

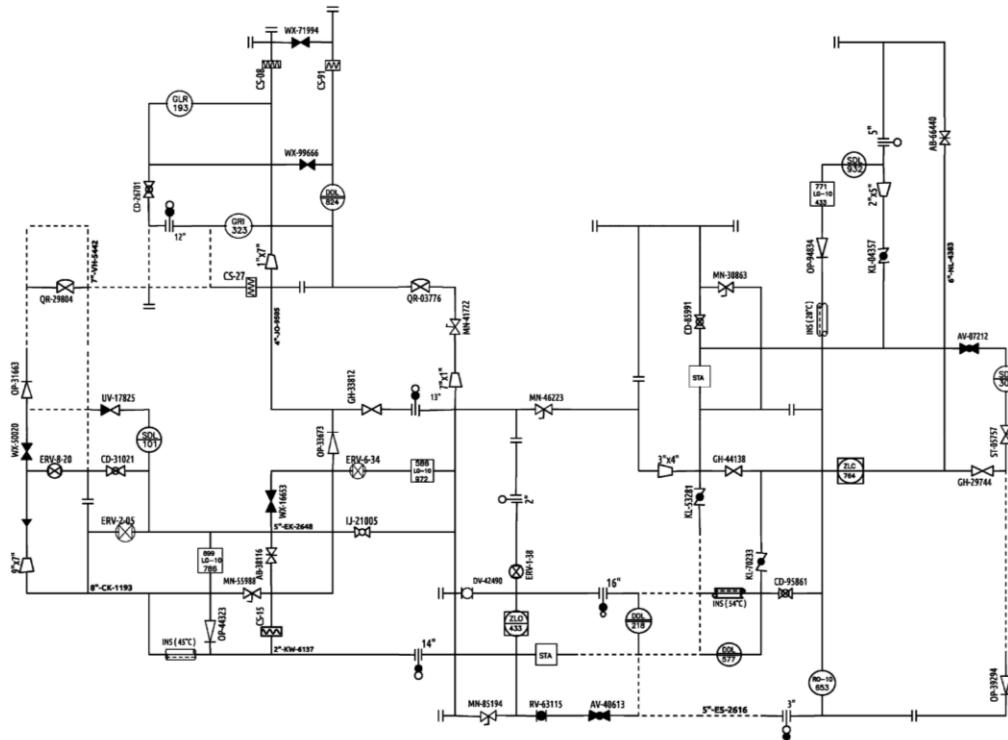
Outline

1. Digitization of P&IDs
 2. 2D Structural CAD to 3D Revit
 3. GenAI for Image Data augmentation
 4. SfM vs NeRF for 3D reconstruction
- Q&A

Outline

1. Digitization of P&IDs
 2. 2D Structural CAD to 3D Revit
 3. GenAI for Image Data augmentation
 4. SfM vs NeRF for 3D reconstruction
- Q&A

Context



P&ID: Piping & Instrumentation Diagram

Context

Downstream Tasks:

- █ Procurement (Material Take-Offs)
- █ Safety Audits (HAZOP)
- █ Regulatory Compliance (OSHA 29 CFR 1910)
- █ Design Review/ Revisions

P&IDs are shared in PDF/JPG formats

█ *Can be performed directly by CAD tools*

█ *Can be facilitated by CAD tools*

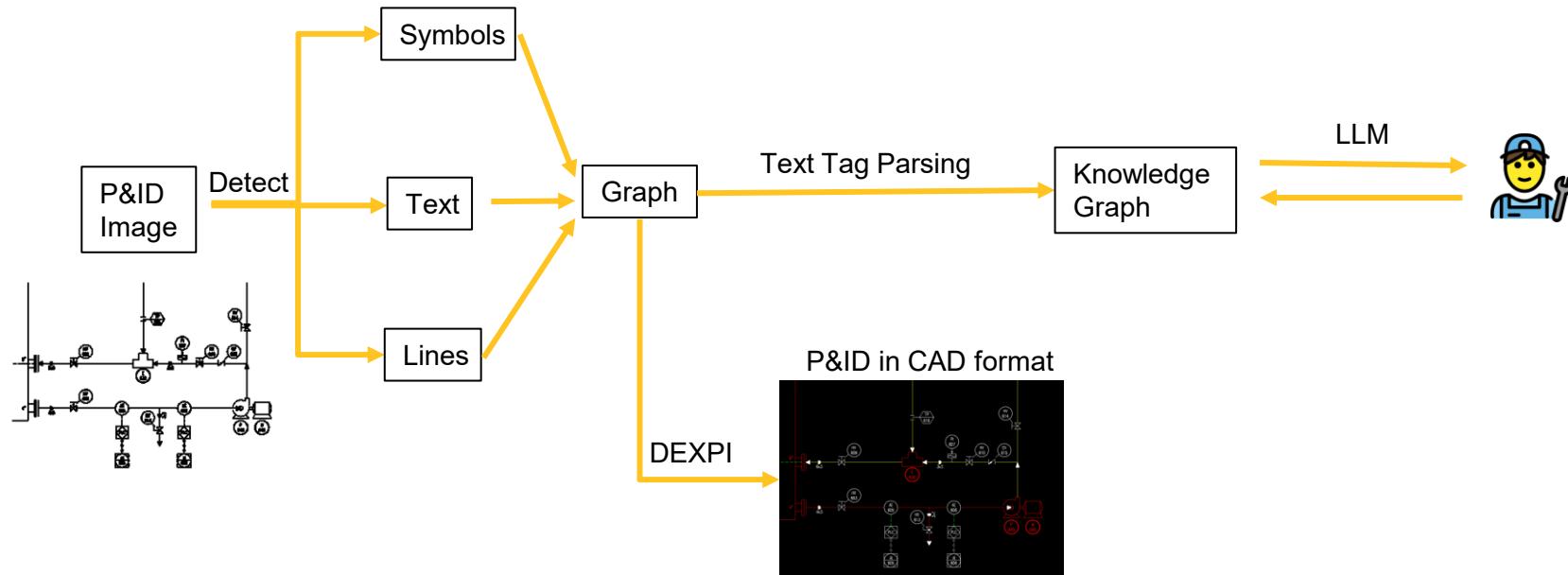


Goal

Make the *visual* information accessible to facilitate downstream tasks performed by engineers.

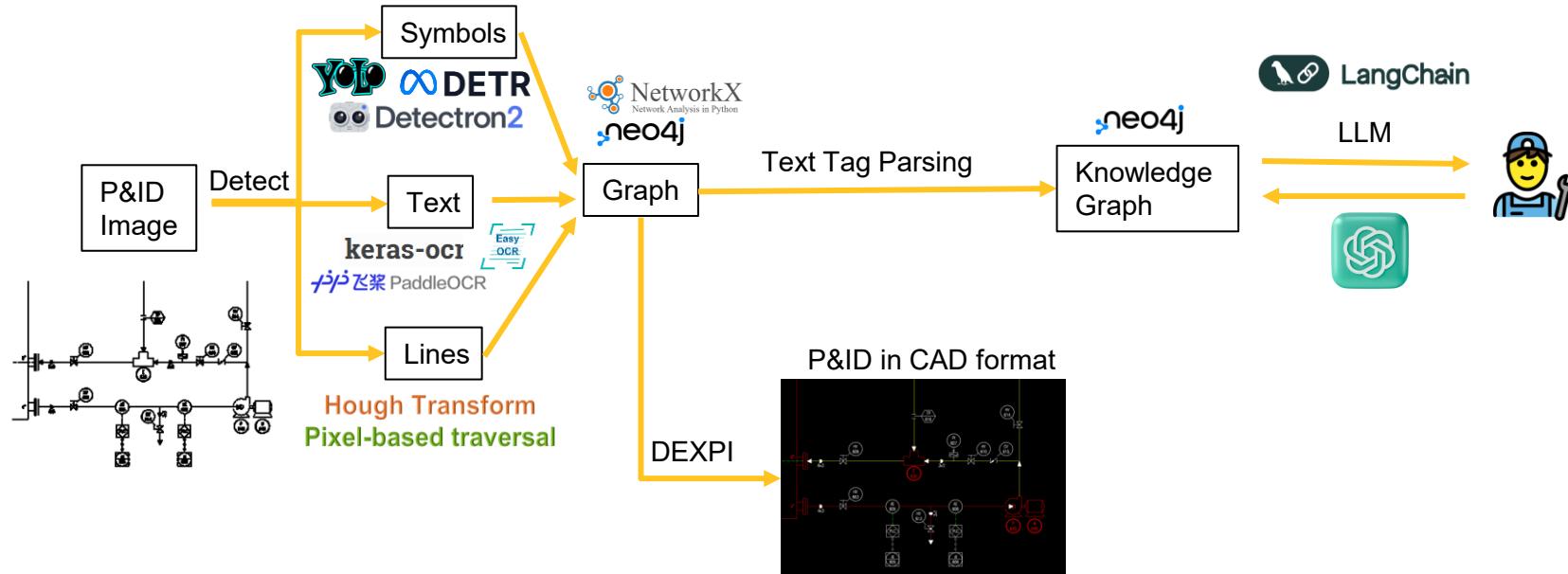
Method Overview

Make the *visual* information accessible to facilitate downstream tasks performed by engineers.

