CMM560 Topic 2: Computer Vision-Related Problems in the Energy Sector

ROBERT GORDON UNIVERSITY ABERDEEN

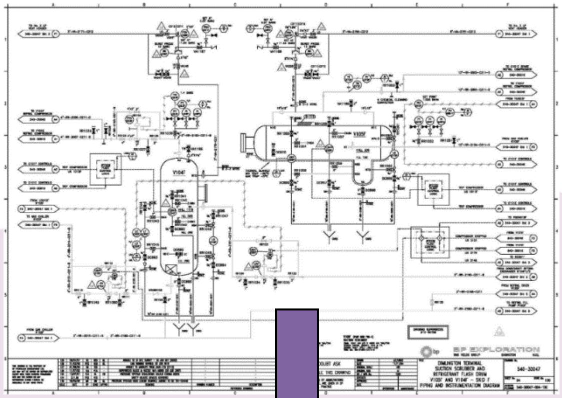
Digitising and Contextualising Complex Engineering Diagrams for Facility Inspection

Principal Supervisor: Prof Eyad Elyan

Collaborators: Laura Jamieson (PhD student), Ikenna Ekeke (PhD Student), Luis Toral Quijas (MRes student, graduated), Elena Rica (PhD student at URV, graduated)

The Problem

Complex Engineering Drawing (CED)



Standardised Parts Count

Event	Equipment Category	Size	Number
JDY/CELLAR/RJAS/W	Piping	16	
JDY/CELLAR/RJAS/W	Act. Valve	16	0.5
JDY/CELLAR/JASIN/W	Piping	16	
JDY/CELLAR/JASIN/W	Act. Valve	16	0.5
JDY/PROC/JASIN/W	Piping	16	
JDY/PROC/JASIN/W	Act. Valve	16	2
JDY/PROC/JASIN/W	Flange	16	7
JDY/PROC/JASIN/W	Piping	6	
JDY/PROC/JASIN/W	Man Valve	16	3
JDY/PROC/JASIN/W	Piping	2	
JDY/PROC/JASIN/W	Flange	2	2
JDY/PROC/JASIN/W	Inst. Con.	2	2
JDY/PROC/JASIN/W	Man Valve	6	0.5

DNV

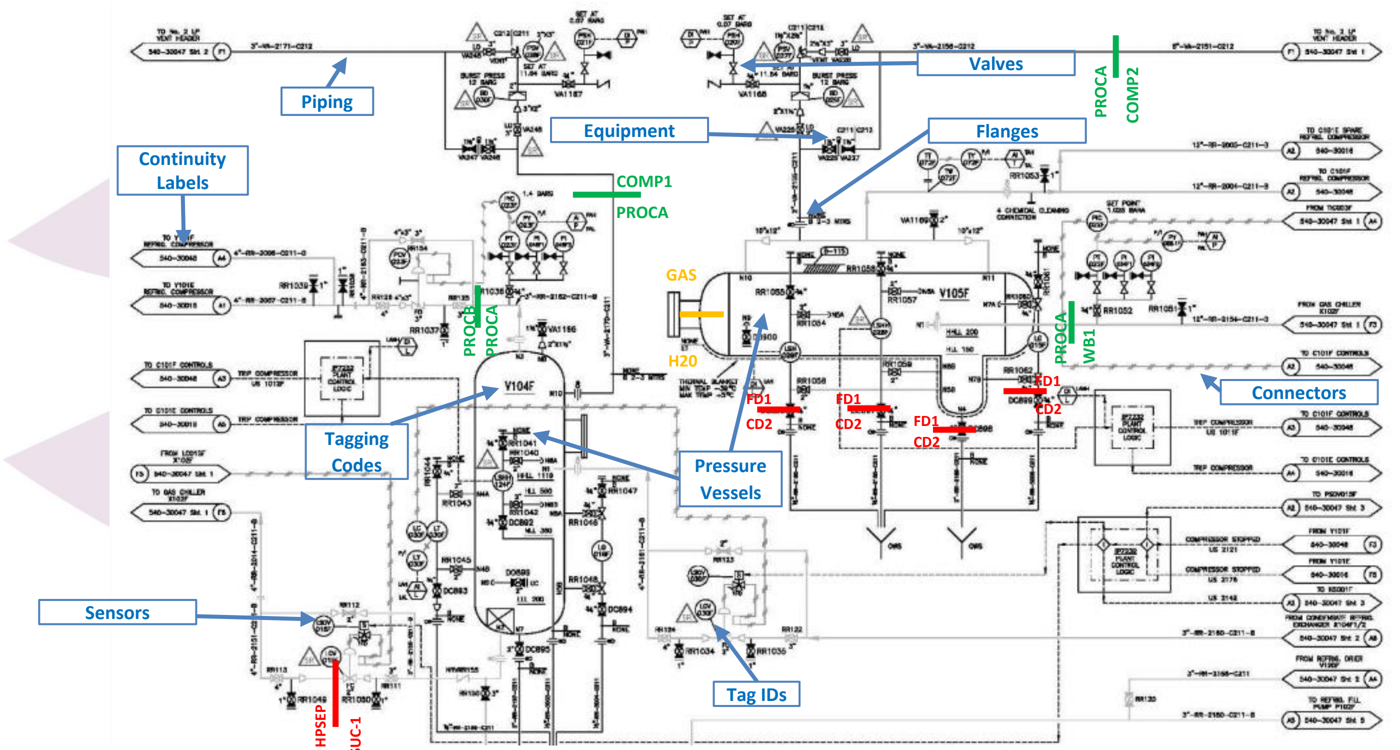
THE DATA LAB value from data

OGIC Oil & Gas Innovation Centre

-RGU and DNV GL join forces to create cost-saving image processing software. Available at https://cfmgcomputing.blogspot.com/2018/06/rgu-and-dnv-gl-join-forces-to-create.html

-OGIC backs digital Research projects to tune of £500k. Available at https://cfmgcomputing.blogspot.com/2018/09/ogic-backs-digital-research-projects-to.html

Information in a CED



Additional data

Change of Installation Area

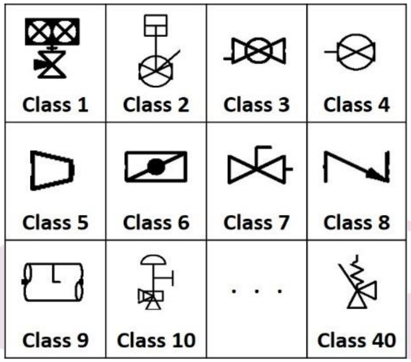
Change of Process Section

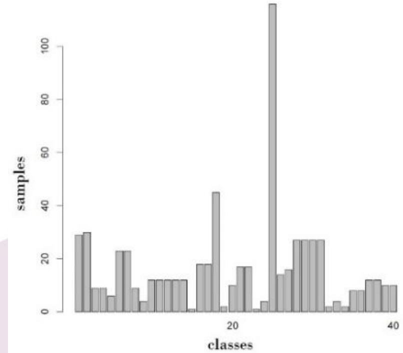
Change of Composition

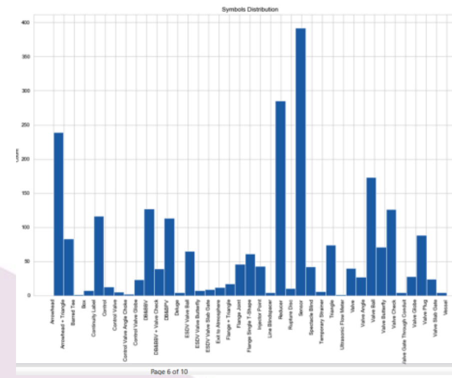
-Moreno-García, C. F., Elyan, E., & Jayne, C. (2018). New trends on digitisation of complex engineering drawings. Neural Computing and Applications, 1–18. https://doi.org/10.1007/s00521-018-3583-1

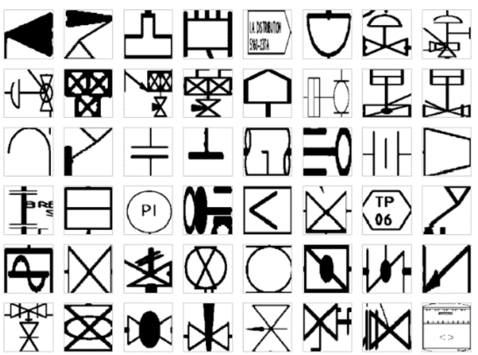
-Jamieson, L., Moreno-García, C. F., & Elyan, E. (2024). A review of deep learning methods for digitisation of complex documents and engineering diagrams. Artificial Intelligence Review, 1–37. https://doi.org/10.1007/s10462-024-10779-2

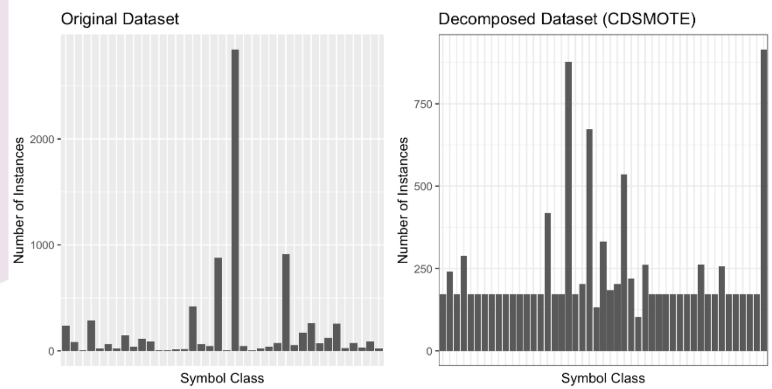
Symbols Detection & Classification











-Elyan, E., Moreno-García, C. F., & Jayne, C. (2018). Symbols Classification in Engineering Drawings. In International Joint Conference in Neural Networks (IJCNN). Available at https://www.researchgate.net/publication/327791936_Symbols_Classification_in_Engineering_Drawings.

-Elyan, E., Moreno-García, C. F. & Johnston P. (2020). Symbols in Engineering Drawings (SiED): An Imbalanced Dataset Benchmarked by Convolutional Neural Networks. In: *Engineering Applications of Neural Networks (EANN)*. ; 2020:215-224. https://doi.org/10.1007/978-3-030-48791-1.

