Information Fusion and Data Augmentation for Risk-based Maintenance Optimization of Hydrogen Gas Pipelines

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Main Objective

This project was awarded to Arizona State University in order to develop a risk-based maintenance optimization framework based on Bayesian causal network (BCN) and dynamic maintenance planning for hydrogen gas pipelines to provide decision support for pipeline integrity management.

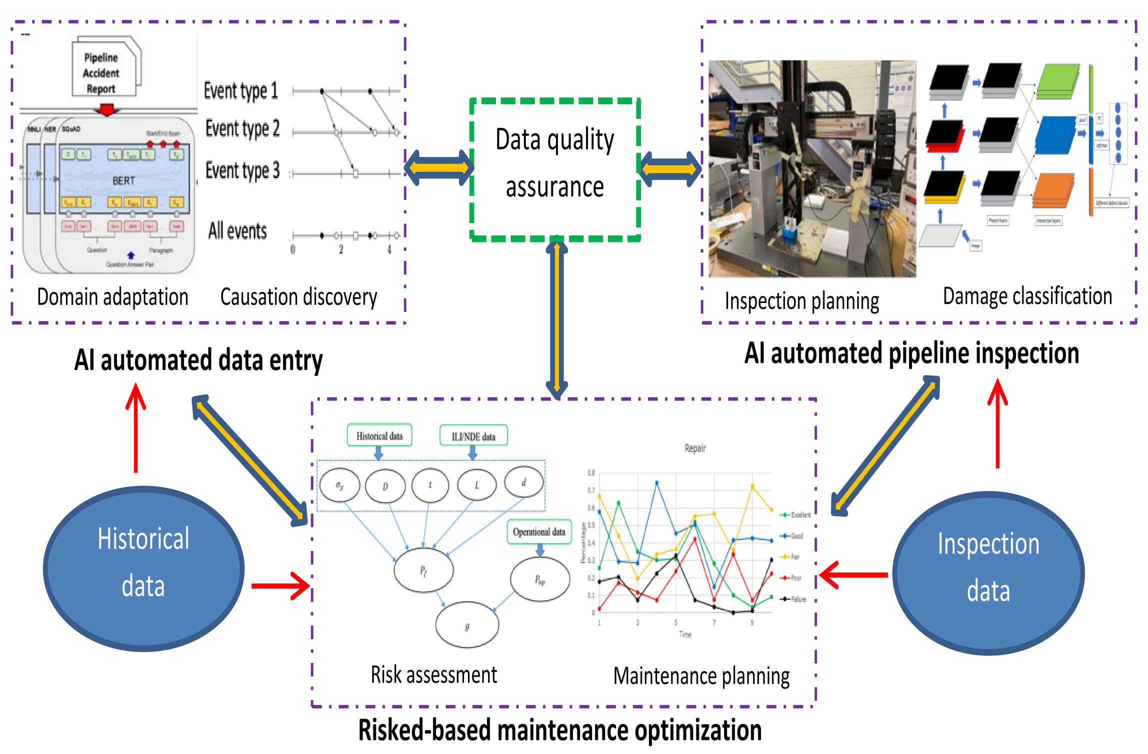


Figure 1. Schematic illustration of the proposed framework for the project.

