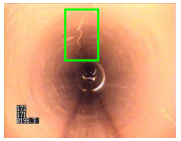
Tap; Deposit

Level 3. Sub-Classification

Detect the position, extent, descriptors, and modifiers of deterioration indicators



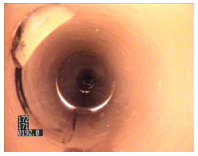
Tap Factory Defective (TFD)



Longitudinal Crack (CL)

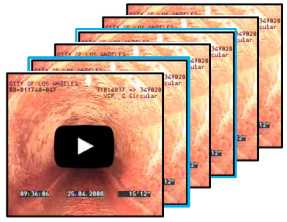
Level 1. Classification

Identify the presence of deterioration indicators



Tap

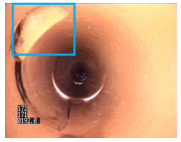
Crack



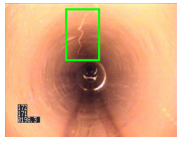
Inspection Video

Level 4. Localization

Perform sub-classification and determine the position of deterioration indicators in pipes



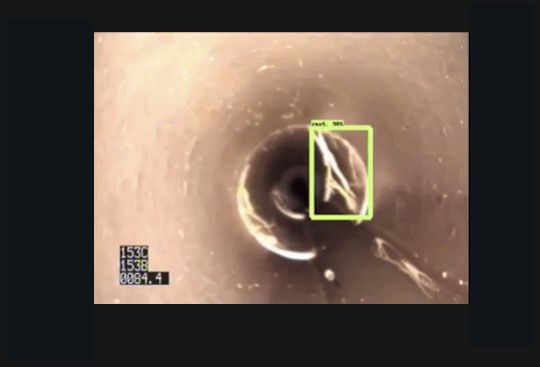
TFD, 10 o'clock, 192.0 ft