-Jamieson, J., Moreno-García, C. F. & Elyan, E. (2024). A multiclass imbalanced dataset classification of symbols from piping and instrumentation diagrams", In: Barney Smith, E.H., Liwicki, M., Peng, L. (eds). International Conference on Document Analysis and Recognition (ICDAR 2024). Lecture Notes in Computer Science, vol 14804, pp. 3-16. Springer, Cham. https://doi.org/10.1007/978-3-031-70533-5_1.

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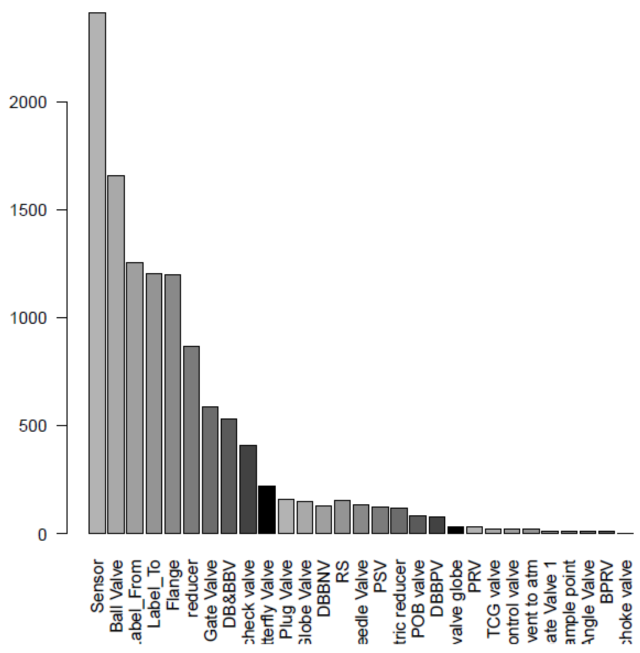
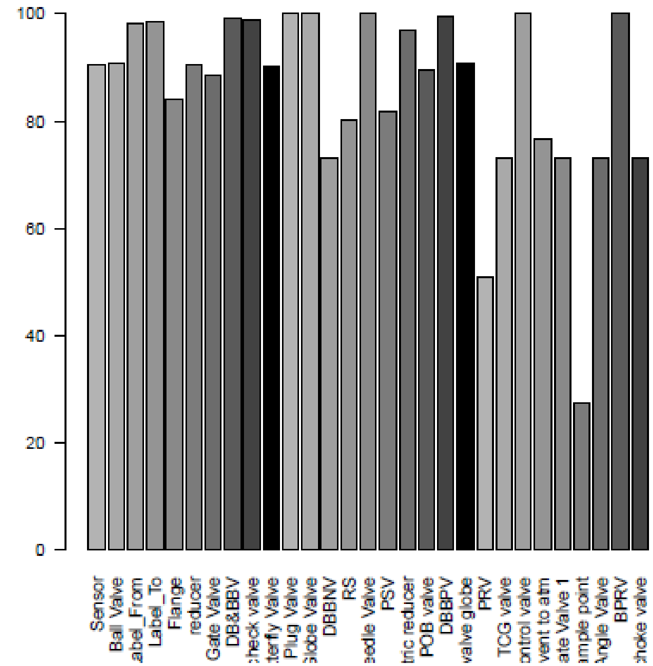
Distribution vs Precision

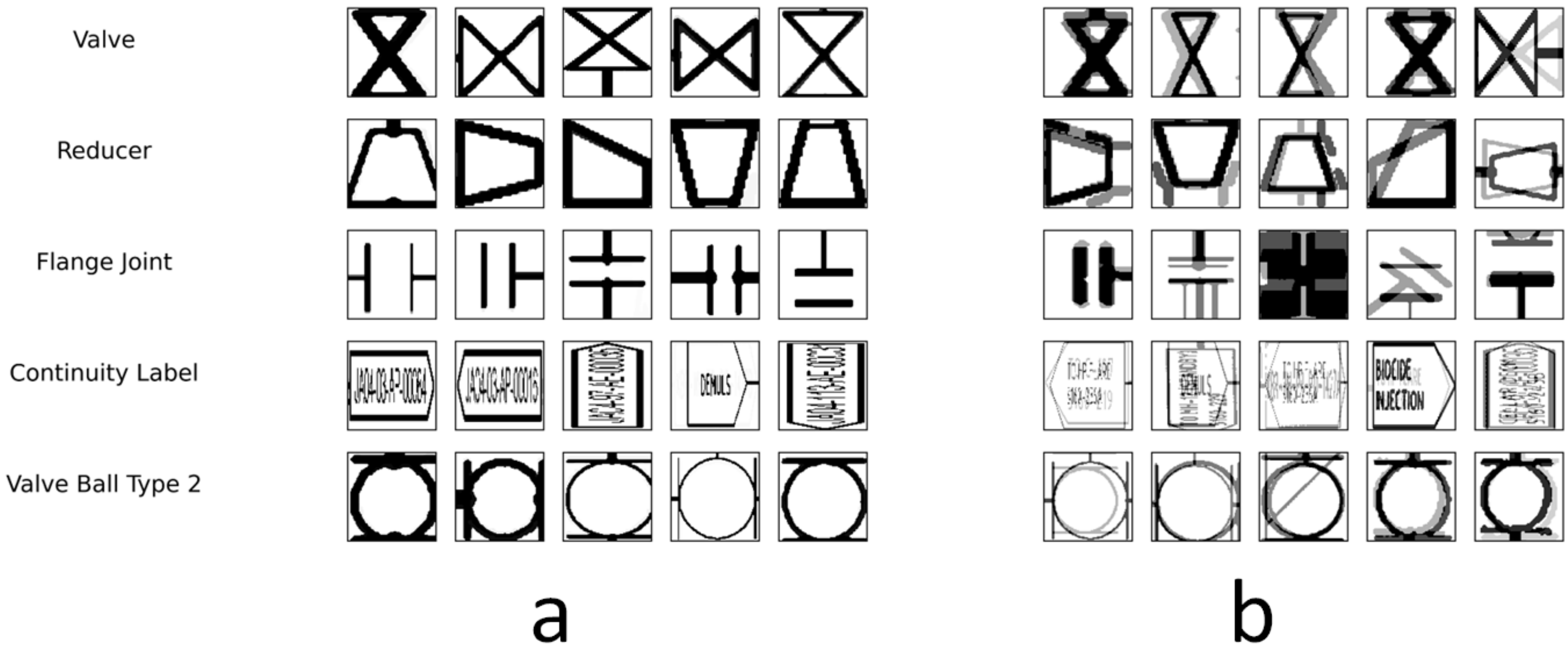
Class Distribution



Class Precision



Artificially Generated Symbols



Data Extraction Tool (DET)

-Moreno-García, C. F., Elyan, E., & Jayne, C. (2017). Heuristics-Based Detection to Improve Text/Graphics Segmentation in Complex Engineering Drawings. In Engineering Applications of Neural Networks (Vol. CCIS 744, pp. 87–98). https://doi.org/10.1007/978-3-319-65172-9_8

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Data Contextualisation

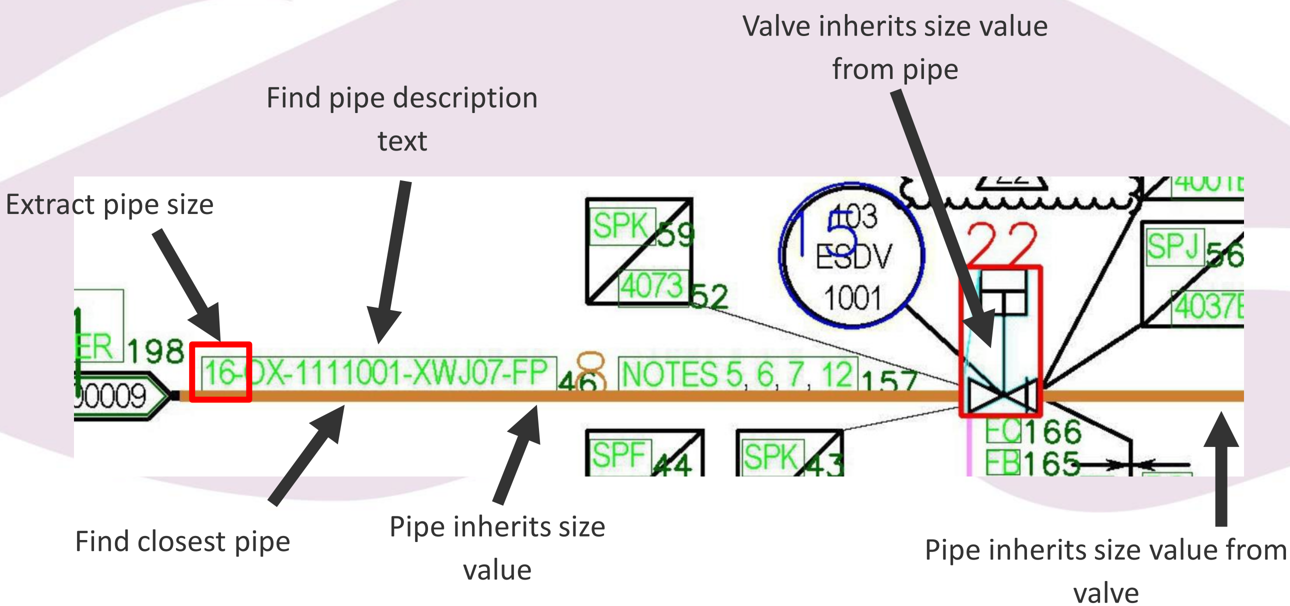
- Converting the netlist into the proper standard.