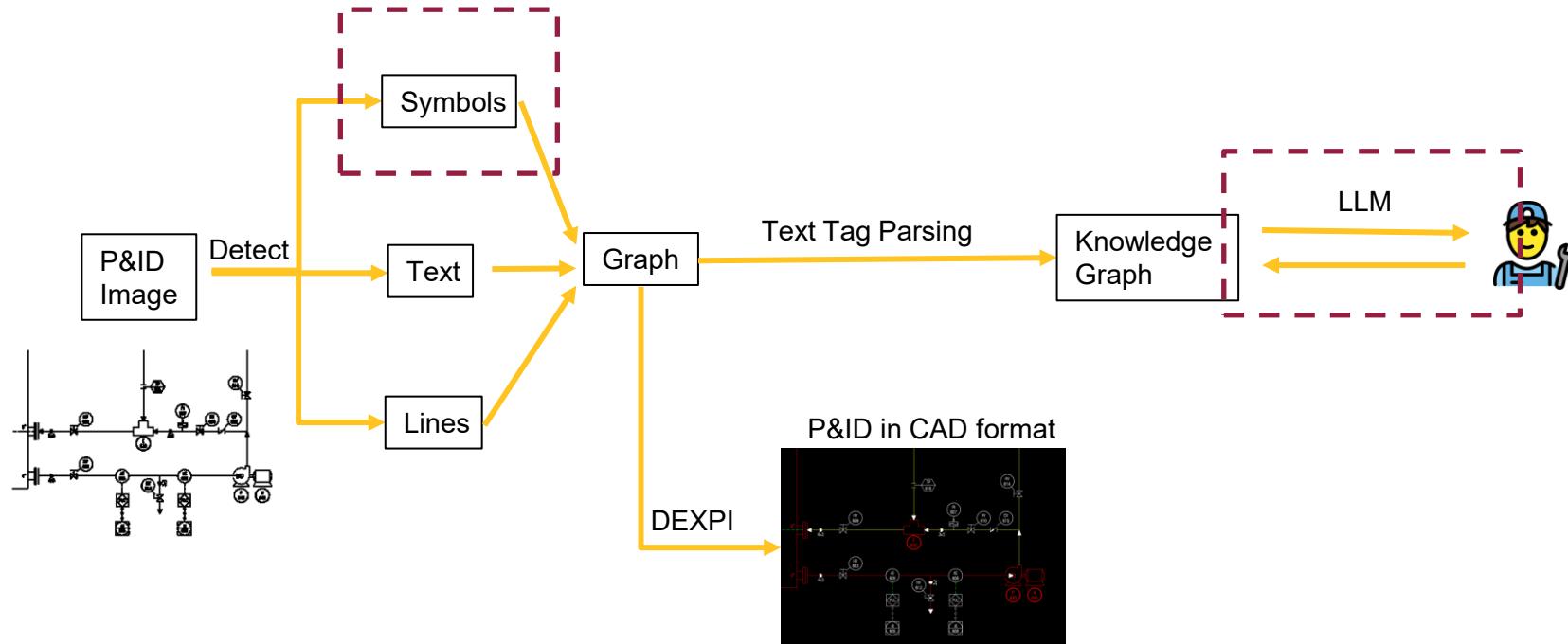


Method Overview

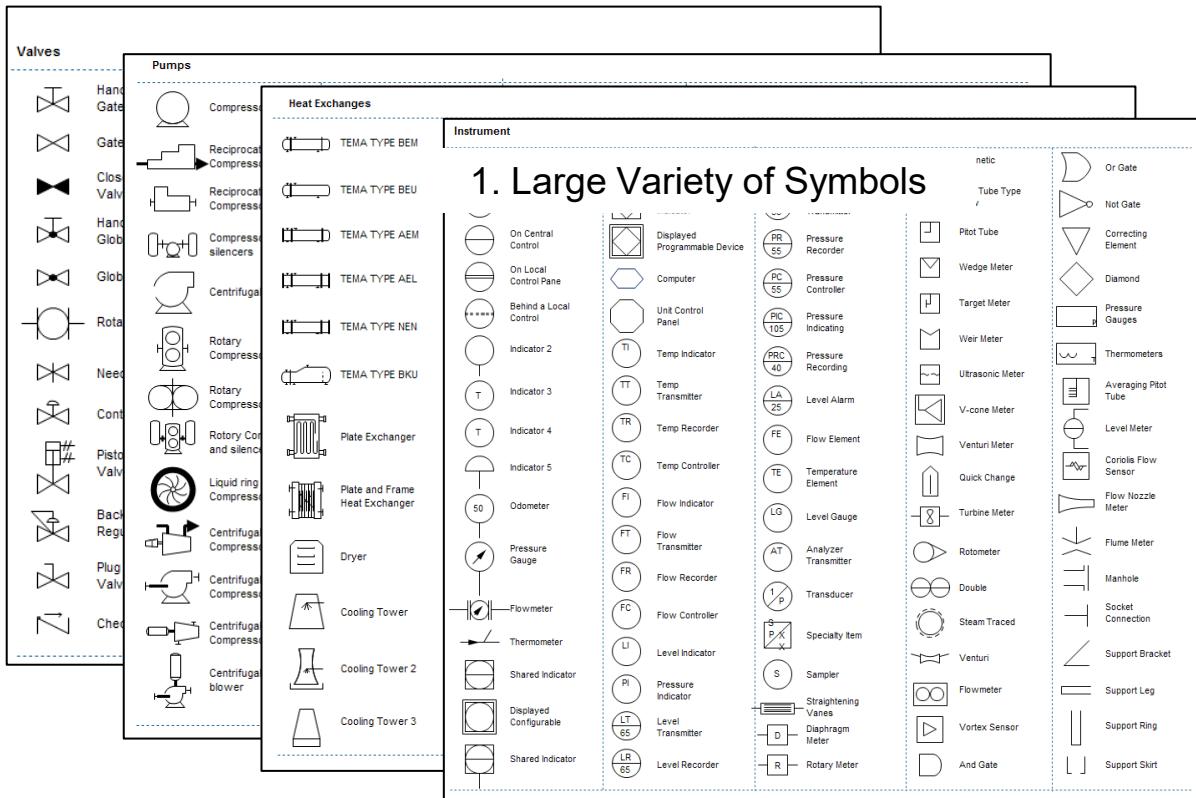
Make the *visual* information accessible to facilitate downstream tasks performed by engineers.



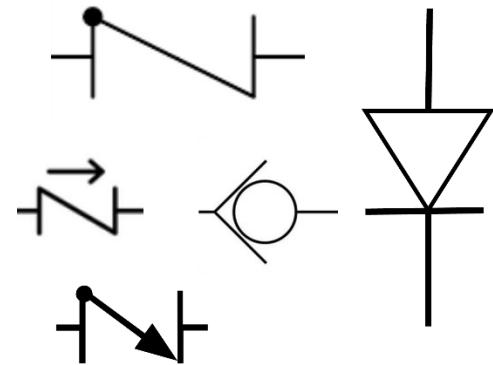
Challenges



Challenges



2. Non-standardized symbol representation



Five different ways to show a Check valve

Challenges

LLM response is sensitive to lexical perturbations

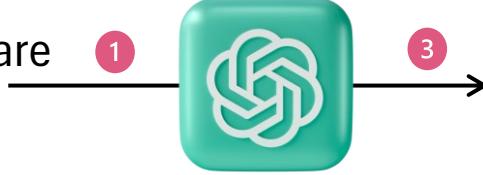
Could you provide the count of symbols of class 27?



Answer: There are 6 symbols belonging to class 27



How many symbols of type are 27 present?

