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Minimising pipeline leaks and maximising operational life by application of machine learning at Cooper Basin

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ABSTRACT

The development of technologies in the last few decades has enabled operators to collect significantly more data than previously possible. Despite availability, making data-driven decisions on asset health, and developing efficient asset management strategies, is not common. This is mainly due to challenges with compilation, and alignment of all the data into a comprehensive picture of pipeline integrity, as it consumes significant resources deploying conventional methods. A critical advantage of modern data storage, analysis and visualisation techniques is the relative ease of performing statistical assessments of integrity data. Analysis of correlated data can be equally challenging as algorithms used can be overly simplistic and inaccurate. Machine learning algorithms parse, analyse and learn from data, enabling the operators to make an educated decision. This has been extensively deployed in other industries such as finance, healthcare and supply chain management but has never been fully developed and enhanced in pipeline integrity industry until very recently. This paper provides an overview of the development in machine learning tools in pipeline integrity, allowing enhancement of asset performance, through the application of machine learning and automation, to predict integrity threats, and prevent leaks and failures. It provides a case study where a tool was developed, and this technique was successfully implemented across a significant number of upstream pipelines in the Cooper Basin, enabling the Santos integrity engineering team to make the most effective decisions on asset condition and to develop a data-driven asset management plan.

Keywords: artificial intelligence, corrosion, cost, in-line inspection, machine learning, pipeline integrity, remaining life.

Introduction

Industry surveys (DNV 2020) suggest human resource and skill shortages have remained as the main challenges in the oil and gas industry. The development of technology in pipeline integrity and specifically in In-Line Inspection (ILI) enabled operators to collect significantly more data than previously possible. The conventional analysis approach are resource intensive, have limited application, and are unable to integrate and use all available information and data. As a result, the new inspection data is not often correlated effectively with past inspection data increasing the uncertainty and cost, and also risk of failure (Khalilpasha 2021).

Artificial intelligence, machine learning and deep learning

Machine Learning (ML) is a subset of Artificial Intelligence (AI), designed to learn on its own, with minimum human intervention. A typical approach to ML might be to start with a training set of labelled data in which, for a given set of inputs, the answer or result has already been determined. Tools based on ML are well suited to problems such as pipeline integrity management that involve ‘big data’, where the scale of a dataset is too large for any comprehensive manual approach to be practical. Manual data analysis can often consider only a limited scale or subset of the available data and often involve filtering a dataset down to a scale where a human analyst can manage it. These modern analytical tools allow for incorporation of more of the available data into decision-making and business intelligence (Petrov *et al.* 2020).

This paper presents how ML was successfully implemented across a significant number of upstream pipelines in the Cooper Basin enabling Santos' integrity engineering team making the most effective decisions on asset condition and to develop a data-driven asset management plan.

Application of ML to assess integrity of Cooper Basin pipelines

Santos operates a significant number of pipelines in Cooper Basin. The pipelines in this study carry gas and condensate with a variety of material grade, sizes, length and other physical properties. Santos performed a significant amount of inspection on these pipelines using different ILI technologies through multiple vendors and direct examination tests using Non-Destructive Testing (NDT) methods such as Phased Array Ultrasonic testing. Given the historical data and complexity of manual handling of the ILI information, a solution was developed to enhance the data integration and alignment across multiple ILIs as shown in Fig. 1. This resulted in three main pillars, labelled the Ingestion Algorithm, Cognitive Learning and Business Intelligence.

Ingestion algorithm

The data ingestion algorithms are based on a Bayesian classifier trained on data from over 5000 ILI reports, and more than 50 million anomaly indications that have been gathered from existing operators currently utilising the tool in Australia (OneBridge Solutions 2021*c*) internationally (OneBridge Solutions 2020*a*, 2021*a* 2021*b*, 2021*d*). The solution interprets ILI vendor report format and normalise into structured dataset and schema.

The ingestion process also extracts the semantic meaning of vendor anomaly type and comment information into a standardised alias taxonomy, classification, category and type structure. Again, data science is critical here. It can observe patterns in the data to, for example, extract the word 'dent' from the comment field, tag the record, and update its alias to reflect this, while maintaining the original user classification. The identified feature can now be used in 'corrosion' with 'dent' interacting with the threat algorithm.