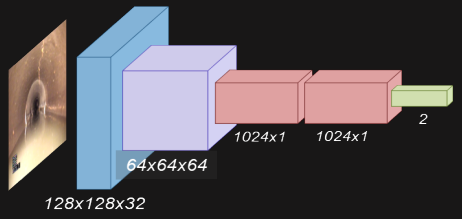


CL, 12 o'clock, 198.3 ft

Objective 1

Automated Inspection Coding

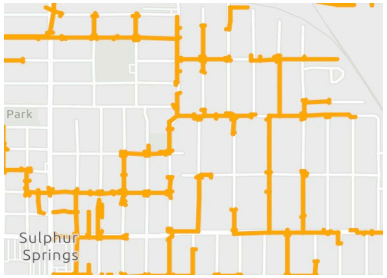


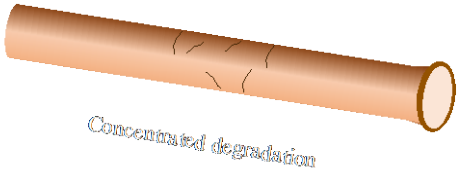


State-of-the-Art Deep Learning

Objective 2

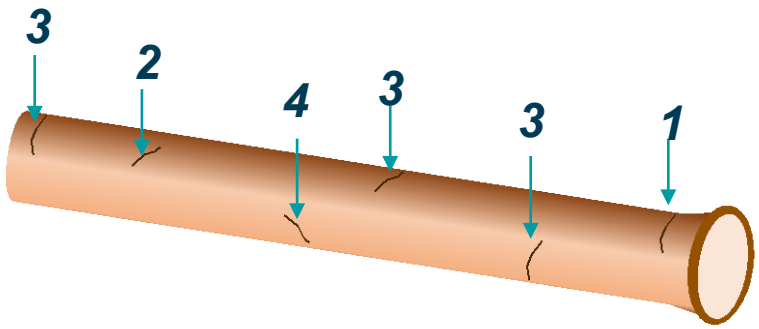
Predictive Analytics for Sewer Failure



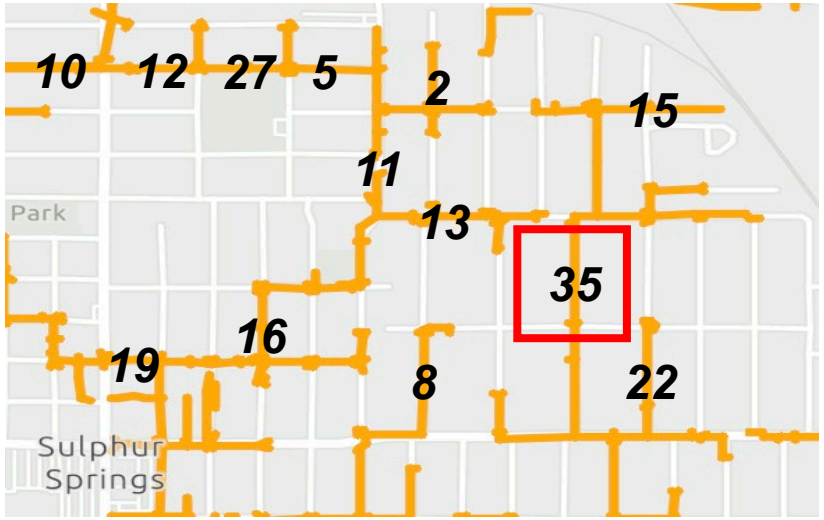


Big-Data Mining of Sewer Condition History

Sewer Condition Assessment



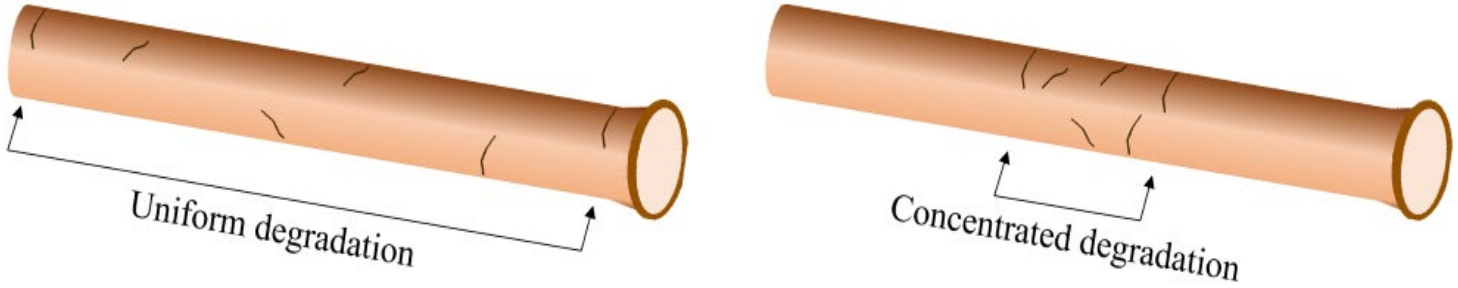
3 + 2 + 4 + 3 + 3 + 1 = 16



Higher scores indicate higher likelihood of failure

Defect Clusters

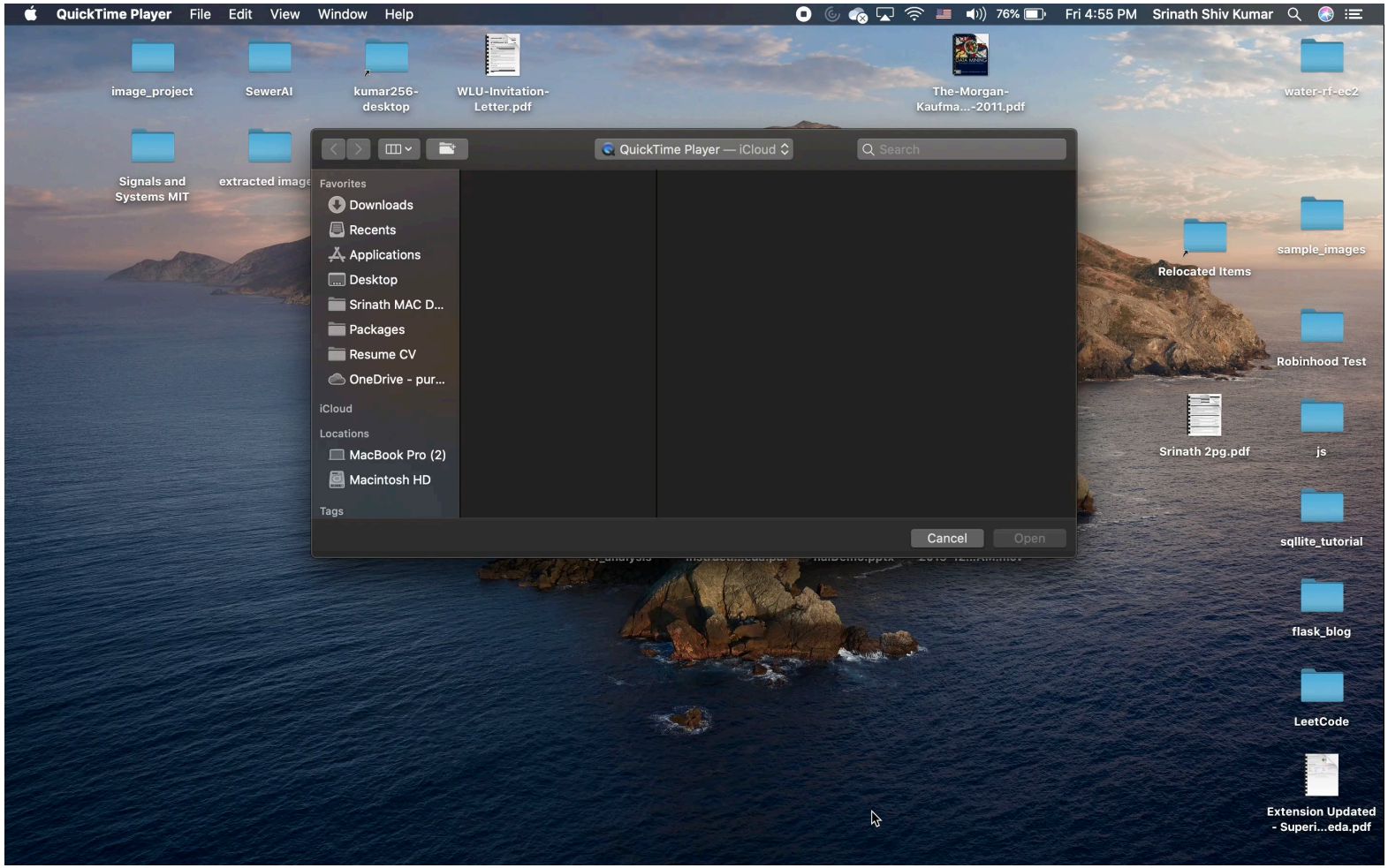
Previous studies assume that both pipes have equal likelihood of failure