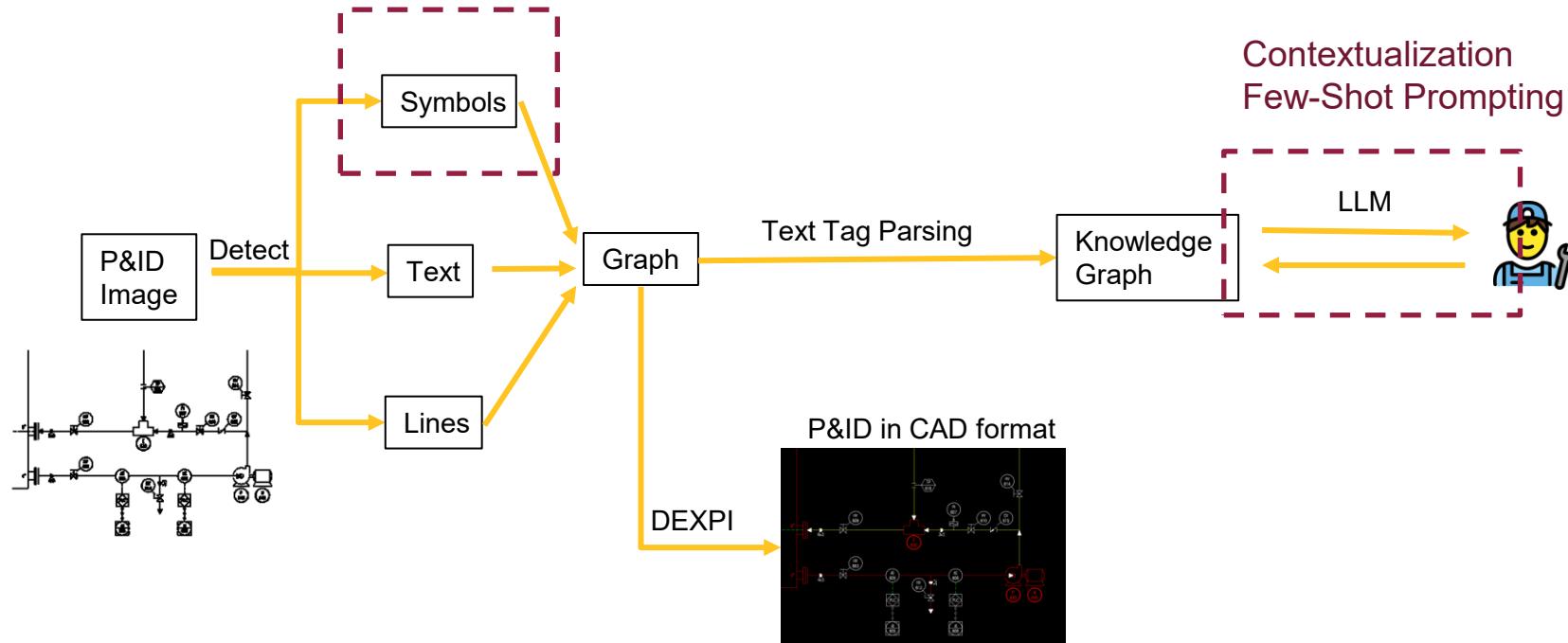


Answer: There are 0 symbols belonging to class 27

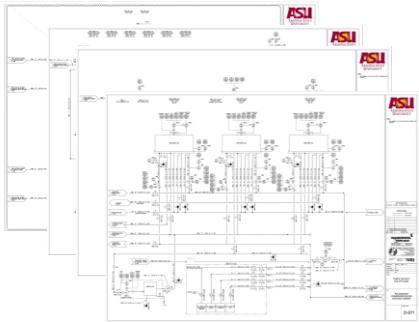


Solutions

Class-Agnostic Training & One-shot classification
Active Learning

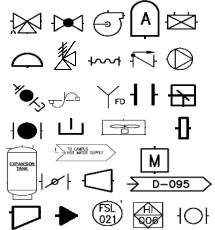


Results: Symbol Detection



Conventional Method

Proposed Method

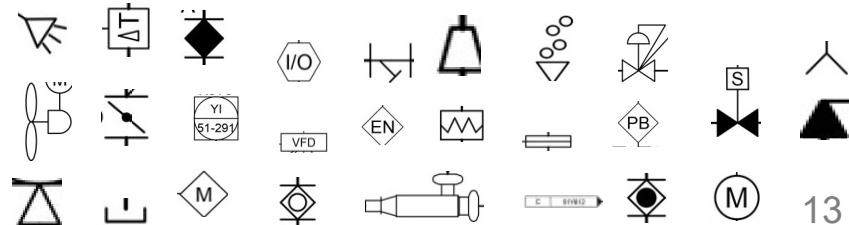
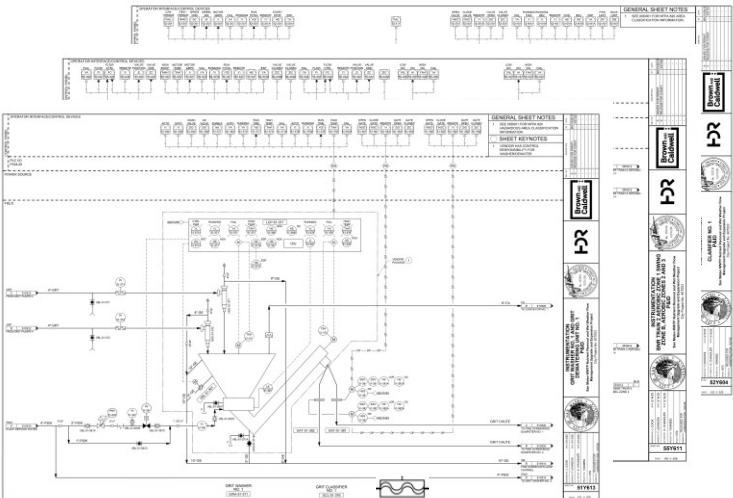
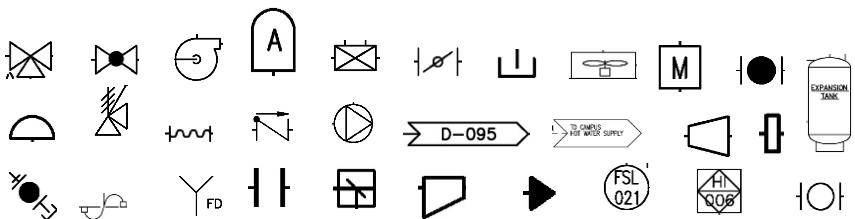
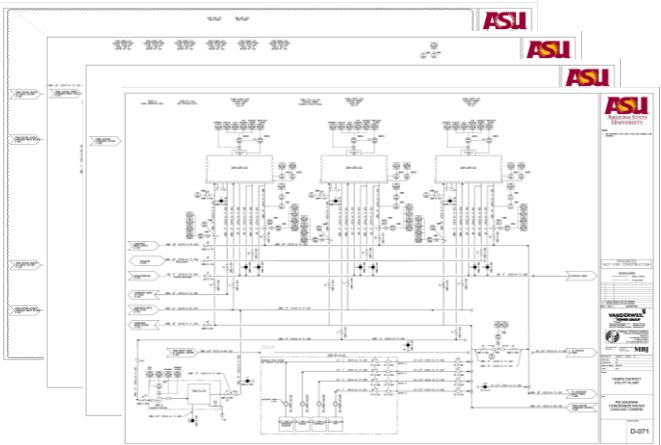


Macro Metrics

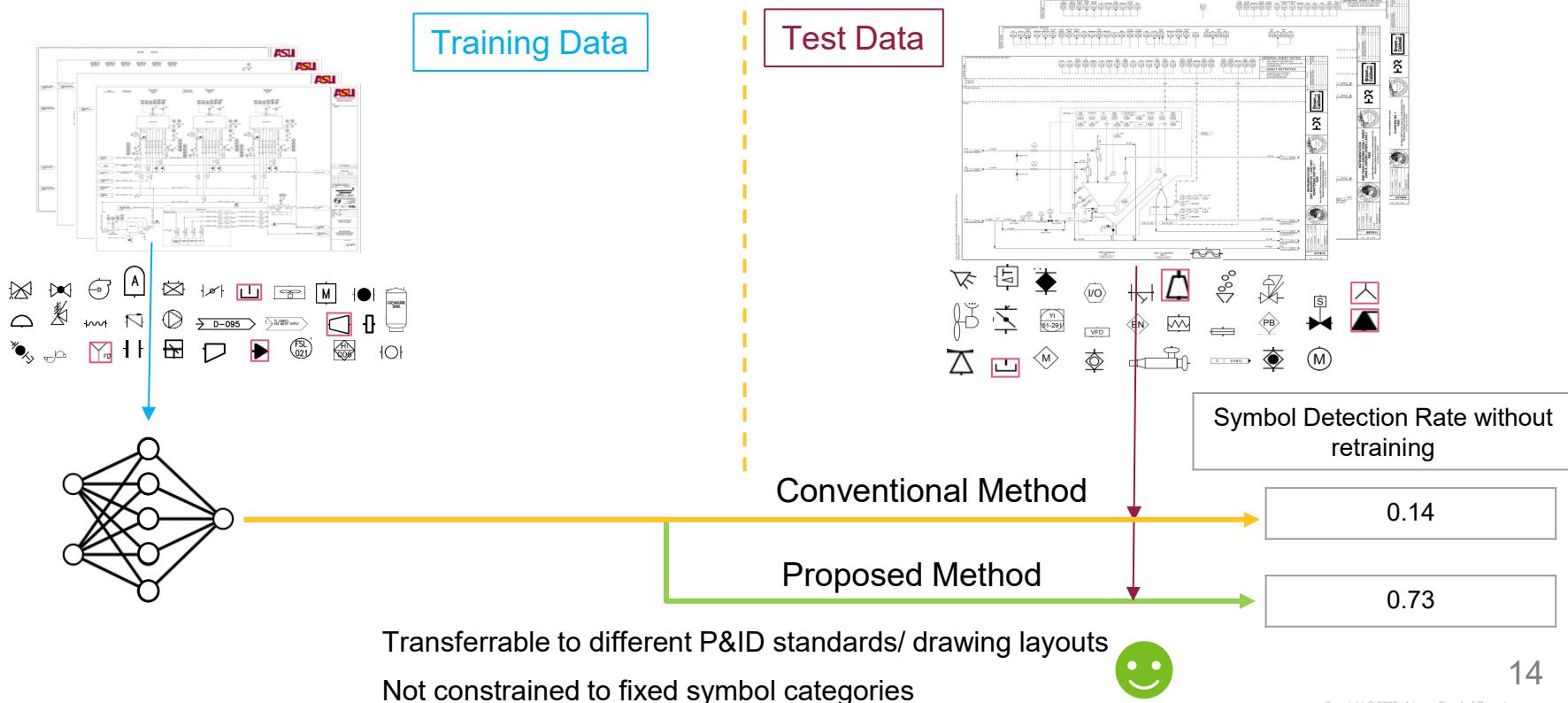
Recall	Precision	F1-score
0.57	0.53	0.55