Automated girth weld alignment and anomaly alignment identifies geometric patterns in the data, which can then be used to infer the most accurate matching of like features across independent datasets, including flow reversal where the values reported in one dataset are inverse with respect to another. The result is a spatially normalised representation of the data, which supports growth analysis and integration of data from otherwise independent systems.

Cognitive learning

The tool leverages ML and applies an approach based on data science to the challenges of ingesting and normalising a wide variety of integrity datasets such as ILI, Geospatial Information Systems (GIS), asset data, Cathodic Protection (CP) survey (OneBridge Solutions 2020*b*), Non-Destructive Evaluation (NDE), and repair data into a standardised structure which can then be aligned and analysed.

Algorithms based on pattern recognition are applied to these datasets first to identify and spatially align the mutually visible features present in each dataset such as block valve locations, and girth welds, down to the

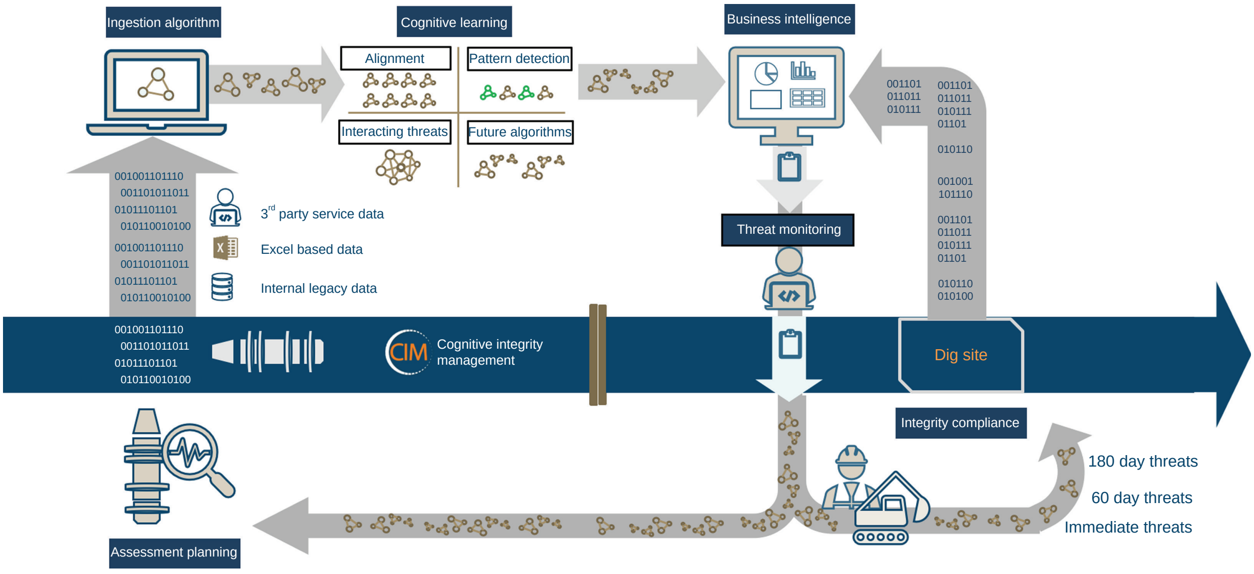

Fig. 1. Main characteristic parameters of the ML Solution (courtesy of OneBridge Solutions 2022).

individual geometric patterns of corrosion and ILI features. This enables the solution to identify and analyse how specific features are changing over time and supports the development of a comprehensive corrosion growth model.

A pit-to-pit depth comparison based on measured wall thickness over time is used to determine a unique corrosion growth rate for each active anomaly in the pipeline system. This is one of the most accurate and least conservative methods for calculating corrosion rates.

Business intelligence

The insights resulting from cognitive learning and algorithmic processing of pipeline integrity data are then combined into a comprehensive analytical data model that supports business intelligence queries and advanced analysis capabilities.

Discussion/results

The analysis was performed on more than 500 sets of inspection data including ILI and direct examination reports. The assessment outcome was used to calculate the remaining life and develop integrity management program across more than 50 flowlines. The results showed a significant benefit of using ML in three areas including saving on time, cost and enabling Santos to prevent failure using the predictive analytics.