Number	Tag	x	y	w	h	Pointing	Location
1	JA03-03-AP-00009	182	3872	284	61	right	A5
2	JA04-03-AP-00131	182	2448	284	61	right	A3
Sensors							
Number	Tag	x	y	r	Location		
1	103-TT-1182	2564	2748	70	C4		
2	103-PT-1013	4224	1548	66	E2		
Equipment symbols							
Number	Class	x	y	w	h	Location	
1	Flange Joint 2 (Horizontal)	3089	4125	49	25	D5	
2	Barred Tee	2697	3863	94	52	C5	
Pipelines							
Number	Orientation	x1	y1	x2	y2	Thickness	Location
1	horizontal	1990	2479	2317	2479	4	C3
2	horizontal	467	2479	1885	2479	4	B3
Text Strings							
Number	Reading	x	y	w	h	Location	
1	41 O5B	2670	4316	74	36	C5	
2	40418	2516	4312	84	36	C5	
3	40058	2360	4312	84	36	C5	

Event	Equipment Category	Size	Number
JDY/CELLAR/RJAS/W	Piping	16	
JDY/CELLAR/RJAS/W	Act. Valve	16	0.5
JDY/CELLAR/JASIN/W	Piping	16	
JDY/CELLAR/JASIN/W	Act. Valve	16	0.5
JDY/PROC/JASIN/W	Piping	16	
JDY/PROC/JASIN/W	Act. Valve	16	2
JDY/PROC/JASIN/W	Flange	16	7
JDY/PROC/JASIN/W	Piping	6	
JDY/PROC/JASIN/W	Man Valve	16	3
JDY/PROC/JASIN/W	Piping	2	
JDY/PROC/JASIN/W	Flange	2	2
JDY/PROC/JASIN/W	Inst. Con.	2	2
JDY/PROC/JASIN/W	Man Valve	6	0.5

Data Contextualisation

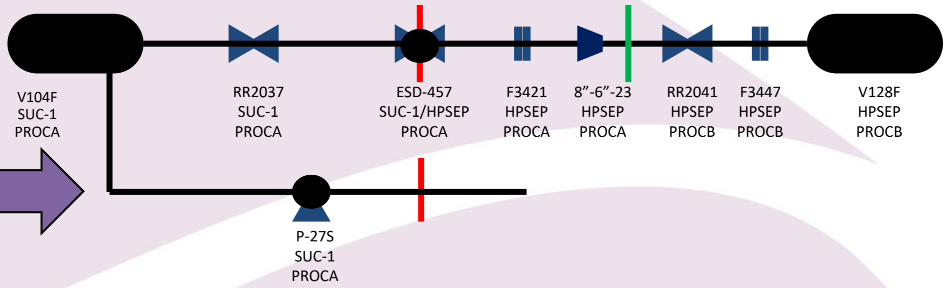
- Data Inheritance.



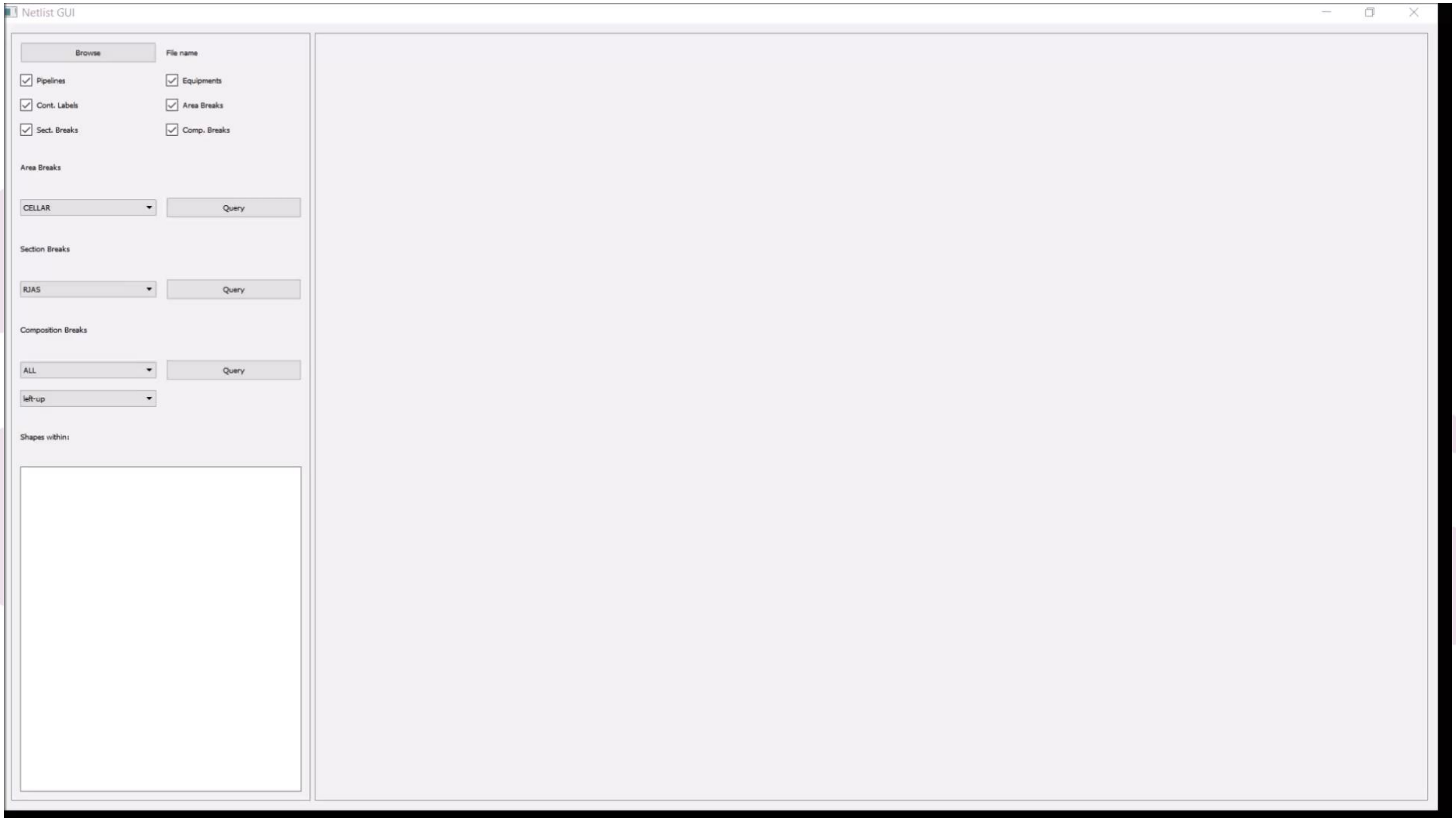
Data Visualisation

- Analysis of sub-sections.

Event	Area	Section	Stream	Type	SIZE	No./Len	TAG
PROCA/SUC-1/G	PROCA	SUC-1	S-23	H-VESS	8	0.6	V104F
PROCA/SUC-1/G	PROCA	SUC-1	S-23	M-VAL	8	1	RR2037
PROCA/SUC-1/G	PROCA	SUC-1	S-23	ESD-VAL	8	0.5	ESD-457
PROCA/SUC-1/G	PROCA	SUC-1	S-23	PIPE	8	4	-
PROCA/SUC-1/C	PROCA	SUC-1	S-27	H-VESS	4	0.4	V104F
PROCA/SUC-1/C	PROCA	SUC-1	S-27	PUMP	4	1	P-27S
PROCA/SUC-1/C	PROCA	SUC-1	S-27	PIPE	4	6	-
PROCA/HPSEP/G	PROCA	HPSEP	S-23	ESD-VAL	8	0.5	ESD-457
PROCA/HPSEP/G	PROCA	HPSEP	S-23	FLANGE	8	1	8"-6
PROCA/HPSEP/G	PROCA	HPSEP	S-23	PIPE	8	3.5	-
PROCA/HPSEP/G	PROCA	HPSEP	S-23	PIPE	6	2	-
PROCB/HPSEP/G	PROCB	HPSEP	S-23	REDUCER	8-6	1	RR2041
PROCB/HPSEP/G	PROCB	HPSEP	S-23	FLANGE	6	1	F3447
PROCB/HPSEP/G	PROCB	HPSEP	S-23	V-VESS	6	1	V128F
PROCB/HPSEP/G	PROCB	HPSEP	S-23	PIPE	6	3	-