Recall	Precision	F1-score
0.89	0.76	0.81

Results: Symbol Detection

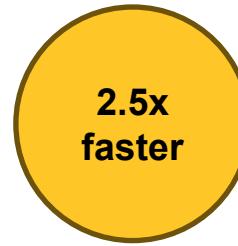


Results: Symbol Detection



Results: Symbol Detection

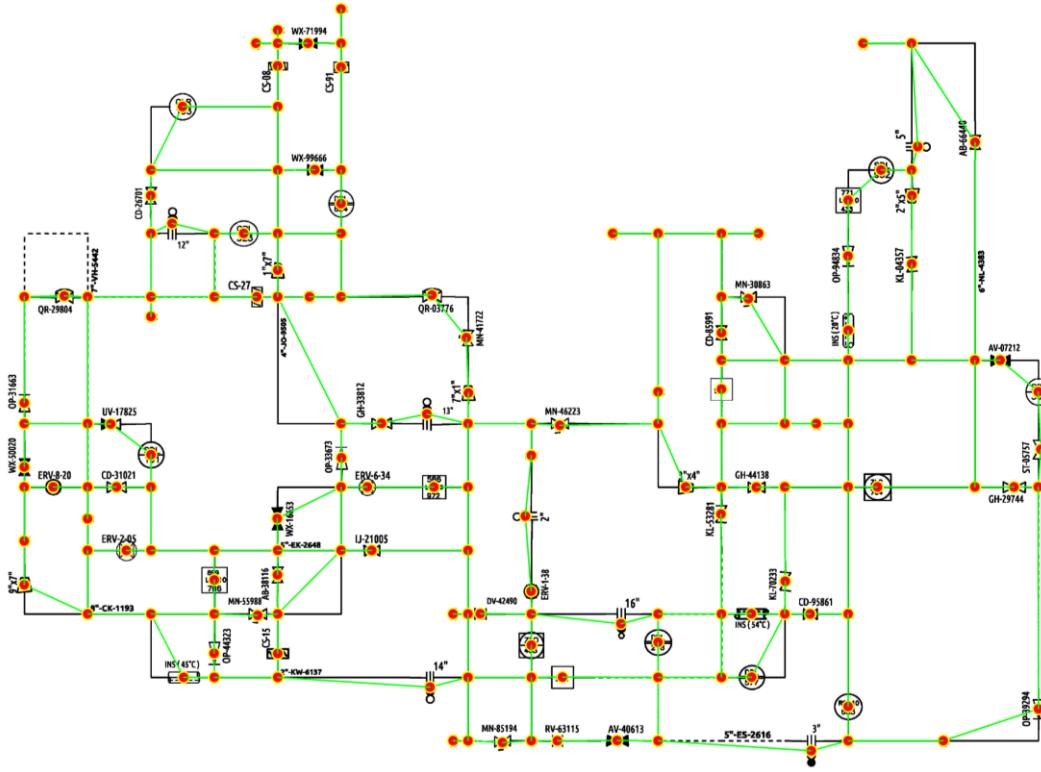
Time to label a dataset containing 32 types of symbols in class-agnostic manner is



than class-aware approaches

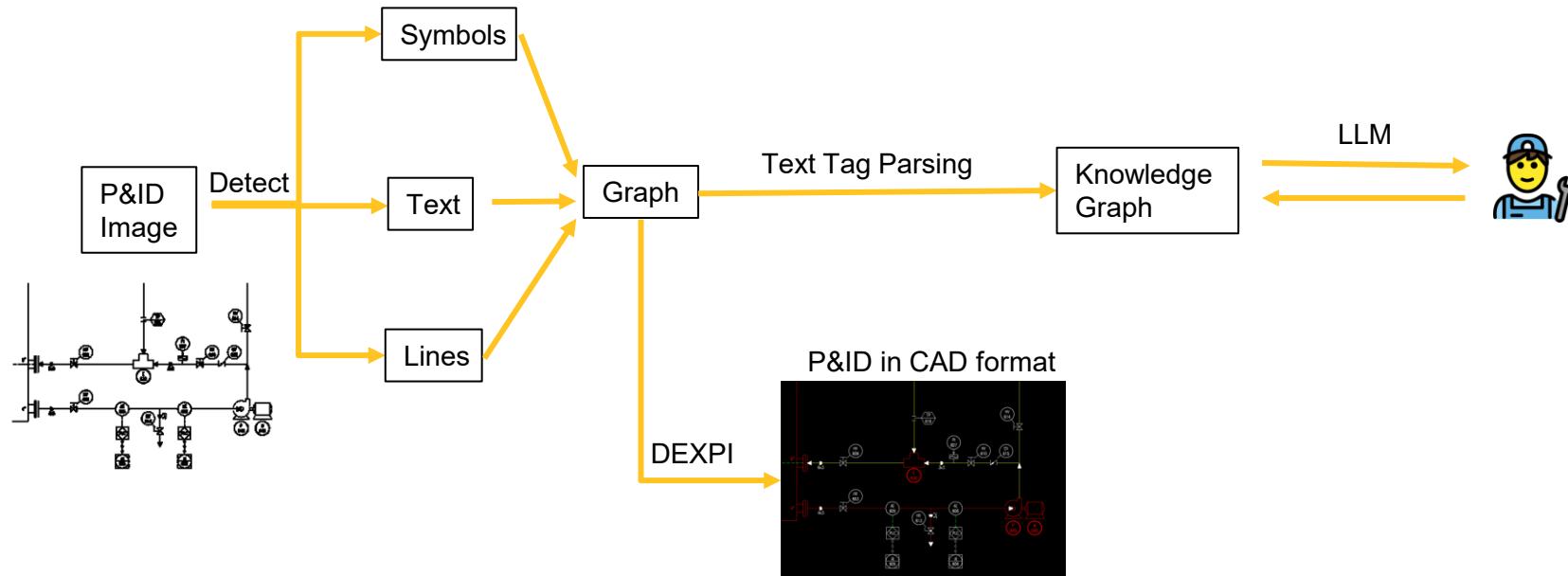
Symbol	Class No.
■	1
▲	2
△	3
▢	4
▢	5
▢	6
▢	7
▢	8
▢	9
▢	10
...	..
...	..
STA	32

Results: Graph

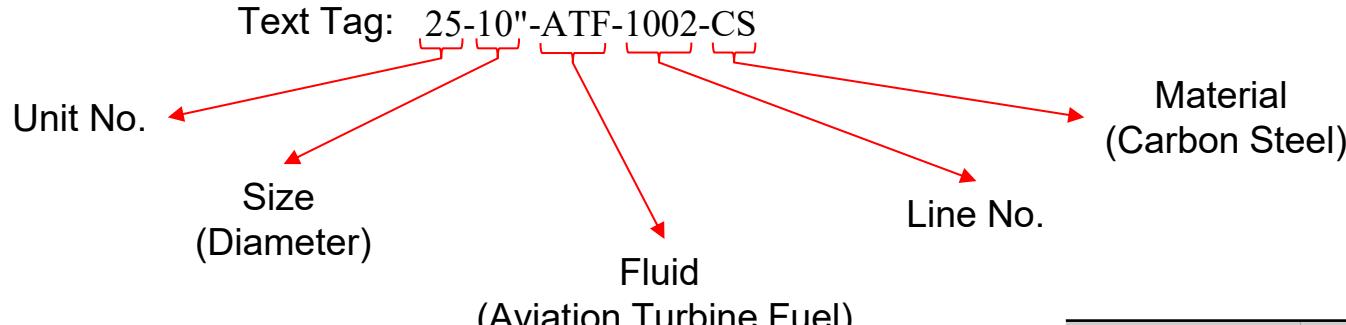


Method Overview

Make the *visual* information accessible to facilitate downstream tasks performed by engineers.