Time saving

The assessments were completed in 3 months averaging a pipeline every 1.2 days. This is significantly more time effective in contrast to conventional methods of 2–4 weeks per pipeline, reducing the assessment timeline by a factor of

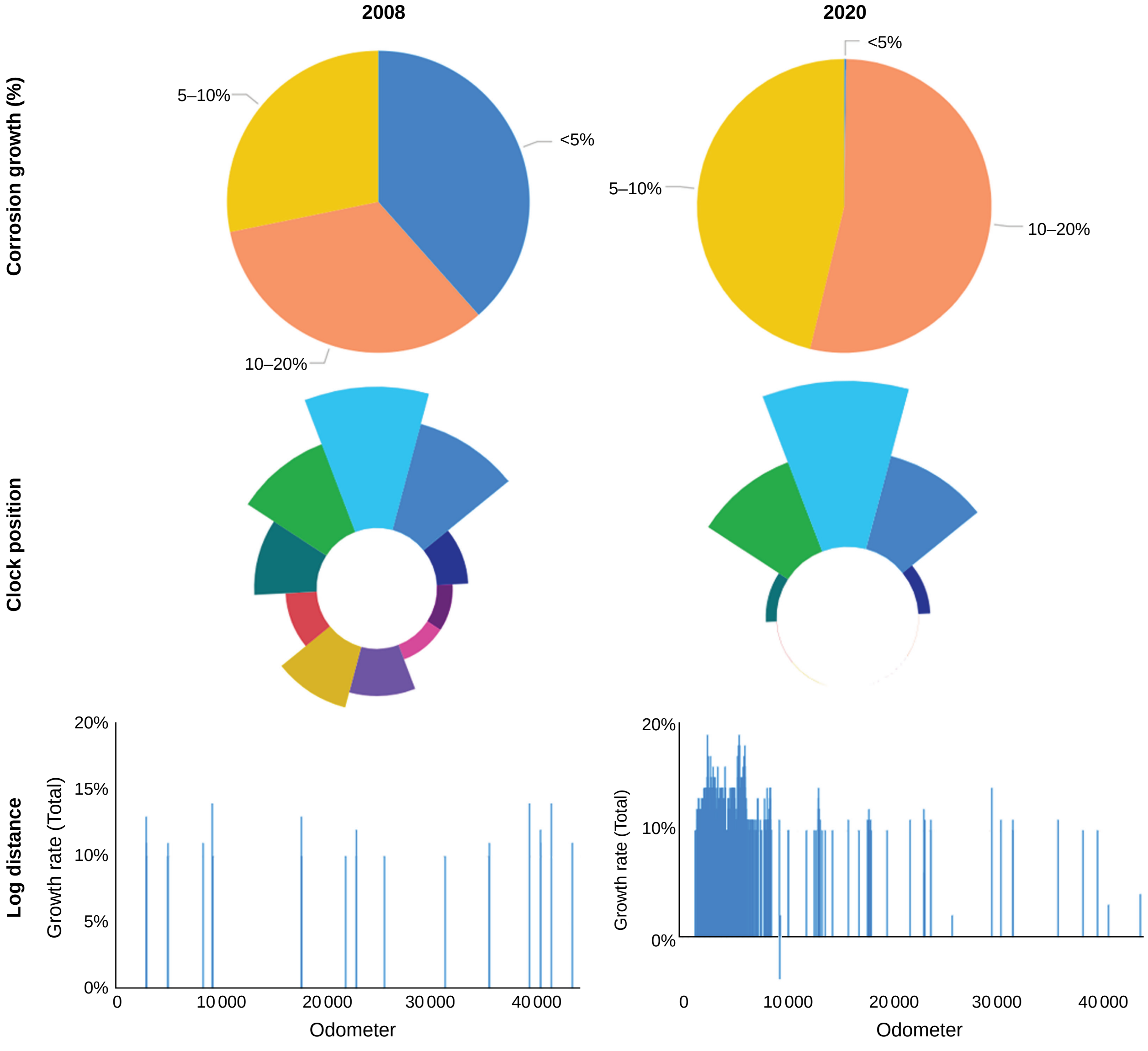

Fig. 2. Flowline with two inspection and associated data.