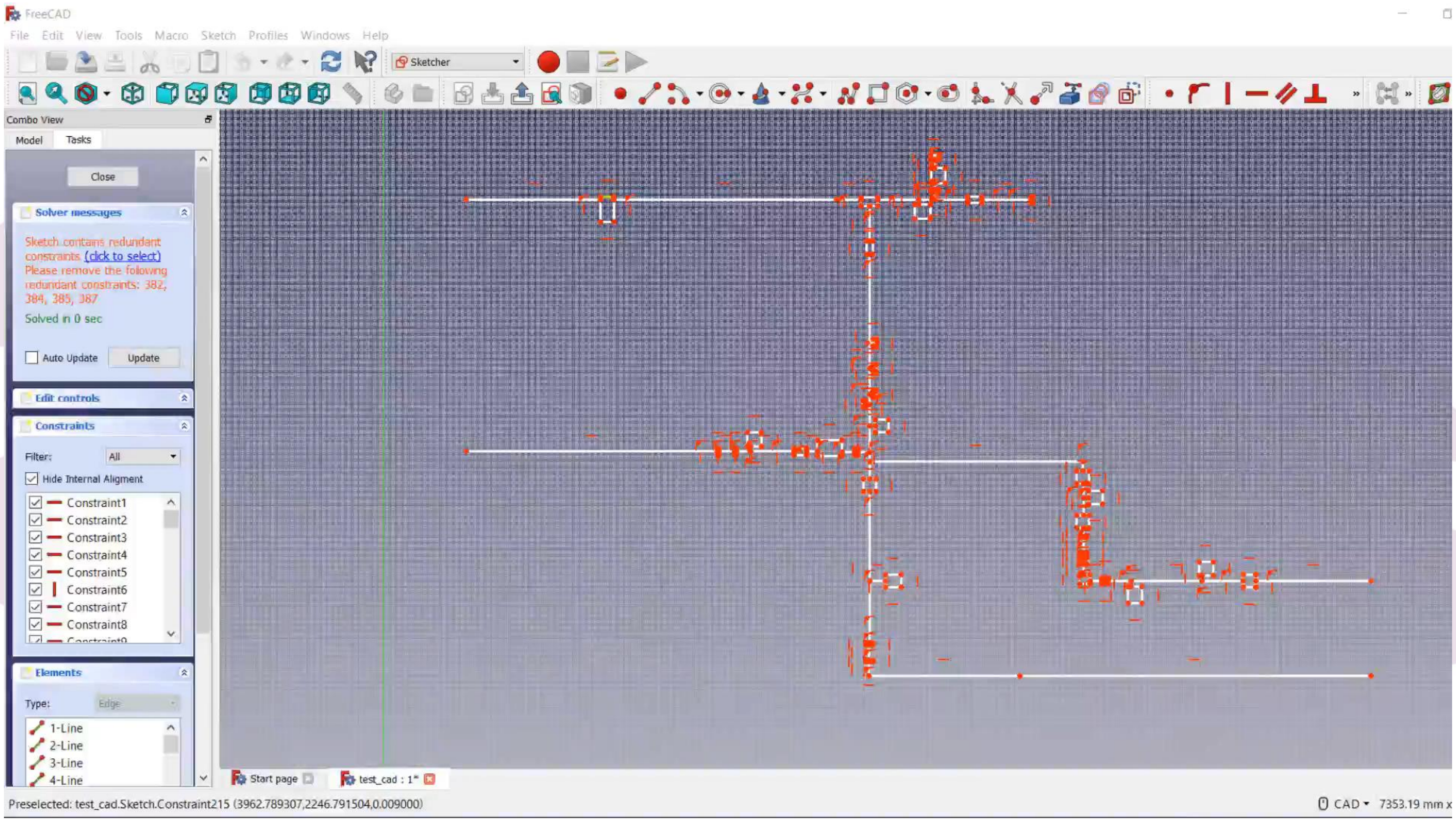


Netlist Visualizer



-Njoku, I. (2018). Visualising Subsections of Digital Assets from the Oil & Gas Industry using Graph Representations. Ms. C. Thesis. Supervisor: Moreno-García, C. F.

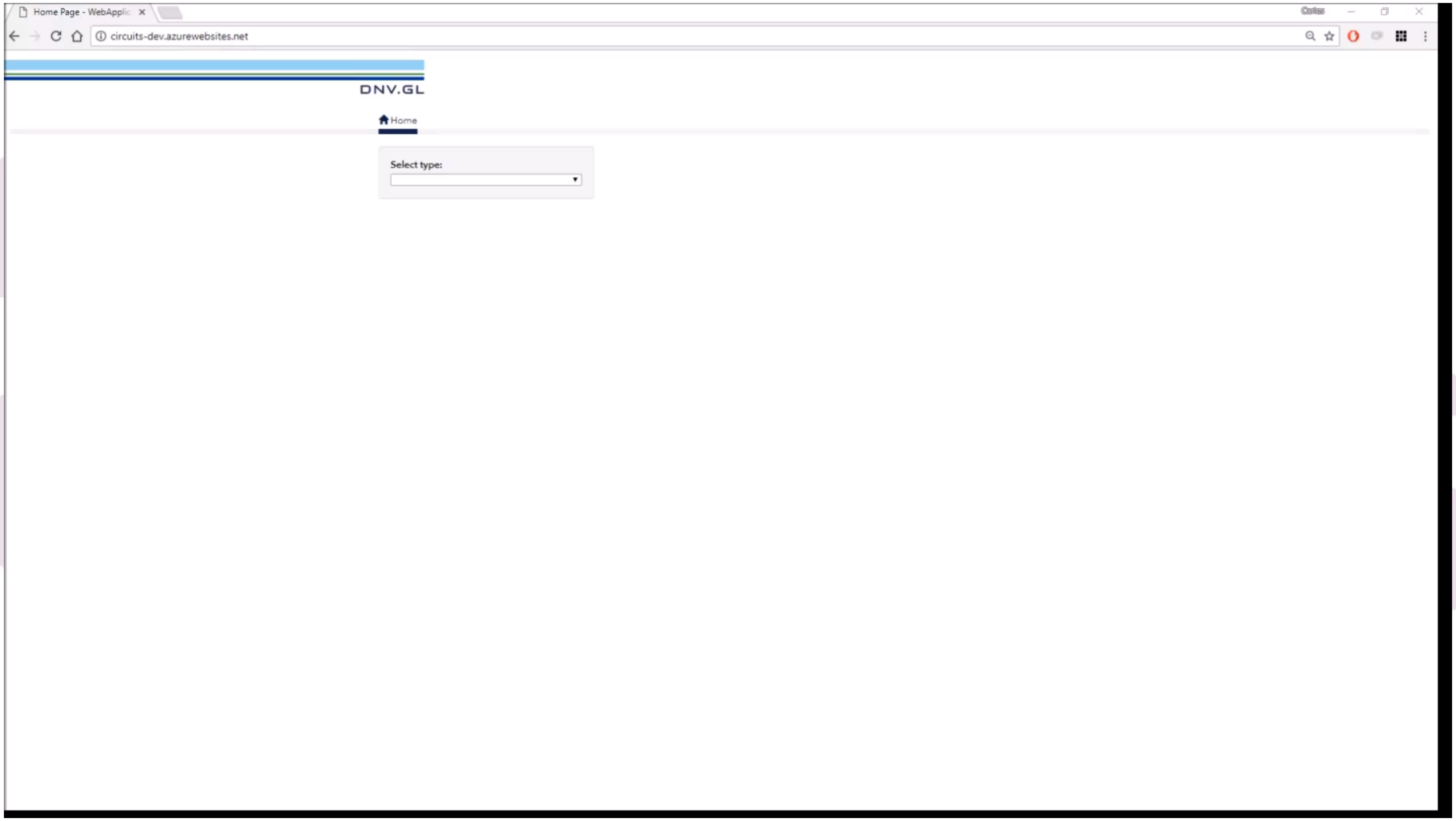
Netlist2CAD



-Chybowski, B.. (2018). Netlist2CAD. Standalone project. Supervisor: Moreno-García, C. F.

Sensor-Equipment Diagram Digitisation

DEMO AVAILABLE AT: http://cfmgcomputing.blogspot.com/p/circuits-dev-digitisation-tool.html

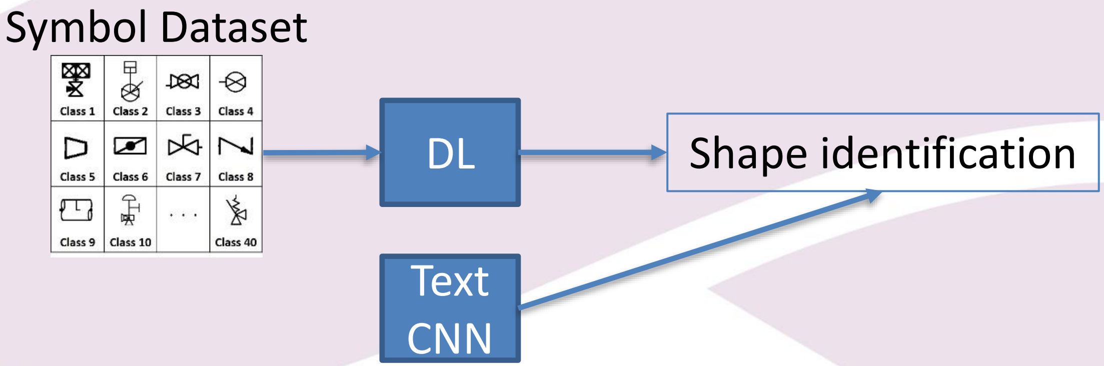


-Moreno-García, C. F., Digital interpretation of sensor-equipment diagrams, Proceedings of the SICSA Workshop on Reasoning, Learning and Explainability (ReaLX 2018), Aberdeen, Scotland, CEUR Workshop Proceedings, vol. 2151, http://ceur-ws.org/Vol-2151/Paper_s2.pdf