Text Tag Parsing



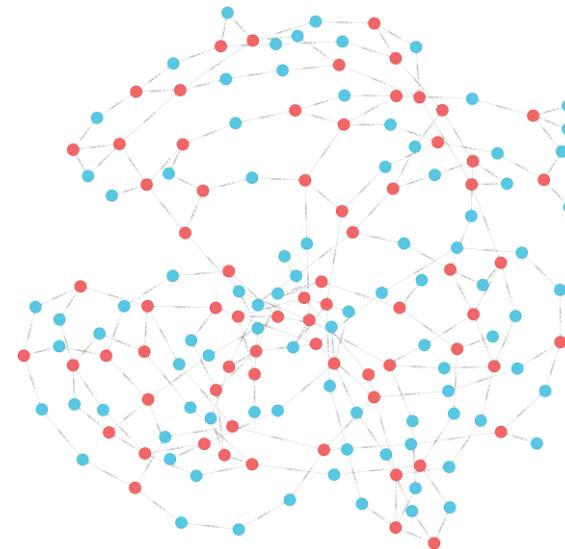
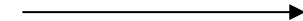
Connected to/ Flowing Into

Name	Ball Valve
Tag	RV-63115
Class	16
Material	Carbon Steel (CS)
Fluid	ATF
Safe Pressure	30 Kpa
Pipe IN	1002
Pipe Out	1003

Knowledge Graph



Text Tag Parsing



Knowledge Graph

LLM Response Stabilization

Q. How many class 7 symbols are present?

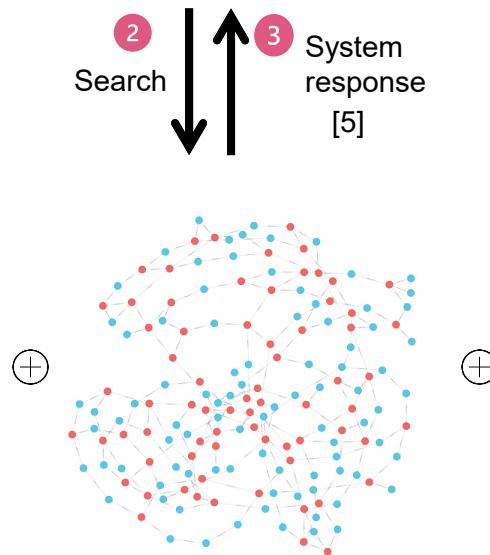


Ans: There are 5 symbols of class 7.

Contextualization

```
Node properties:  
- **Junction**  
- `alias`: STRING Example: "J55"  
- `tag`: STRING Example: "line_NN_513-line_NN_713"  
- `class`: INTEGER Min: -999, Max: -999  
- `center_x`: INTEGER Min: 643, Max: 5204  
- `center_y`: INTEGER Min: 798, Max: 3934  
- **Symbol**  
- `alias`: STRING Example: "symbol_20"  
- `tag`: STRING Example: "OP-39294"  
- `class`: INTEGER Min: 1, Max: 32  
- `center_x`: INTEGER Min: 643, Max: 5216  
- `center_y`: INTEGER Min: 644, Max: 3979
```

The relationships:
(:Junction)-[:CONNECTED_TO]->(:Junction)
(:Junction)-[:CONNECTED_TO]->(:Symbol)
(:Symbol)-[:CONNECTED_TO]->(:Symbol)
(:Symbol)-[:CONNECTED_TO]->(:Junction)



Few-shot prompting

```
[[examples]]  
question = "what are all the tags of class 7 symbols that have QW as their prefix?"  
query = "MATCH (s:Symbol) WHERE s.class = 7 AND s.tag STARTS WITH 'QW' RETURN s.tag"  
  
[[examples]]  
question = "Could you list the tags for class 22 symbols that begin with the string YKX?"  
query = "MATCH (s:Symbol) WHERE s.class = 22 AND s.tag STARTS WITH 'YKX' RETURN s.tag"  
  
[[examples]]  
question = "Fetch the tags of 28 symbols where each tag starts with the prefix MS."  
query = "MATCH (s:Symbol) WHERE s.class = 28 AND s.tag STARTS WITH 'MS' RETURN s.tag"  
  
[[examples]]  
question = "Can you return the tags of all class 14 symbols that start with FU as their pr  
query = "MATCH (s:Symbol) WHERE s.class = 14 AND s.tag STARTS WITH 'FU' RETURN s.tag"
```

Results

Dataset for Evaluation

Question Type	Number of Questions	
	1 sheet	500 sheets
Simple counting	32	16000
Spatial counting	32	16000
Spatial connections	32	16000
Value-based	32	16000
Total	128	64000

Results

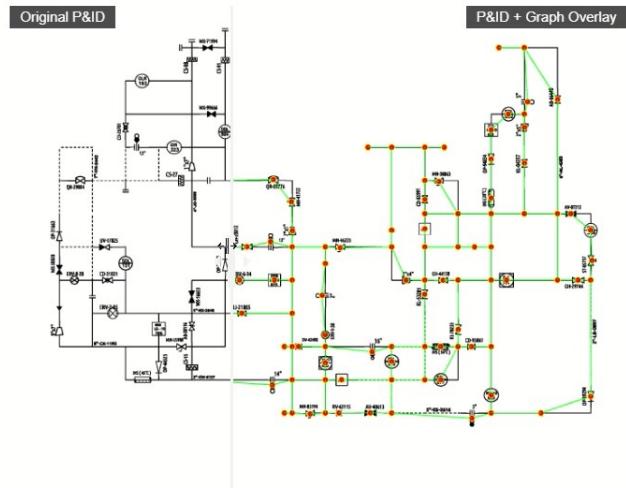
Task	Accuracy with context			
	Level-0	Level-1	Level-2	Level-3
Simple Counting	0.127	0.866	0.871	0.995
Spatial Counting	0.571	0.713	0.88	0.986
Spatial Connection	0.135	0.29	0.54	0.975
Value	0.172	0.565	0.762	0.97

Demo

Link to Demo: <https://pid-knowledgegraph-demo.streamlit.app/>

P&ID QA System

Use the **slider** to compare the original P&ID with the graph overlay.



This is a Question Answering System for P&ID (Piping and Instrumentation Diagram) graphs.

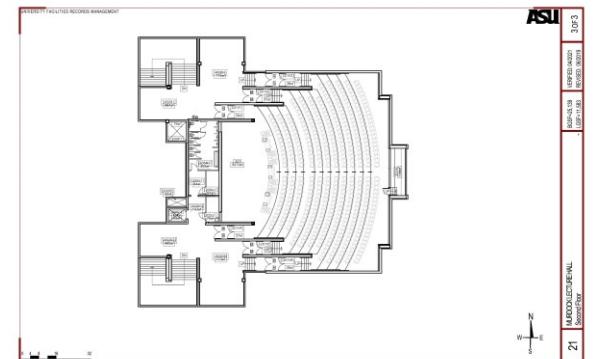
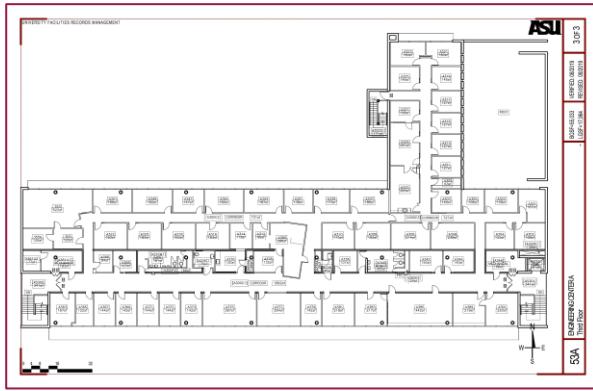
The P&ID linked above contains 32 symbols, each labeled numerically from 1 to 32.