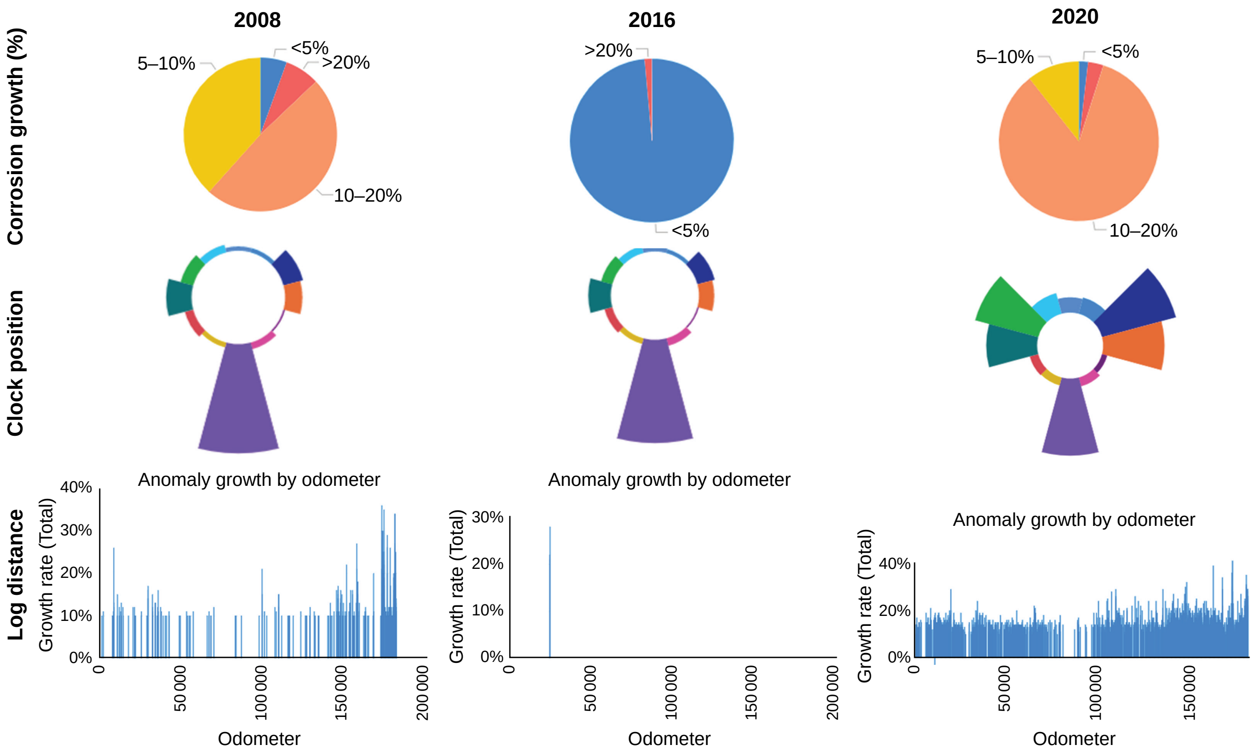

Fig. 3. Pipeline with three inspection and associated data.

8–16. The time saved on the assessment has allowed the Santos' integrity team to dedicate their effort to manage the integrity issues well ahead of time and dedicate the integrity department's time to plan for inspection, repair and revising corrosion management strategies where required.

Cost saving

The assessment tool uses a pit-to-pit corrosion rate calculation method which is one of the most accurate assessment methods, removing multiple layers of conservatism from traditional calculation methods such as using flat rate corrosion rate based on highest corrosion growth rate. This is enabled by utilising ML and data analytics where pipeline features are aligned, and patterns are recognised through comprehensive algorithms trained by more than 50 million anomaly indicators gathered from previous analyses. As a result, the number of dig ups and repair has significantly decreased by a factor of 5–10 in some cases. Furthermore, this has enabled the integrity team to identify the most critical anomalies to attend to prevent any future interruption in production. The combination of the two has reduced the cost of pipeline integrity significantly.

Preventing failure using predictive analytics

The analysis leveraged pattern detection capabilities trained through ML, which enabled Santos to proactively manage pipeline integrity. Figs 2, 3 show two examples of pipelines.

Fig. 2 is an upstream gas pipeline with top-of-the-line CO_2 corrosion as main integrity threat. The analysis has demonstrated a future pattern of failure at the immediate start of the pipeline between the two ILIs attributed to the change of operational condition between two inspections. As a result, a strategy was developed to prevent further progression of this pattern. If this had been left for too long, this pattern could potentially result in leak, failure and ultimately loss of production and not to mention the CAPEX cost for replacing a significant section of the pipe.