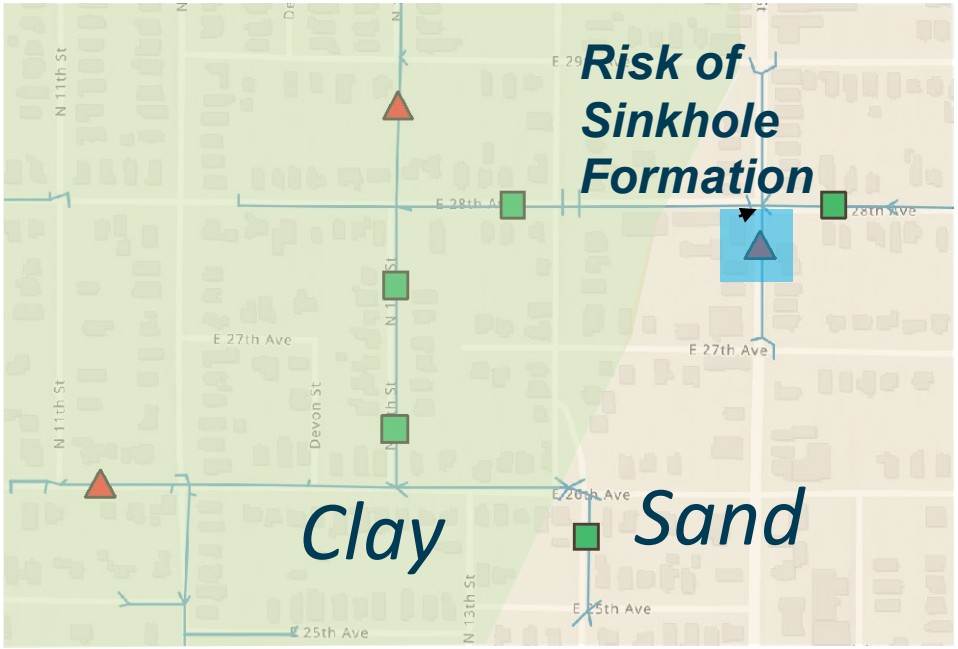
Clustered Defects => Higher Risk of Failure

Patch Repair vs Whole Pipe

Demonstration Example



Avenues for Future Work



- ***Draw attention to highly deteriorated sections***
- ***Combine with contextual data such as:***
  soil type, locations of trees, etc.

High Cluster Severity

Medium Cluster Severity

Acknowledgements

This study was funded by the Water Research Foundation (WaterRF #4902). The contents of this presentation reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The content does not necessarily reflect the official views or policies of WRF at the time of publication.

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Questions?

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Thank You

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