For more info on symbols representation - [Click here](#)

Outline

1. Digitization of P&IDs
 2. 2D Structural CAD to 3D Revit
 3. GenAI for Image Data augmentation
 4. SfM vs NeRF for 3D reconstruction
- Q&A

Context

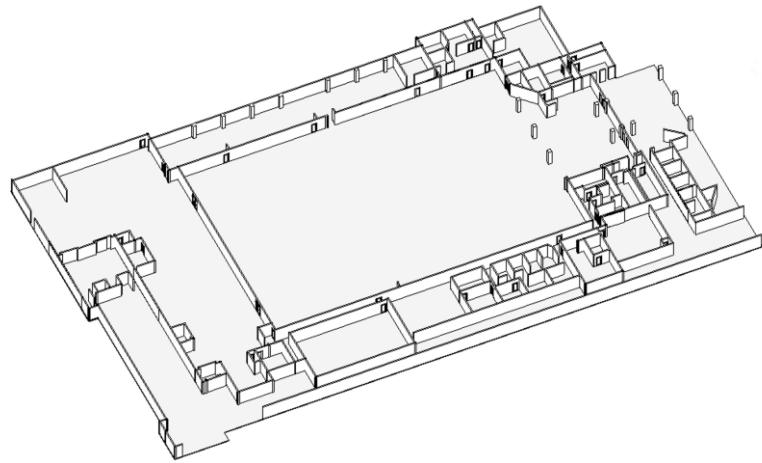
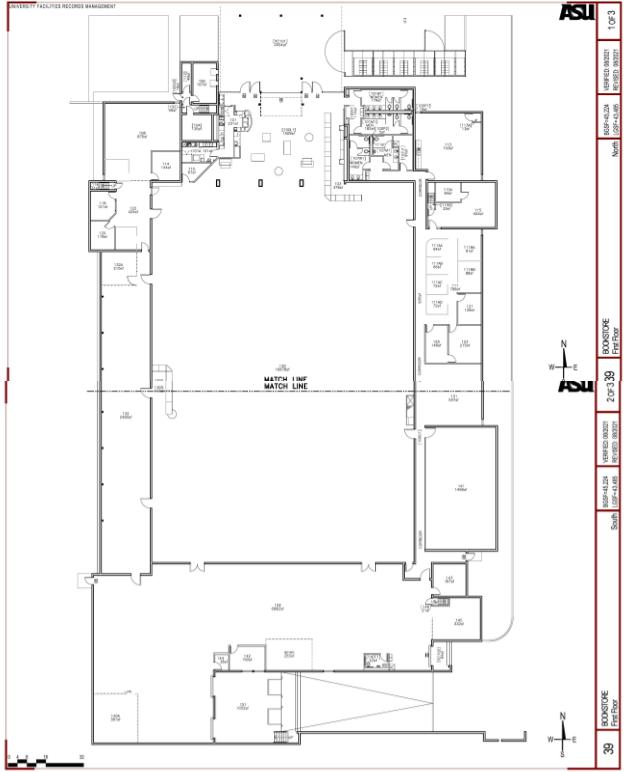


2D Campus Floorplan

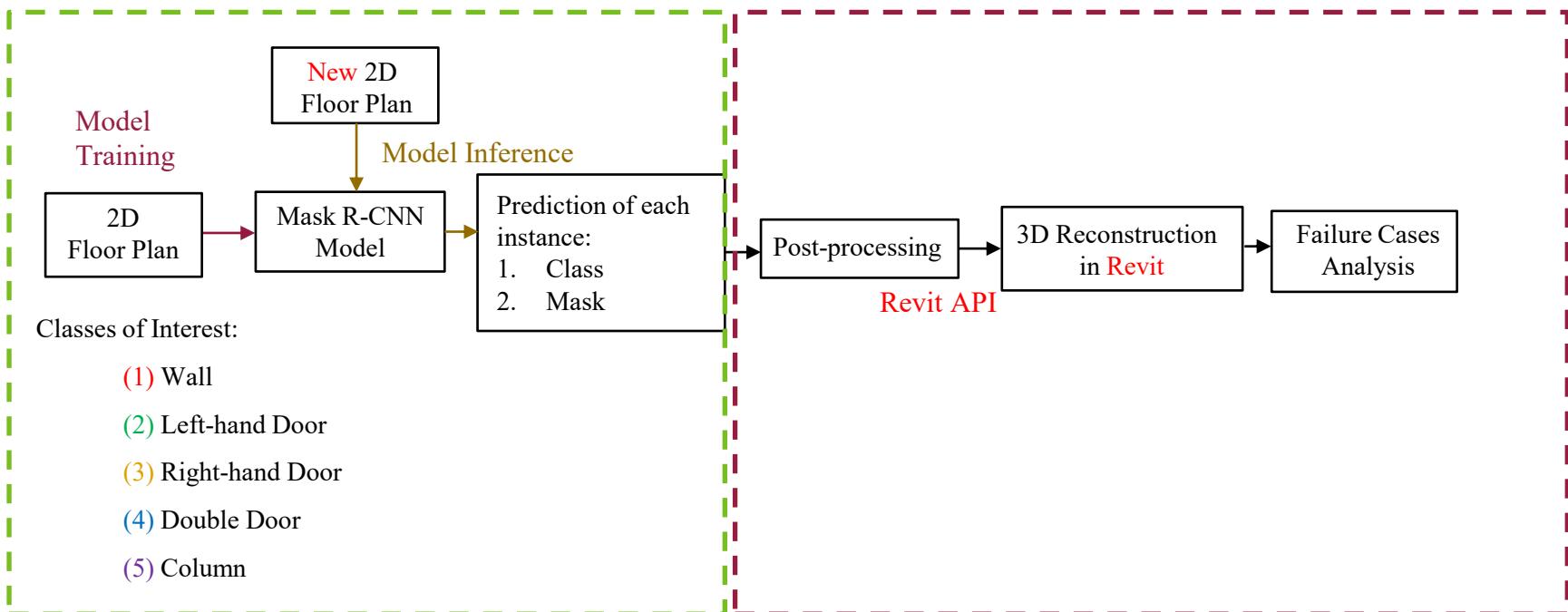


Interactive Digital Campus for Online Student

Context



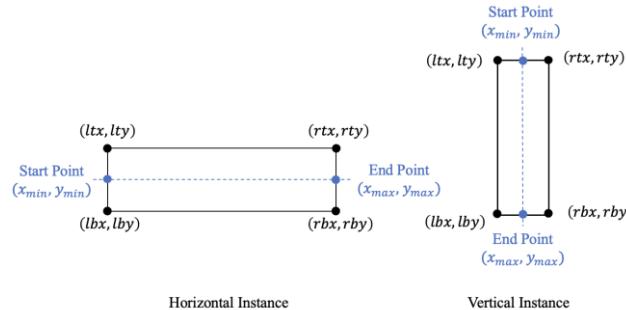
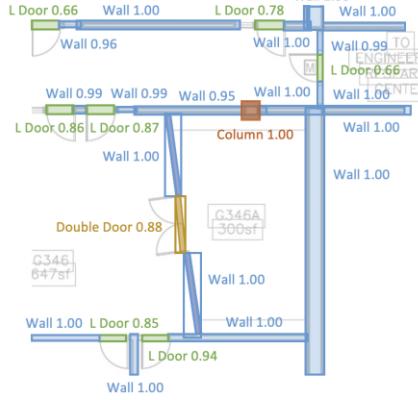
Method Overview



Neural Network Training & Inference

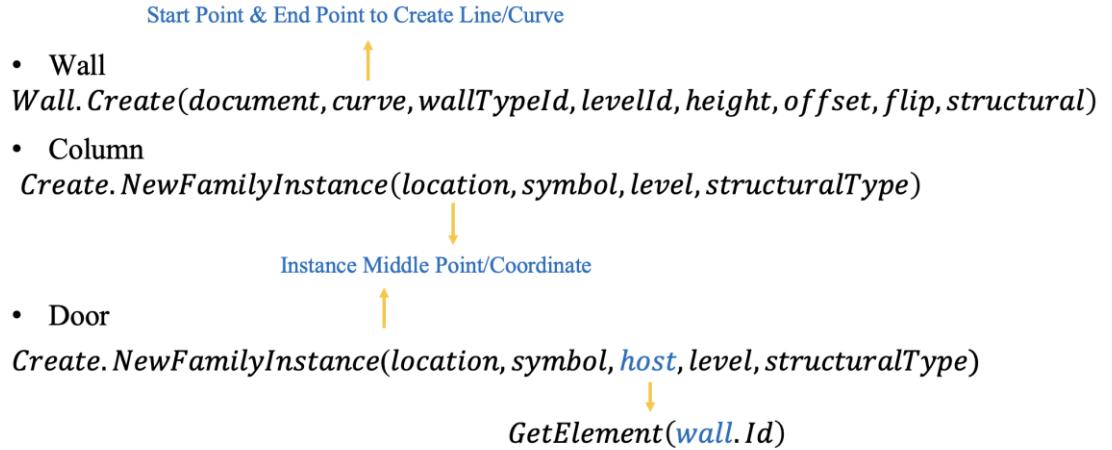
3D Model Reconstruction

Sample Results



class	probability	ltx	lty	rbx	rby	polygon points from predicted mask
wall	1.00	20	20	70	25	[[20,20],[70,20],[20,25],[70,25]]
wall	0.99	100	30	105	45	[[100,30],[105,30],[100,45],[105,45]]
L door	0.87	24	60	34	65	[[24,60],[34,60],[24,65],[34,65]]
wall	1.00	80	60	90	150	[[80,60],[90,60],[80,150],[90,150]]
column	1.00	60	55	70	65	[[60,55],[70,55],[60,65],[70,65]]
Double door	0.88	40	80	45	100	[[40,80],[42,80],[44,90],[45,100],[43,100],[41,90]]