Fig. 3 shows another example where an oil pipeline was assessed. The pipeline has been inspected three times using Axial Magnetic Flux (MFL) technology in 2008 and 2016 and Ultra MFL in 2020. The analysis leveraging its pattern detection capability identified bottom of the line corrosion due to Microbiologically Influenced Corrosion (MIC). The assessment showed a progression of MIC from bottom of the line all the way to the full circumference, which indicated an ineffective corrosion management strategy. This enabled Santos to invest in the right area by revisiting the corrosion management strategy to prevent future interruptions and maintain the integrity.

Conclusion

This paper presented how ML can be used in pipeline integrity engineering using a newly developed ML-based tool.

Using ML, the paper demonstrated how an integrity engineer would be able to:

- Review all the anomaly and feature data on entire pipeline system.
- Gather insights from interacting threats and pattern detection, rather than relying on single data points.
- Gain visibility into the entire pipeline – bubble up and drill down into the finest level of detail.

The assessments found that utilising ML can significantly decrease assessment time by a factor of 8–16, and cost by a factor of up to 10. Furthermore, utilising ML to align inspection data and identify the future patterns have allowed a change of integrity management strategy from reactive to proactive to prevent failure.

References

DNV (2020) 'New Direction, Complex Choices, the Outlook for the Oil and Gas Industry in 2020.' (DNV: Oslo)

Khalilpasha H, Edward T (2021) Pipeline Integrity in the era of machine learning and artificial intelligence. Houston, USA, s.n.

OneBridge Solutions (2020*a*) Consumers energy advances digital transformation with OneBridge Machine Learning Solution. Available at https://www.onebridgesolutions.com/about/news/onebridge-news-december14_final/ [Accessed 15 March 2022]

OneBridge Solutions (2020*b*) White Paper. Available at https://www.onebridgesolutions.com/learn/case-studies-resources/data-integration/ [Accessed 08 February 2022]

OneBridge Solutions (2022) OneBridge Solutions. Available at https://www.onebridgesolutions.com/ [Accessed 15 March 2022]

OneBridge Solutions (2021*a*) Another large U.S. gas pipeline company adopts OneBridge's Machine Learning SaaS Solution. Available at https://www.onebridgesolutions.com/about/news/another-large-gas-pipeline-company-adopts-onebridge-solutions/ [Accessed 15 March 2022]

OneBridge Solutions (2021*b*) Large U.S. pipeline company adopts OneBridge's Machine Learning SaaS Solution. Available at https://www.onebridgesolutions.com/about/news/large-us-pipeline-company-adopts-onebridge-machine-learning-saas-solution/ [Accessed 15 March 2022]

OneBridge Solutions (2021*c*) OneSoft and Advisian enter into teaming agreement and initiate first CIM project with Australian Pipeline Company. Available at https://www.onebridgesolutions.com/about/news/onesoft-and-advisian-teaming-on-cim-project/ [Accessed 15 March 2022]

OneBridge Solutions (2021*d*) U.S. Midstream energy leader adopts CIM Machine Learning Solution to augment its pipeline asset management system. Available at https://www.onebridgesolutions.com/about/news/us-midstream-energy-leader-adopts-cim-machine-learning-solution/ [Accessed 15 March 2022]

Petrov Y, Dubuc J, Murray MG, Edward T (2020) Statistical analysis of dig operations leading to productive repairs. In 'Pipeline Pigging and Integrity Management Conference' Marriott Marquis Hotel, Houston, USA, s.n. 11p. Available at https://www.onebridgesolutions.com/files/Statistical%20Analysis%20of%20Dig%20Operations%20%E2%80%93%20PPIM%202020%20White%20Paper.pdf

Data availability. The data that support this study cannot be publicly shared due to ethical or privacy reasons and may be shared upon reasonable request to the corresponding author if appropriate.

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Justin Brown is an experienced Engineer with 17 years' experience in the oil and gas industry. He possesses in-depth knowledge across the whole life cycle of pipeline asset management from concept and design through to construction, operation and integrity management. Justin currently is a Senior Integrity Engineer with Santos and has worked for a multitude of both Australian and international companies in various roles where he has honed his craft ensuring safe, reliable and sustainable operation of oil and gas assets.