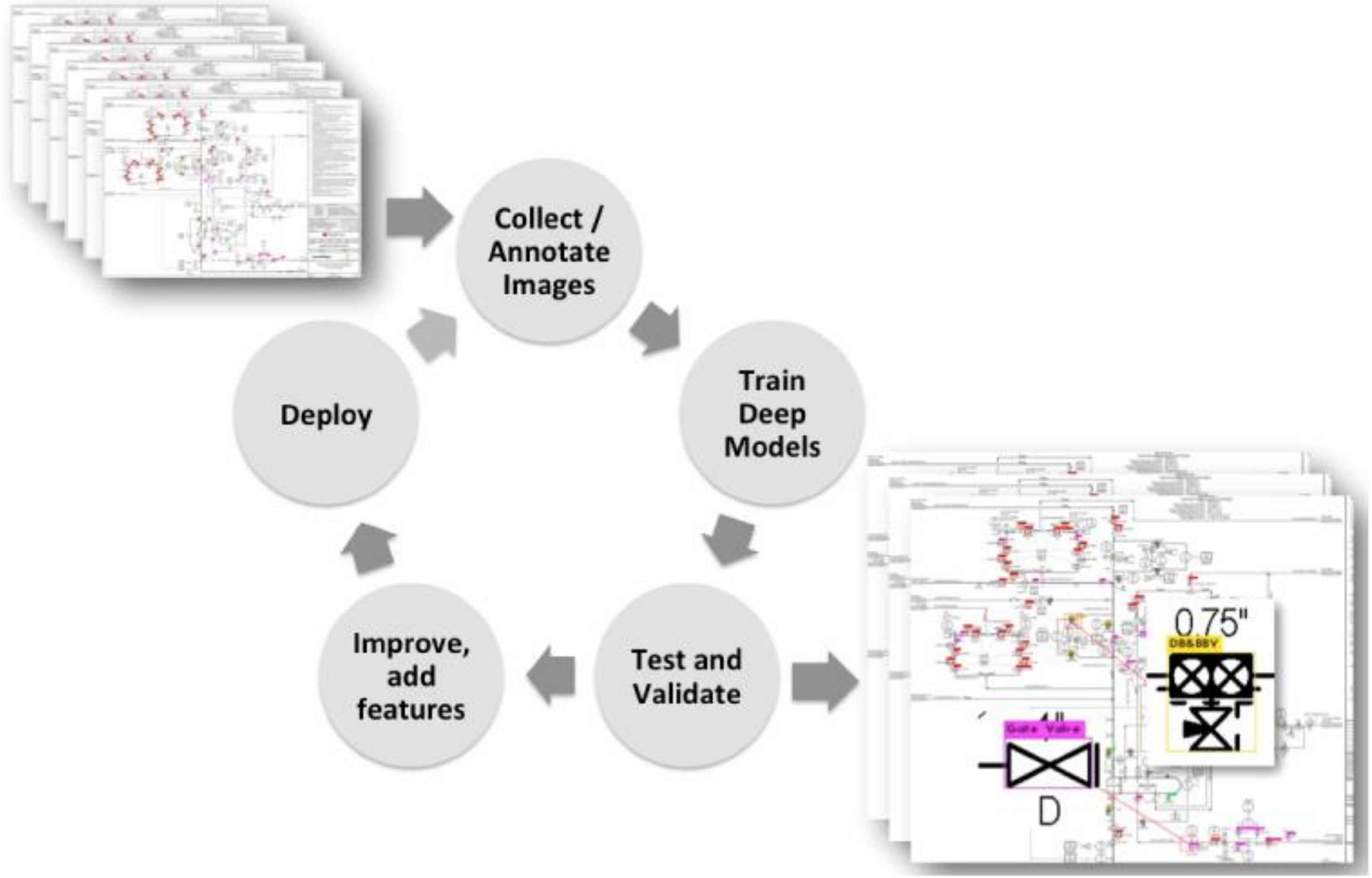
Corrosion Mark-up

-Toral, L., Moreno-García, C. F., Elyan, E., & Memon, S. (2021). A Deep Learning Digitisation Framework to Mark up Corrosion Circuits in Piping and Instrumentation Diagrams. *WIADAR*, *LNCS 12917*, 268–276. https://doi.org/10.1007/978-3-030-86159-9

DL for shape detection and classification



Framework



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Text Detection

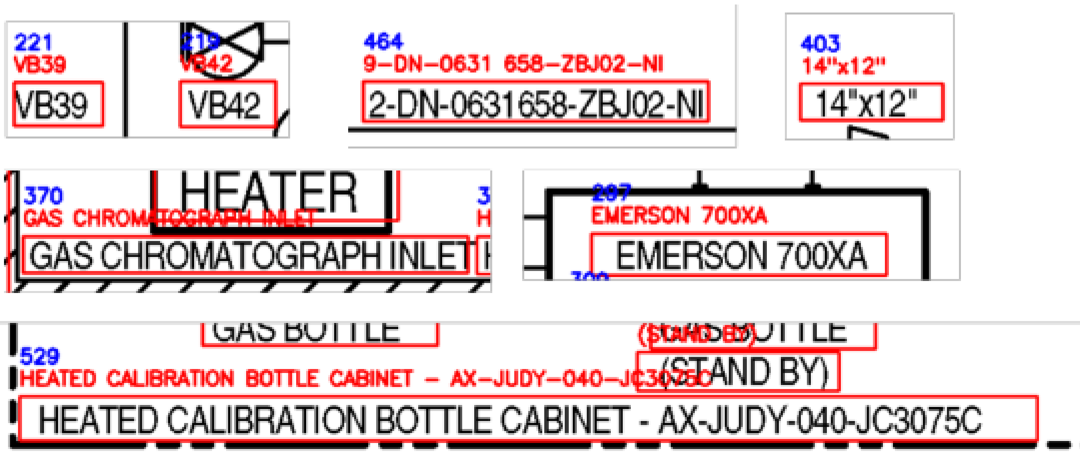
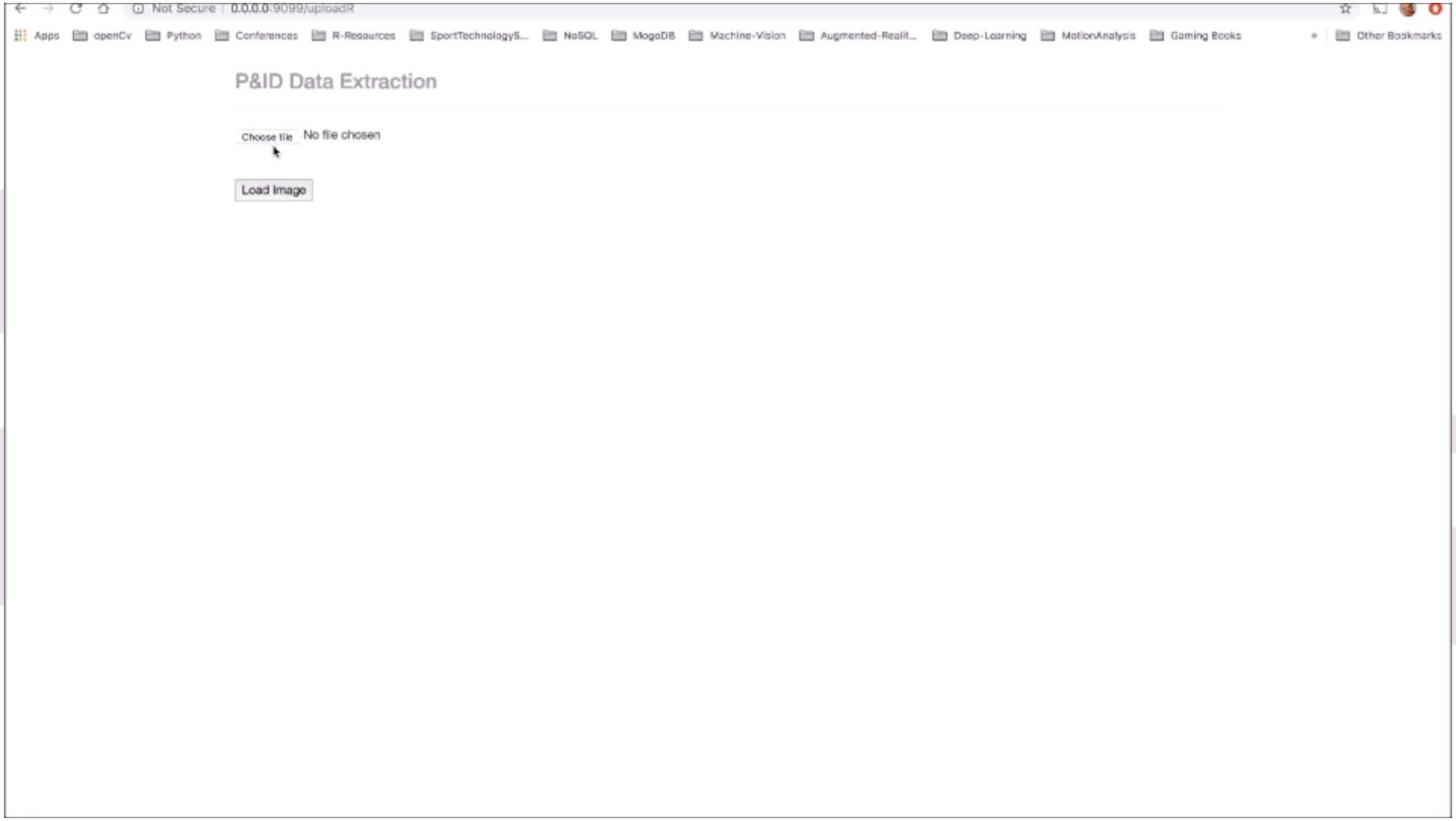


Diagram No.	Text Instances	Detected	FN	FP	Recognised
1	426	388	54	16	337
2	492	463	42	13	384
3	545	506	61	22	439
4	407	385	37	15	333
5	201	194	16	9	167

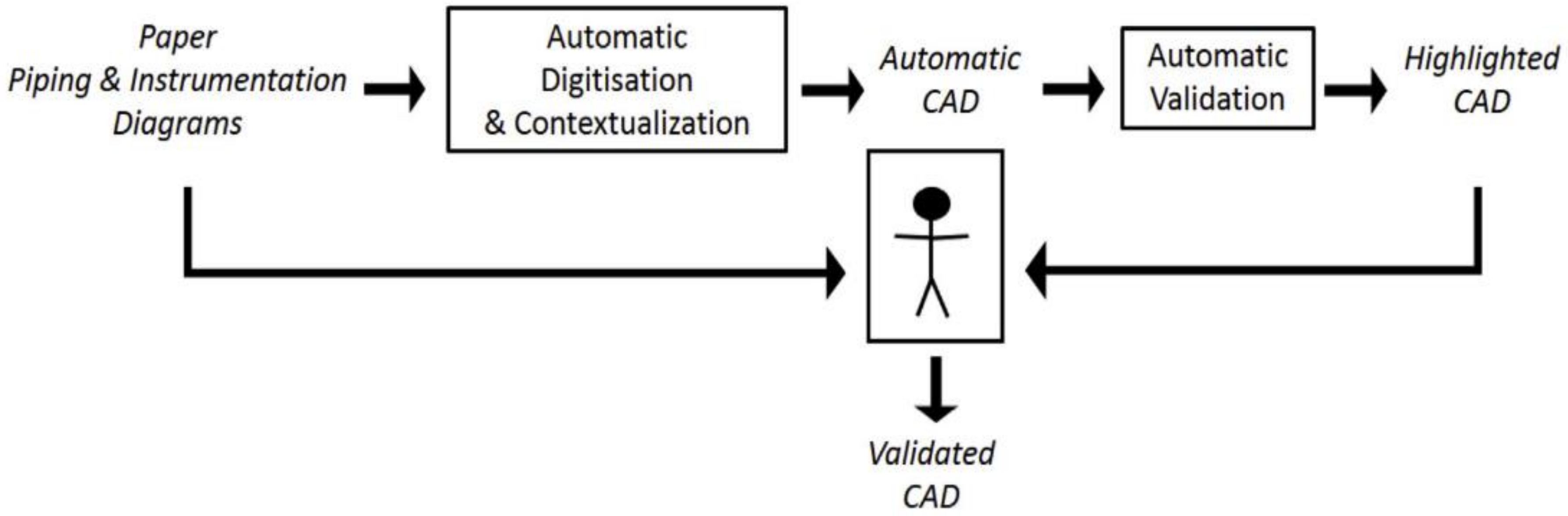
-Jamieson, L., Moreno-García, C. F., & Elyan, E. (2020). Deep learning for text detection and recognition in complex engineering diagrams. International Joint Conference on Neural Networks (IJCNN). https://doi.org/https://doi.org/10.1109/IJCNN48605.2020.9207127