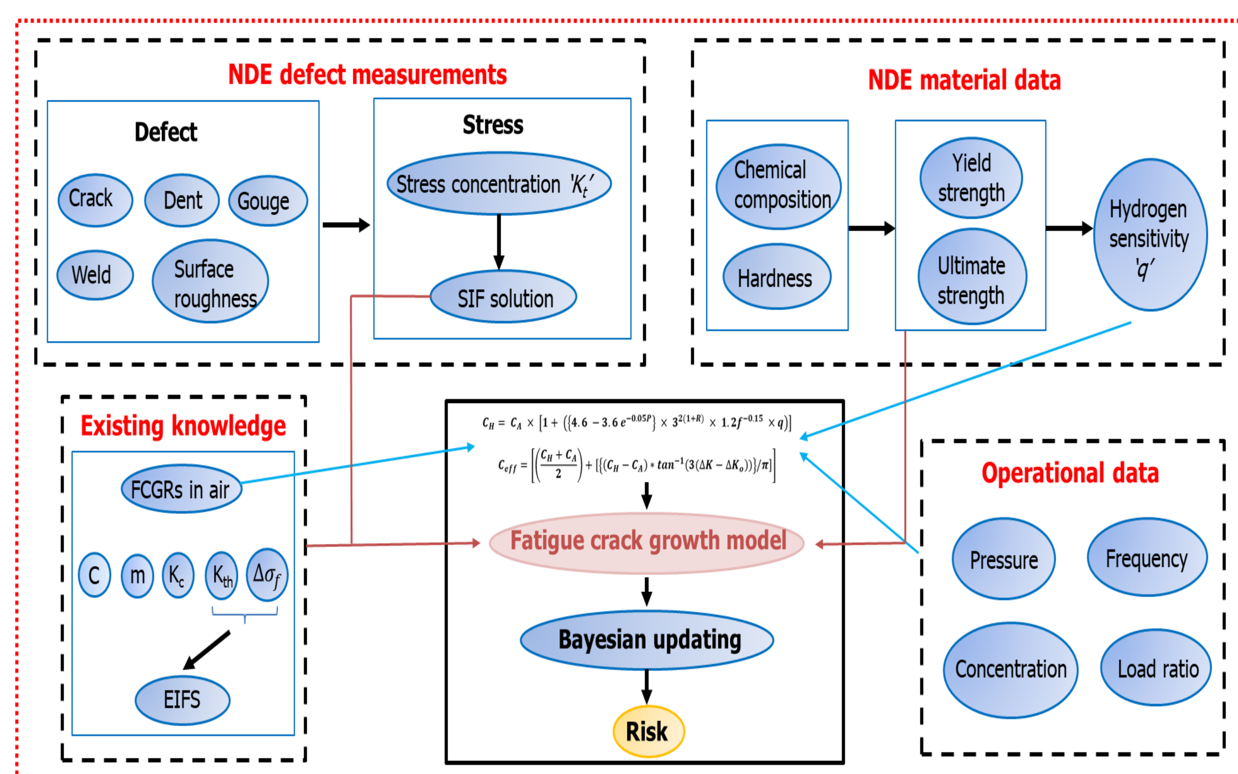
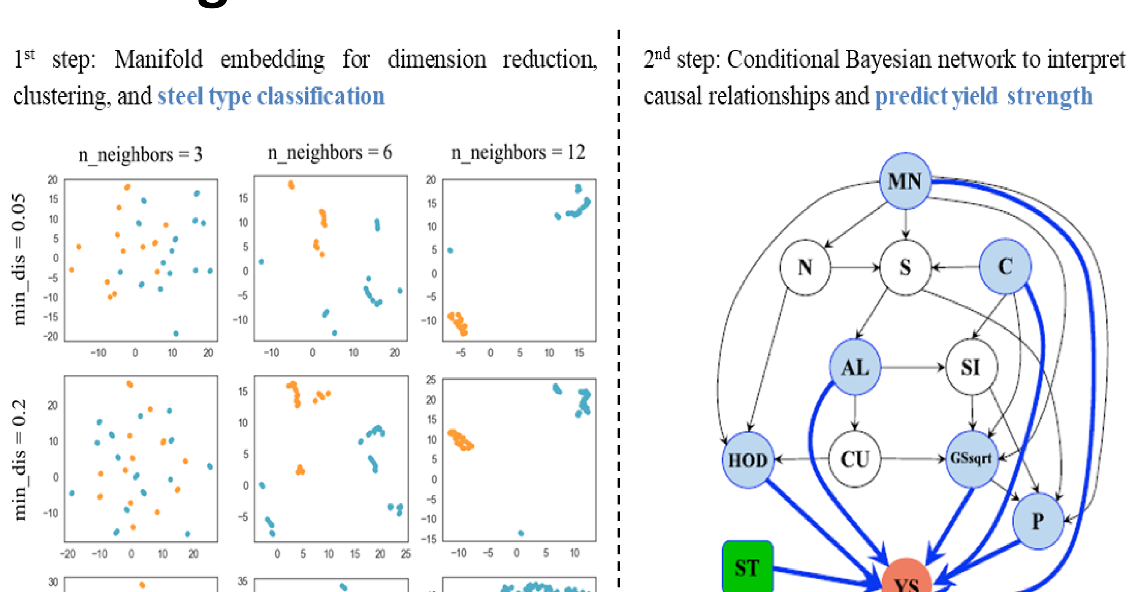


Figure 2. BCN modeling using transfer learning and data augmentation.

Project Approach/Scope

- Development of HA-FCG model and methodology for strength/HSF estimation.
- Uncertainty reduction via sequential Bayesian updating, and model-based risk assessment.
- Finally, risk-based maintenance optimization and planning for real-time decision making with reduced maintenance costs for operators.



	RMSE	MAE	R^2
LBN	3.2680	2.6158	0.7972
LM	3.1849	2.3368	0.8076
BMA	3.2371	2.4404	0.8012
CBN-kNN	3.1839	2.2229	0.8075
CBN-UMAP-kNN	3.2302	2.2839	0.8019
MCBN (CBN-UEK)	2.7554	2.0745	0.8559

Figure 3. Manifold-based conditional Bayesian network for strength estimation [1].