Revit API



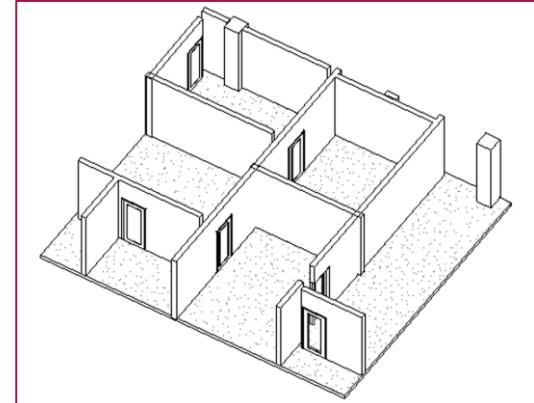
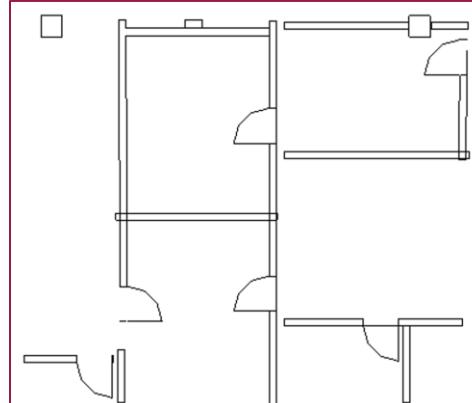
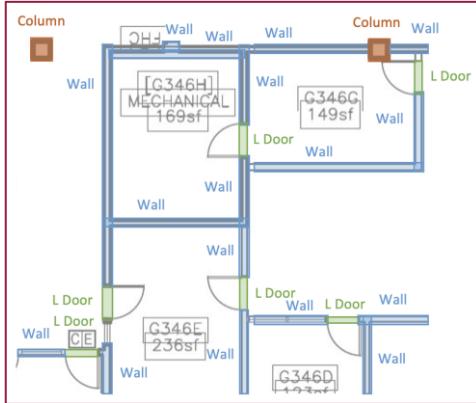
Instance Segmentation Result

class	probability	ltx	lty	rbx	rby	polygon points from predicted mask	
wall	1.00	20	20	70	25	[[20,20],[70,20],[20,25],[70,25]]	
wall	0.99	100	30	105	45	[[100,30],[105,30],[100,45],[105,45]]	
L door	0.87	24	60	34	65	[[24,60],[34,60],[24,65],[34,65]]	
wall	1.00	80	60	90	150	[[80,60],[90,60],[80,150],[90,150]]	
column	1.00	60	55	70	65	[[60,55],[70,55],[60,65],[70,65]]	
Double door	0.88	40	80	45	100	[[40,80],[42,80],[44,90],[45,100],[43,100],[41,90]]	

Revit API

Input for Revit Reconstruction

- Isolated object (wall & column)
 - Class
 - Location : $x_{min}, y_{min}, x_{max}, y_{max}$
 - Elevation
- Door embedded object
 - Door and host wall class
 - Element Id of host wall
 - Location: : $x_{min}, y_{min}, x_{max}, y_{max}$
 - Elevation

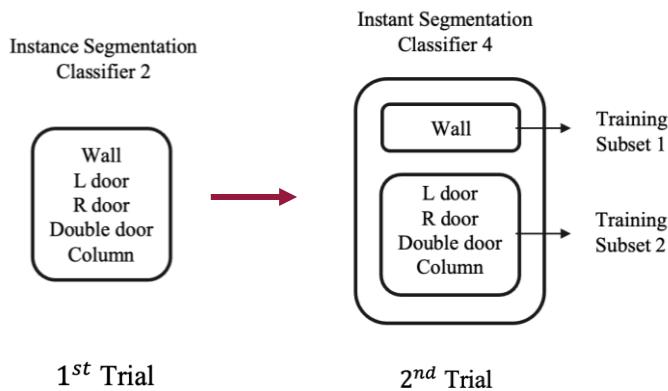


Challenge & Solution

Class-Imbalance

Walls are large-sized objects

Class	Left-hand Door	Right-hand Door	Double Door	Wall	Column
No. of Instances	596	555	283	6722	485



Task	mAP
1 st Trial	76.8%
2 nd Trial	83.9%

Outline

1. Digitization of P&IDs
 2. 2D Structural CAD to 3D Revit
 3. GenAI for Image Data augmentation
 4. SfM vs NeRF for 3D reconstruction
- Q&A

Context

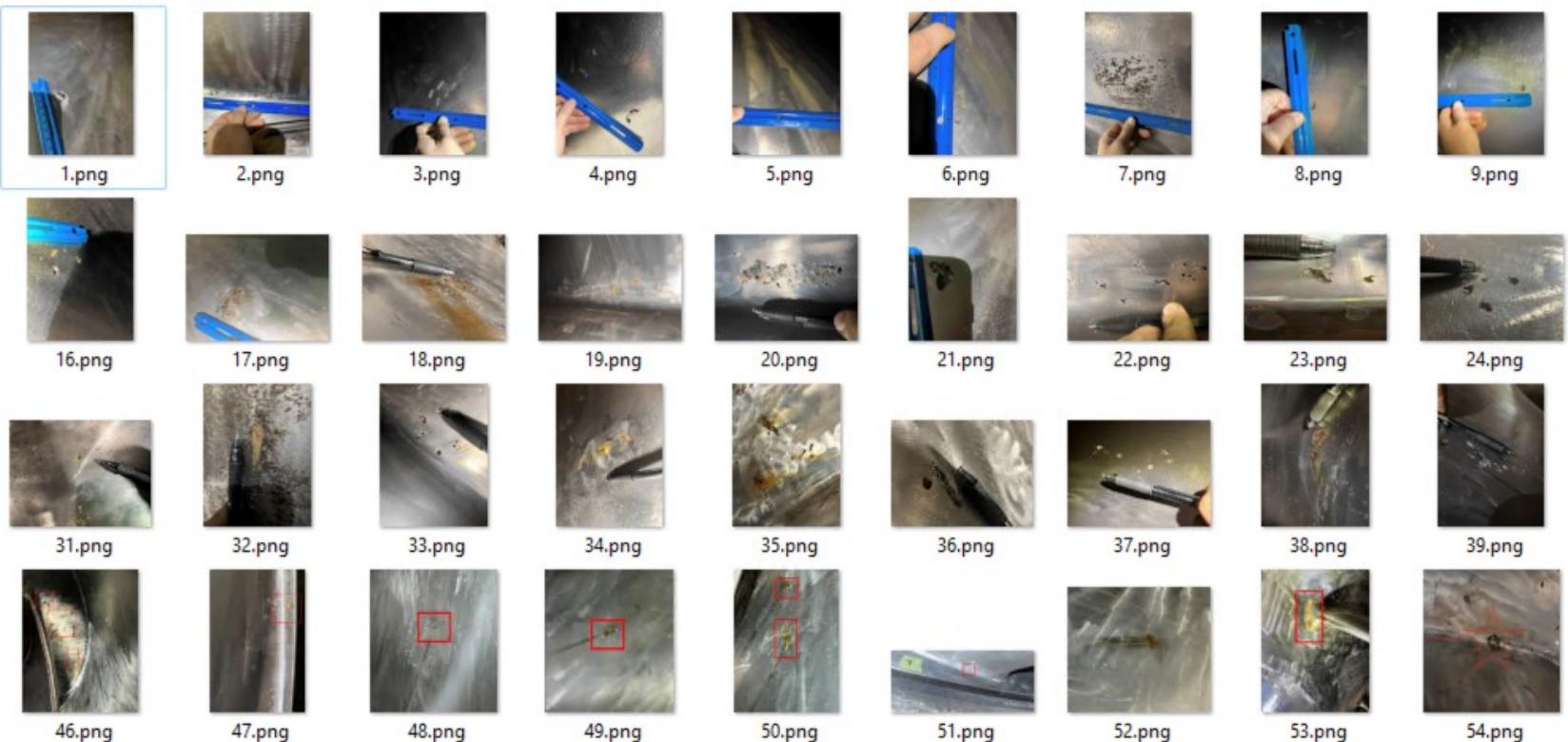


Delivering water and power™



Challenge: Data Scarcity

- Raw data in inspection logs: 62 images



Preprocessing

Remove ruler, pen, hand, red lines

Fill in the missing pixels using Stable Diffusion for Inpainting

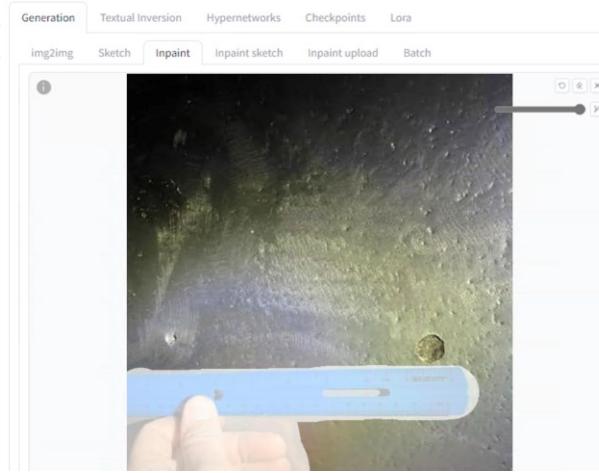
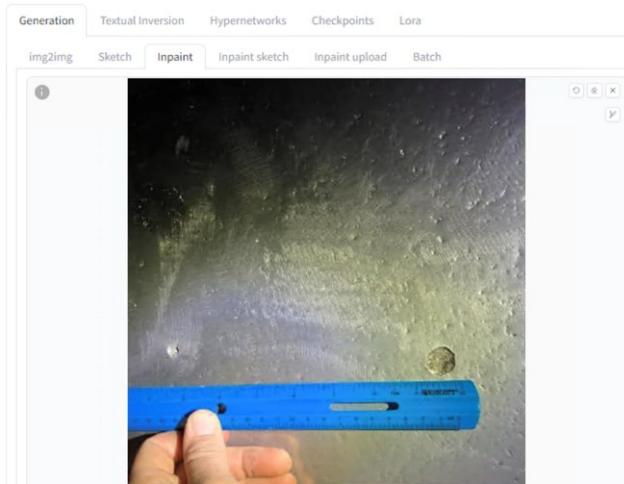