Results



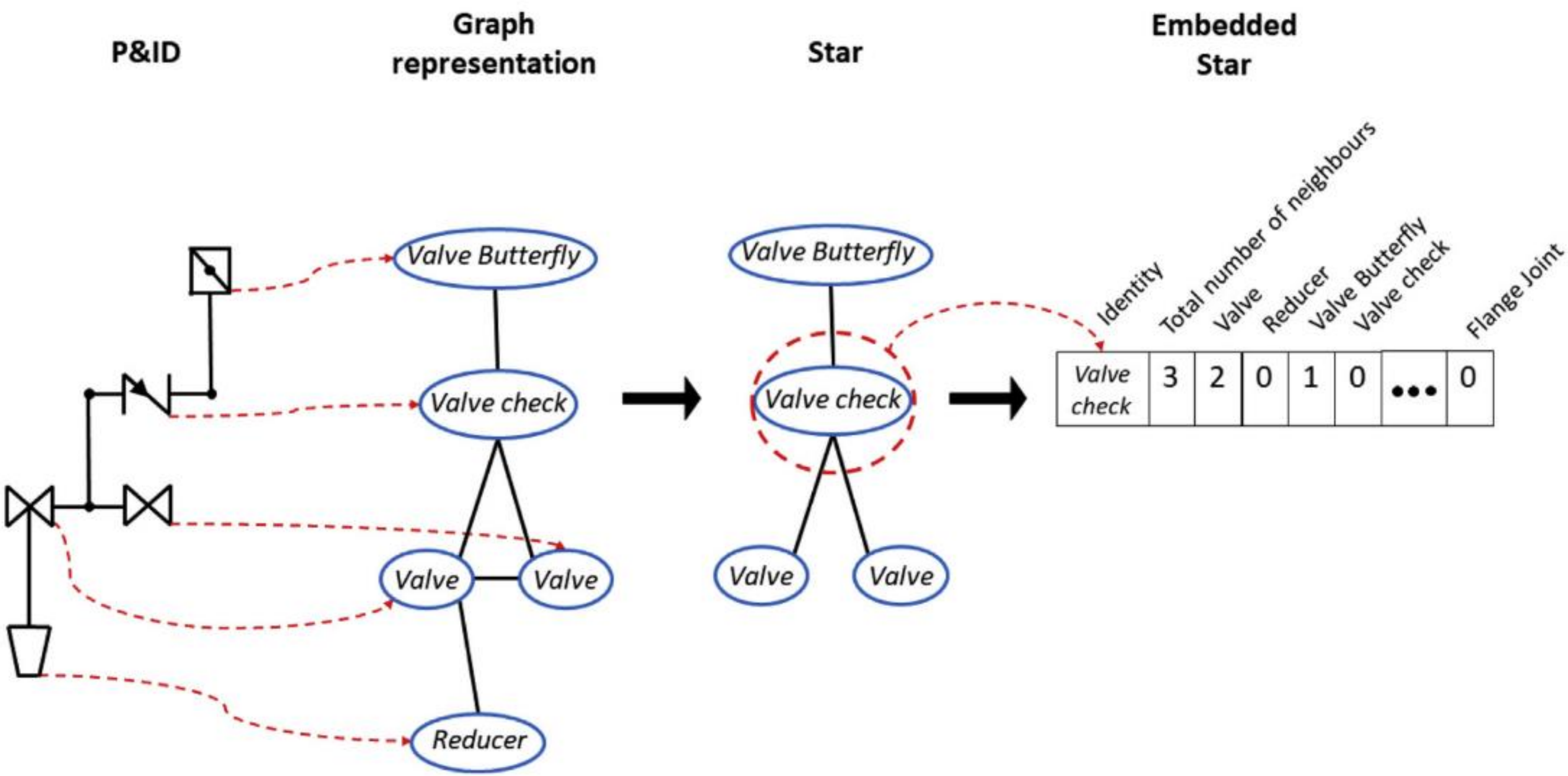
-Elyan E, Jamieson L, Ali-Gombe A. Deep learning for symbols detection and classification in engineering drawings. *Neural Networks*. 2020;129:91-102. http://doi.org/10.1016/j.neunet.2020.05.025

GNNs for automated error correction



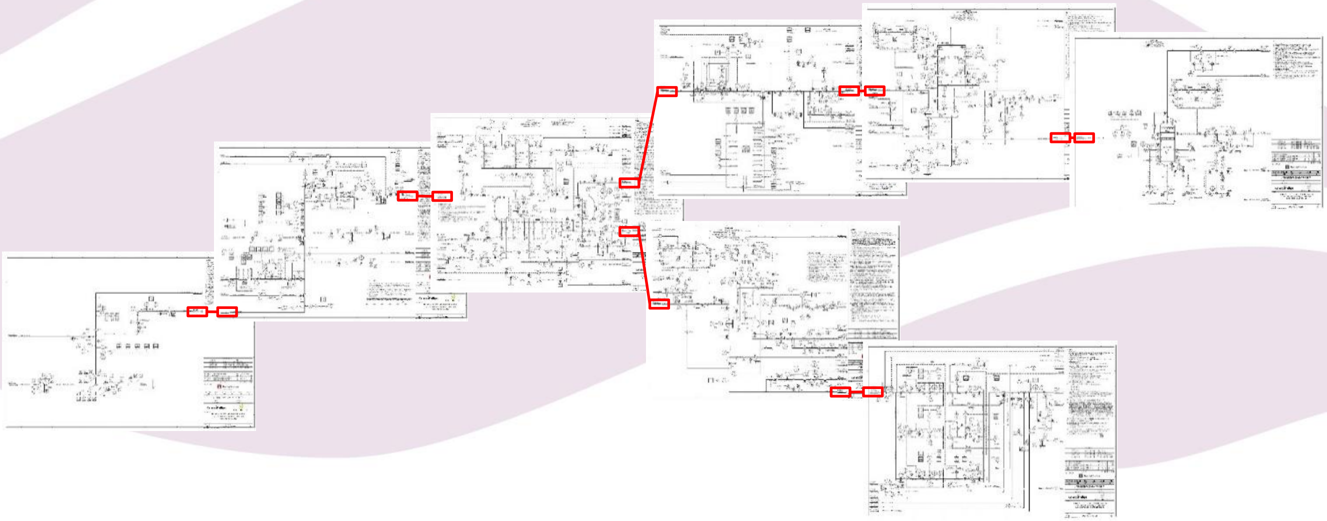
-Rica E, Moreno-García CF, Álvarez S, Serratosa F. Reducing human effort in engineering drawing validation. *Computers in Industry*. 2020;117.
http://doi.org/10.1016/j.compind.2020.103198

GNNs for automated error correction



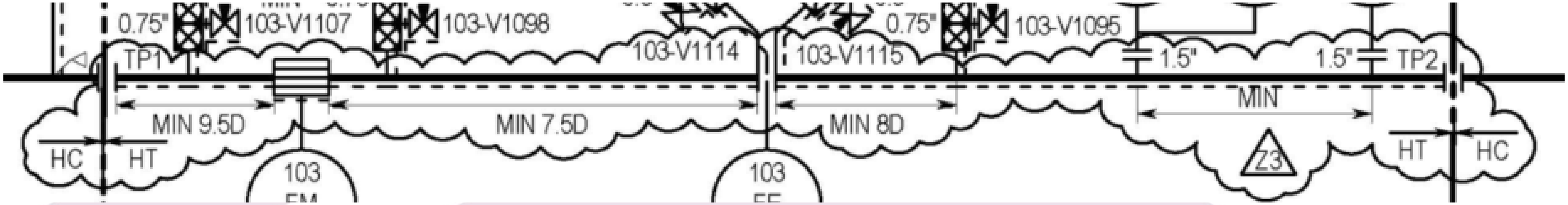
Linking Drawings

Proposed solution: Graph Representations.



-Moreno-García, C.F., Elyan, E., "Digitisation of Assets from the Oil & Gas Industry: Challenges and Opportunities," in International Conference on Document Analysis and Recognition (ICDAR), Workshop on Industrial Applications of Document Analysis and Recognition (WIADAR), pp. 16–19, 2019. https://doi.org/10.1109/ICDARW.2019.60122

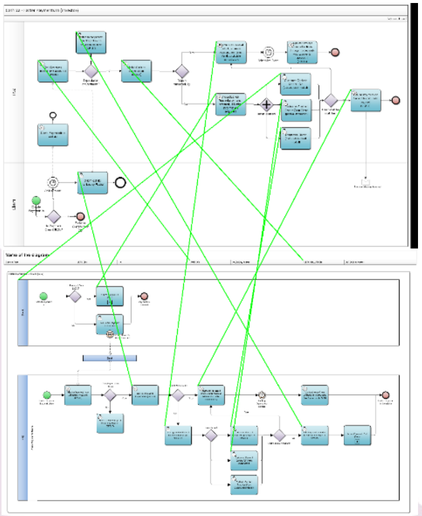
Revision Clouds

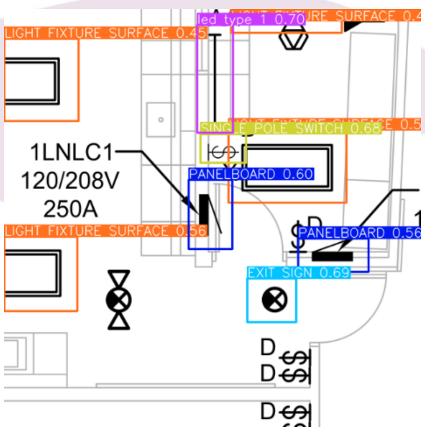


How to find (avoid) them, and how to find out if a drawing has been altered/revised?