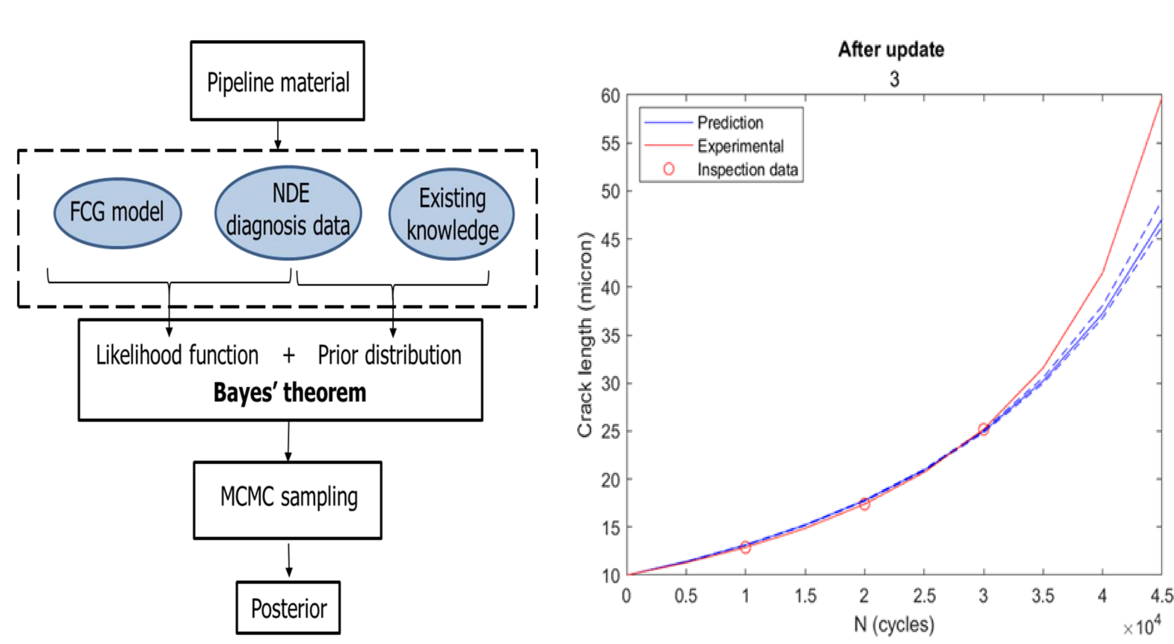


Figure 4. Sequential Bayesian updating methodology and demonstration.

Results to Date

A good agreement between experimental FCGR data and model predictions is observed. Assuming 2 cycles/day, decades will be needed for crack advancement. However, synergistic effect of various defects shows a state of concern. Residual stresses tend to increase the operating stress ratio and general corrosion can act as stress riser, thus promoting hydrogen accumulation. Exact mechanism and behavior needs further investigation before arriving at a strong conclusion.