Image Generation

- Stable Diffusion with ControlNet Reference-only

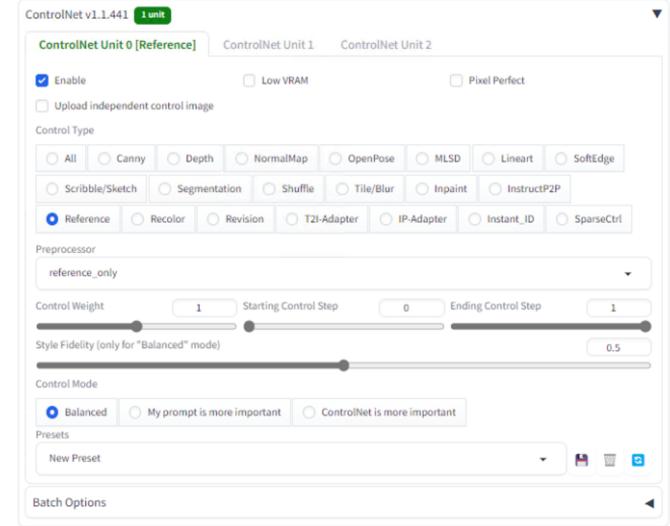
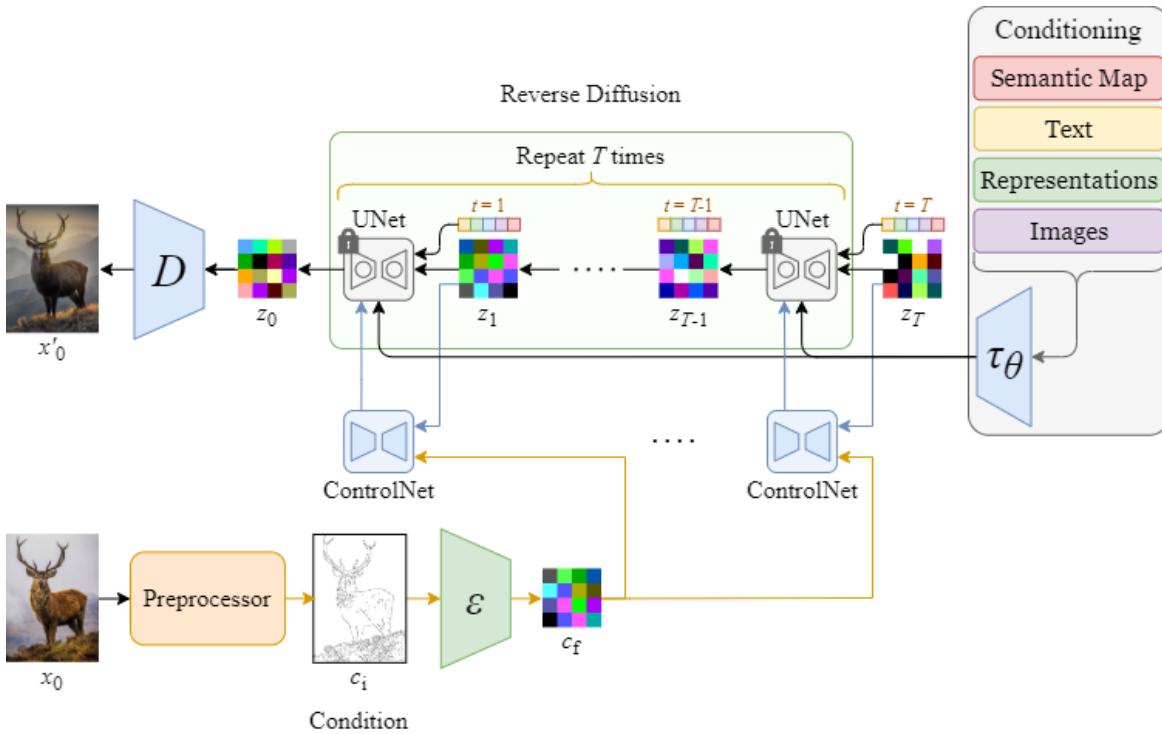
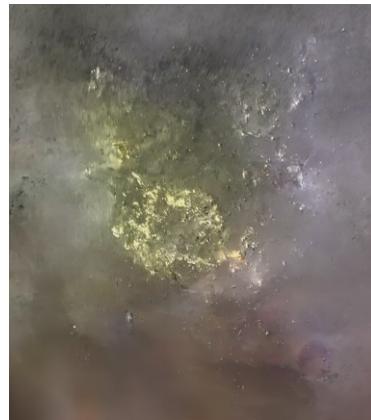


Image Generation



Raw Image



Generated Images

Image Generation



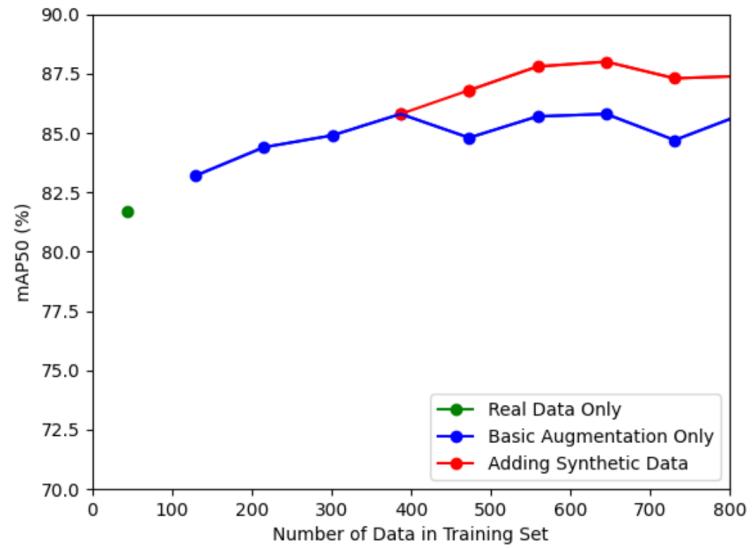
Raw Image



Generated Images

Results

Dataset	1	2	3	4	5	6	7	8	9	10
Original real image	43	43								
Basic Data Augmentation	2	4	6	8	8					
Synthetic Data					2	4	6	8	10	
Total of training set	43	129	215	301	387	473	559	645	731	817
Total of validation set	19	19	19	19	19	19	19	19	19	19
mAP50 (%)	81.7	83.2	84.4	84.9	85.8	86.8	87.8	88.0	87.3	87.4



Outline

1. Digitization of P&IDs
 2. 2D Structural CAD to 3D Revit
 3. GenAI for Image Data augmentation
 4. SfM vs NeRF for 3D reconstruction
- Q&A

Results

[Link](#)

Relevant Papers

Digitization of P&IDs

- Semi-supervised symbol detection for piping and instrumentation drawings, Automation in Construction, 2024.
- PiDQA-Question Answering on Piping and Instrumentation Diagrams, Machine Learning & Knowledge Extraction, 2025.

2D Structural CAD to 3D Revit

- Interoperability between Deep Neural Networks and 3D Architectural Modeling Software Affordances of Detection and Segmentation, Buildings, MDPI, 2023.

GenAI for Image Data augmentation

- Automating Defect Detection in Hydropower Turbine Blades: An Approach to Overcome Small Training Samples in Computer Vision through Synthetic Image Synthesis (ASCE, Multidisciplinary Journal of Civil Engineering)(accepted)

SfM vs NeRF for 3D reconstruction

- Comparison of 3D reconstruction between Neural Radiance Fields and Structurefrom-Motion based Photogrammetry from 360°videos, ASCE I3CE 2023.

Q&A

Thanks for Listening!

Email: mgupta70@asu.edu