More Projects

- Digitisation of financial process maps (firm in Edinburgh)
- Applying this work with a Canadian construction firm
  - Finding more and more complicated symbols
  - Understanding the connectivity of the electrical panels in a building
  - Provisional Patent in the US
- Creation of <u>Digital Twins</u>





Crack Detection in Photovoltaic (PV) Panels and Wind Turbine Blades

Presented by DNV @ Image Processing Day

Project Aim

- Drones and ROVs collect high-resolution images, spectral, geolocation and other data about the health of a renewable asset
- Computer vision and algorithms process the data to identify faults or change in asset condition
- A report is automatically generated providing results
- Skilled engineers review results, make recommendations and complete client deliverables

Transition into Renewable Asset Inspection

DNV

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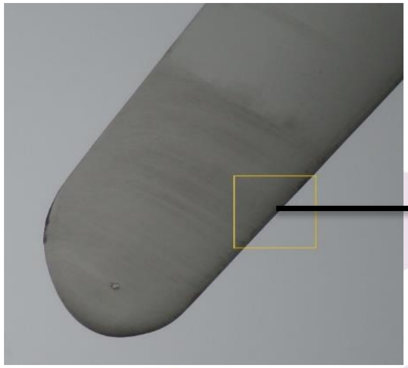
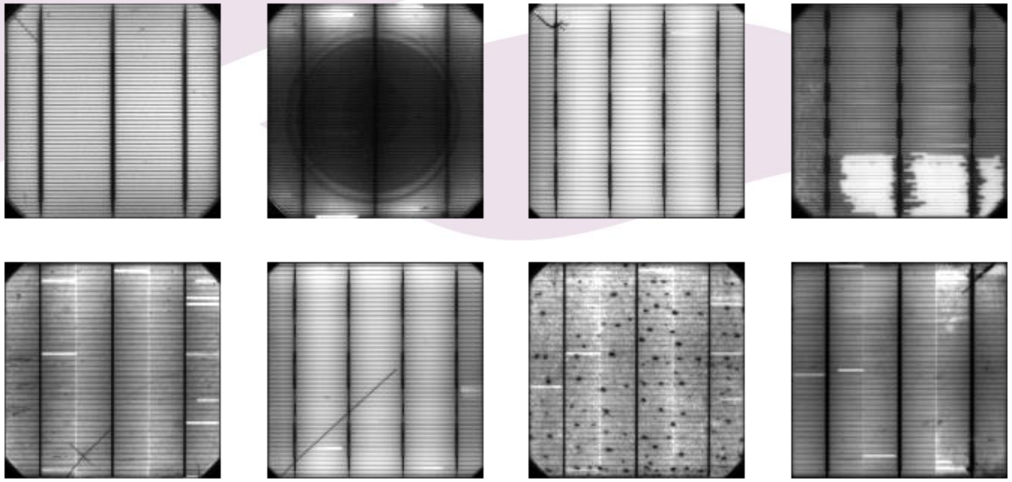
Main Challenges



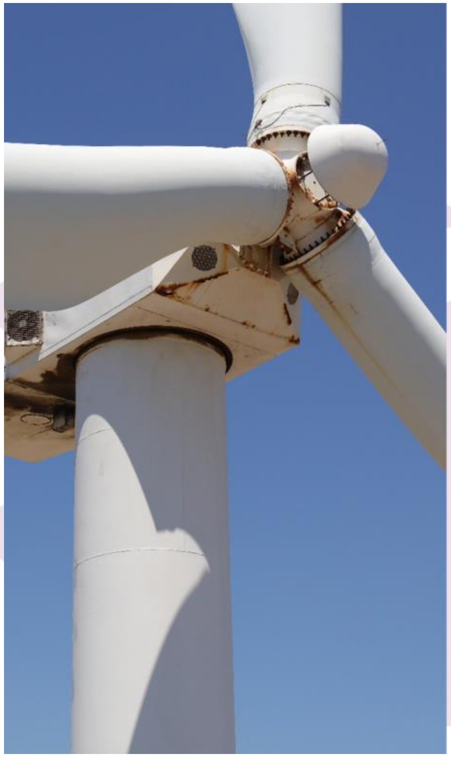
Wind turbine blade

Damaged leading edge

Detection of faulty panels



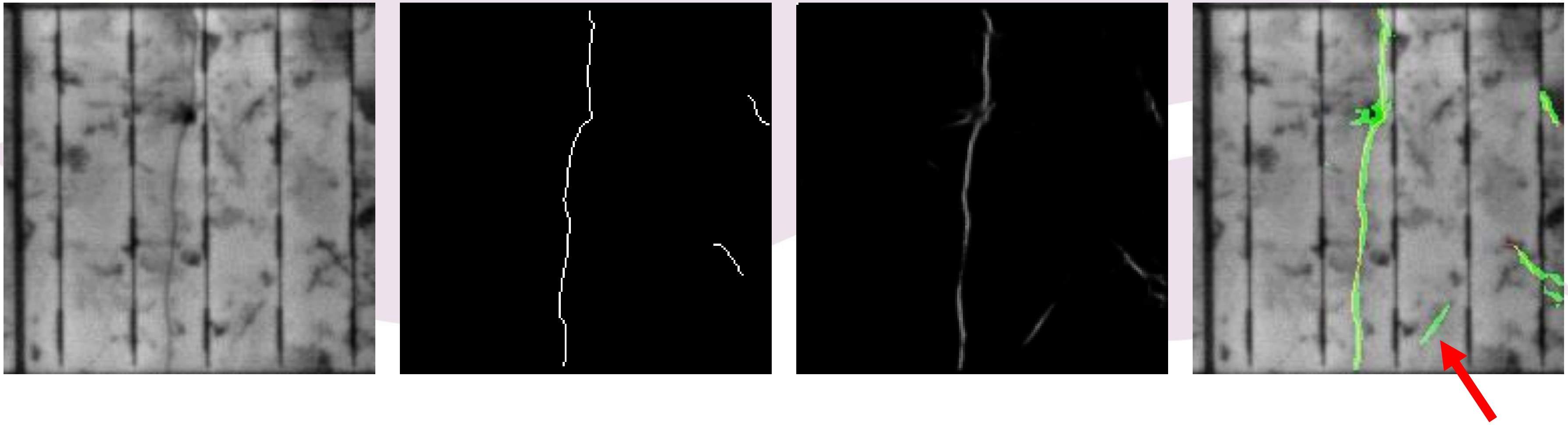
Drone Turbine Data



Part	Distance from hub	Side of Structure	Fault Type	Fault Size
Blade B	1.5m	LE	Crack	0.17m long

Crack Detection

Query image Ground truth Probability mask Predictions



Corrosion Detection in Underwater Images

Honours Project developed by Craig Pirie (PhD student) and supervised by Dr Carlos Moreno-Garcia

Project Aim

- Analyse and compare state-of-the-art computer vision techniques to provide a system that assists inspection engineers in the identification of corrosion.