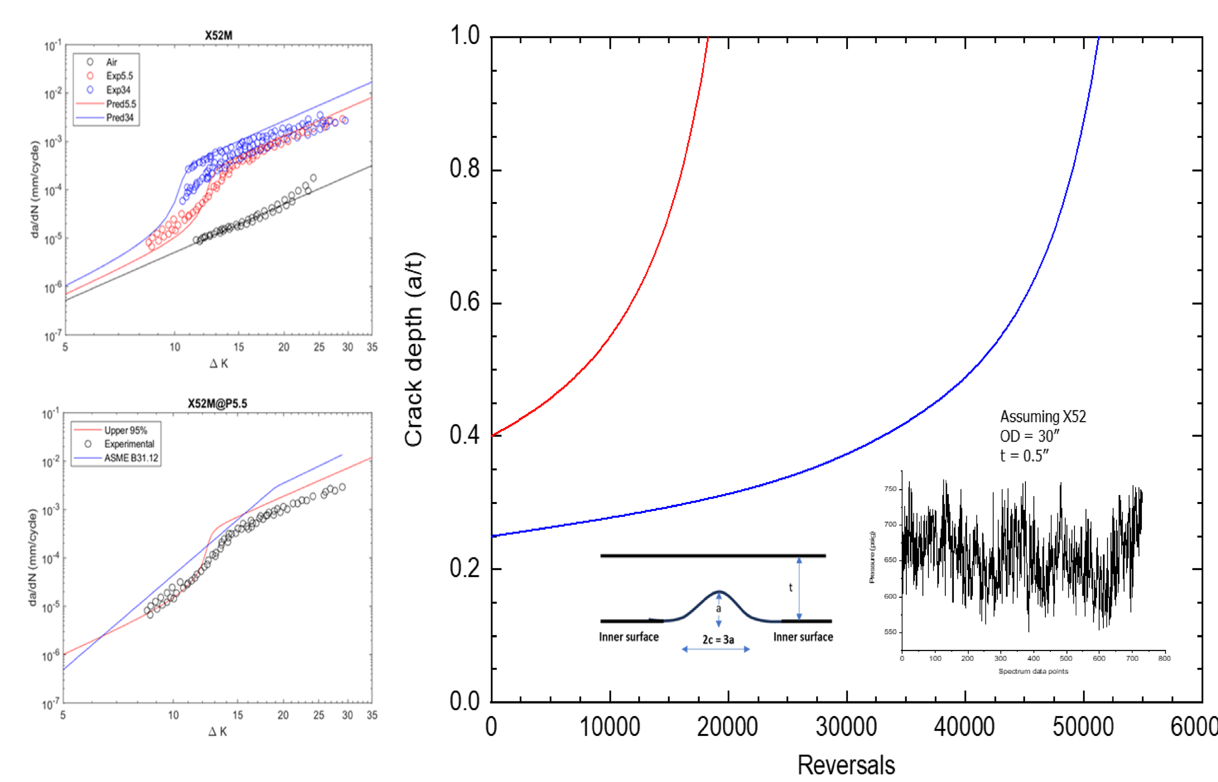


Figure 5. HA-FCG model predictions (left) [2] and life estimation for pipe with semi-elliptical crack under random loading (right).

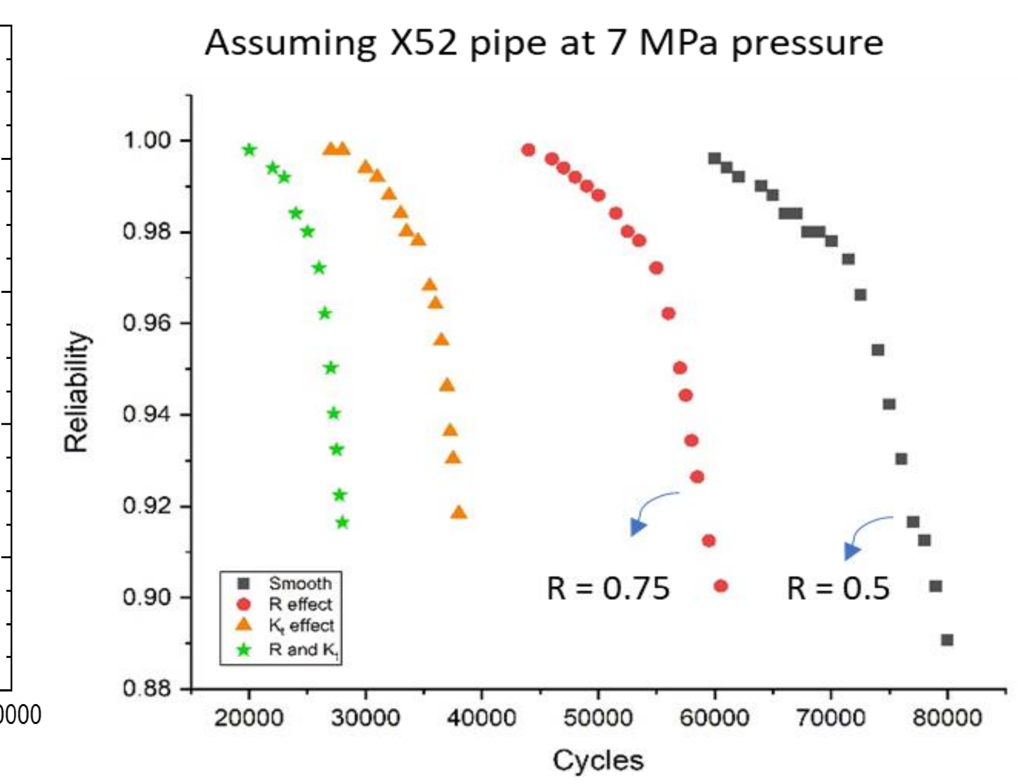


Figure 6. Risk assessment results under various scenarios in an X52 pipe (demo).

Acknowledgments

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References

[1] Zhang, Q et al., (2022). Manifold-based Conditional Bayesian network for aging pipe yield strength estimation with non-destructive measurements. RESS.

[2] Amaro, R. L et al., (2018). Development of a model for hydrogen-assisted fatigue crack growth of pipeline steel. Journal of Pressure Vessel Technology.

[3] Kethamukkala, K et al., (2023). Crack growth-based life prediction for additively manufactured metallic materials considering surface roughness. Int J Fatigue.

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