- Main issues:
  - Few labelled data at hand
  - Computational requirements

Image Pre-processing

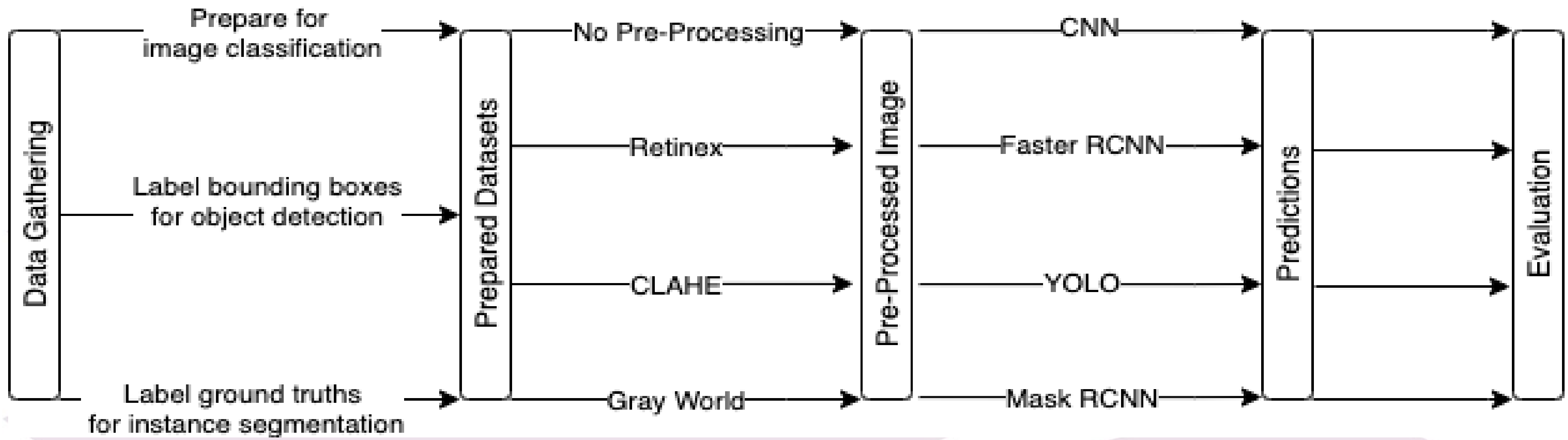
Original

Gray World

Retinex

CLAHE

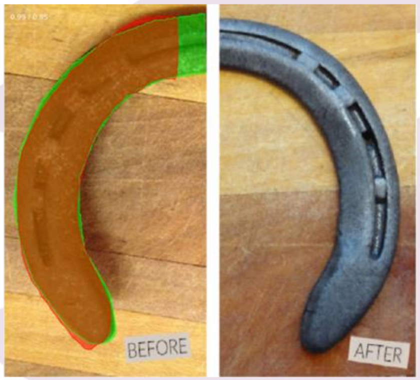
Classification and Recognition

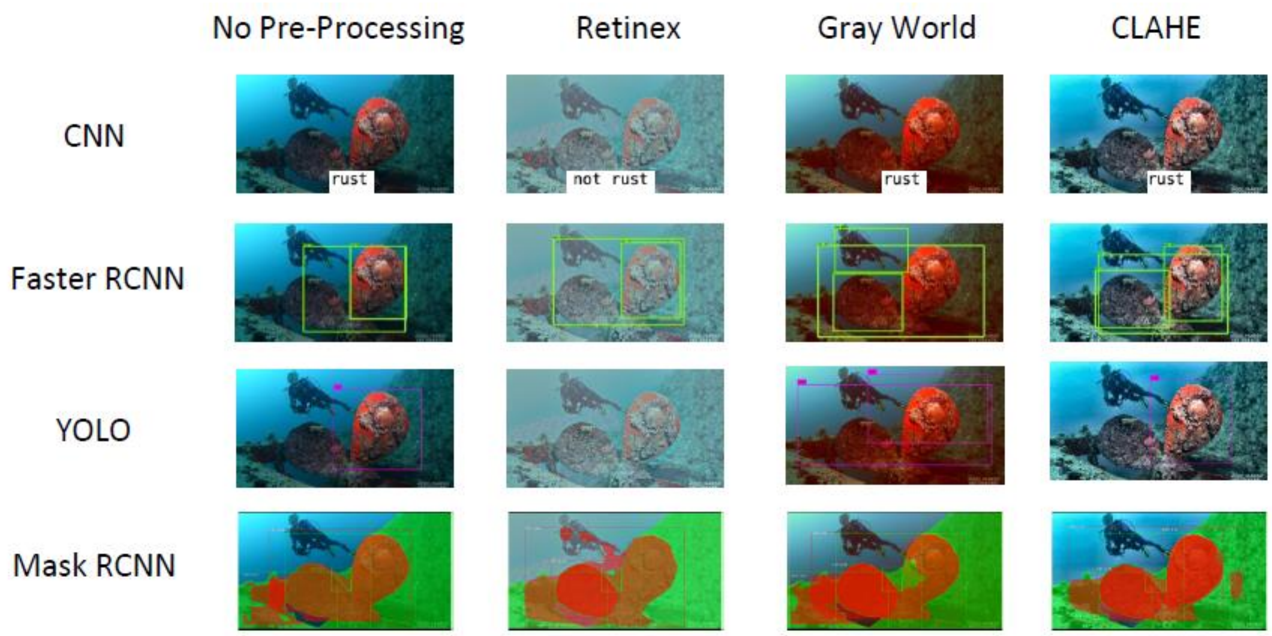


Dataset Acquired	Type	Rust	No Rust
	Surface	1105 (70% labelled)	128
	Underwater	24 (test only)	24

THIS IS YOUR COURSEWORK!

Results



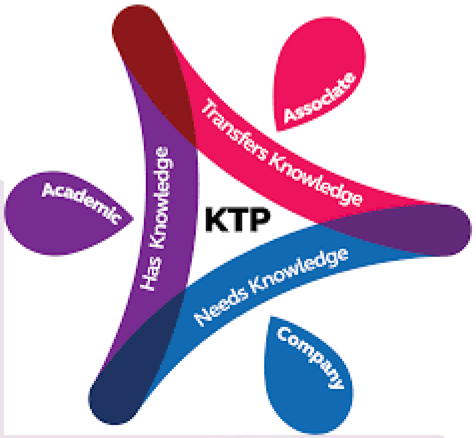


	Study of Network Performance (Precision [%])			
	CNN	Faster RCNN	YOLO	Mask RCNN
Surface	90.9	24.1	7.1	57.0
Underwater	75.0	37.8	9.0	77.1

More Anomaly Detection Problems!

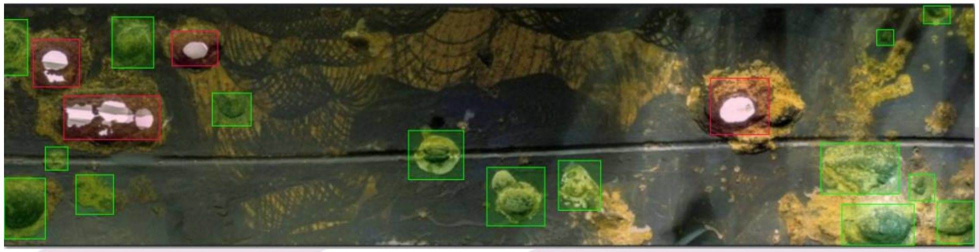
Presented by Luis Toral Quijas

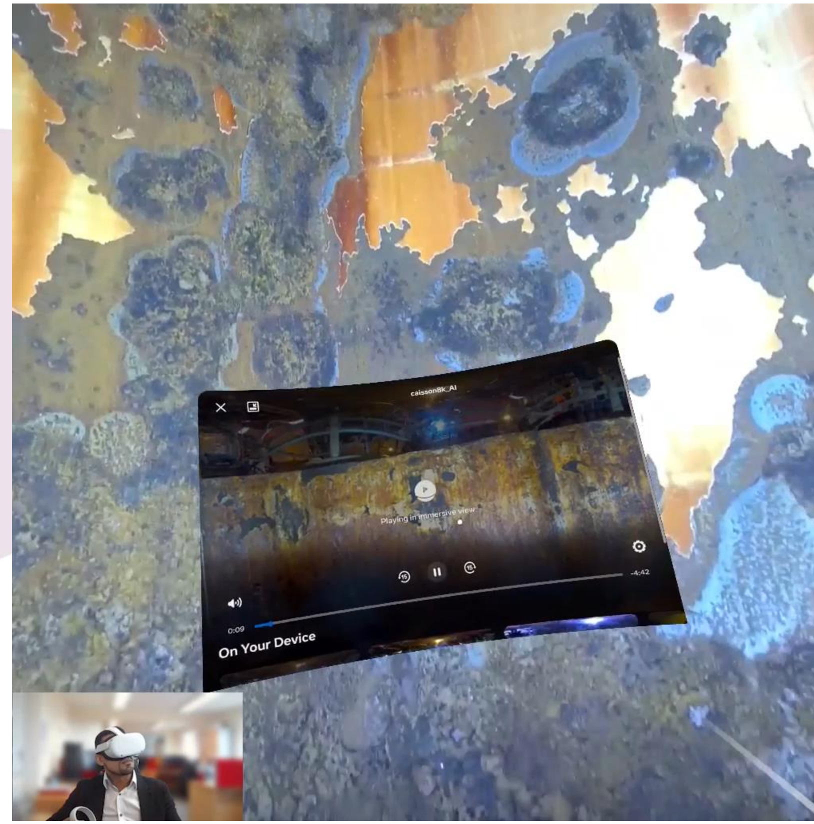
Underwater Image Enhancement



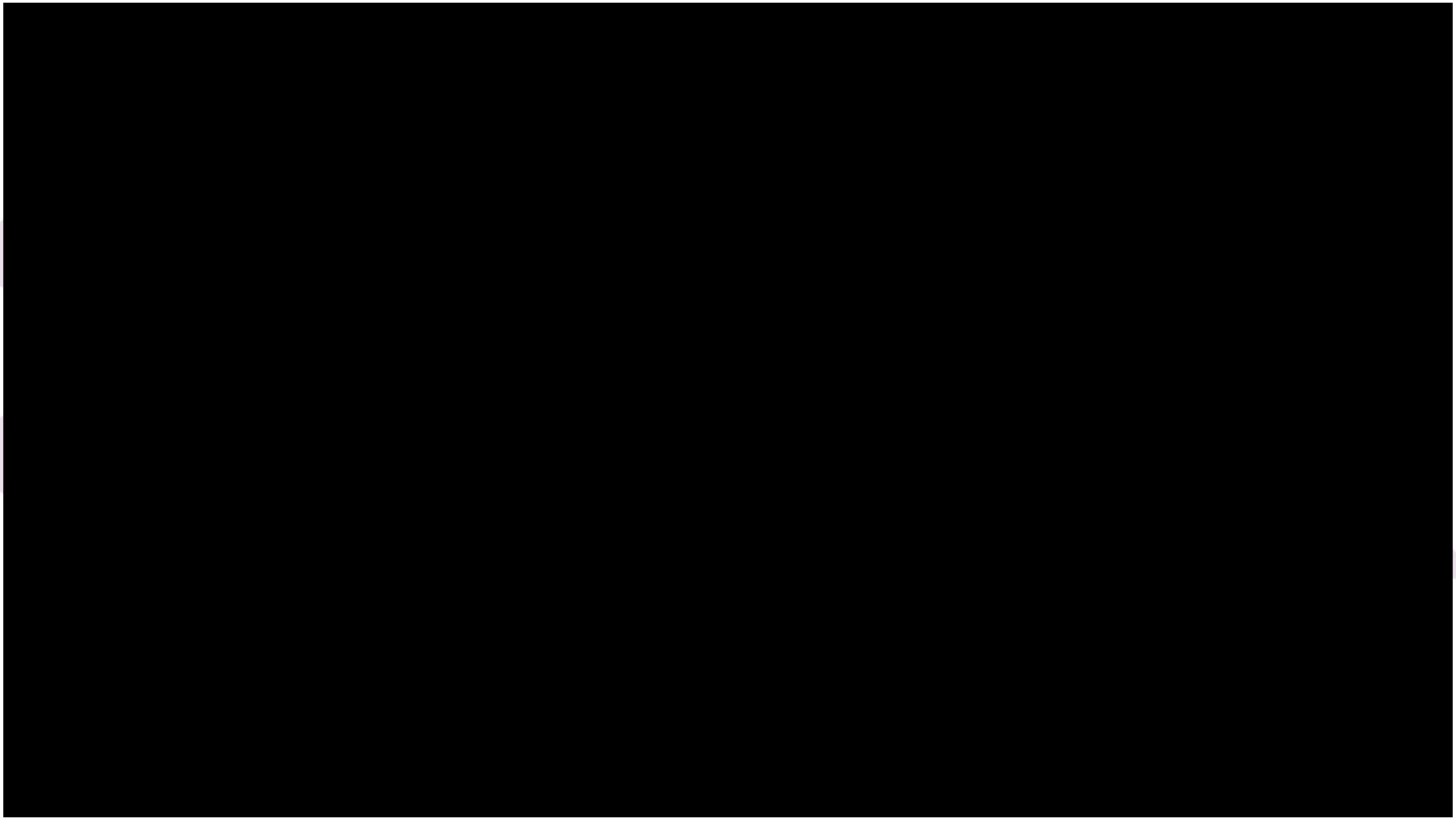
AISUS

Anomaly Detection





Weld Classification



InspectionTag Recognition (OCR)