Pinnacle eBook

Reducing Lifecycle Spend by Leveraging Advanced Image Analytics in Asset Integrity Programs

This eBook will illustrate how image analytics can help you reduce waste and costs by minimizing the overall variability and uncertainty in external corrosion due to human subjectivity in inspections.

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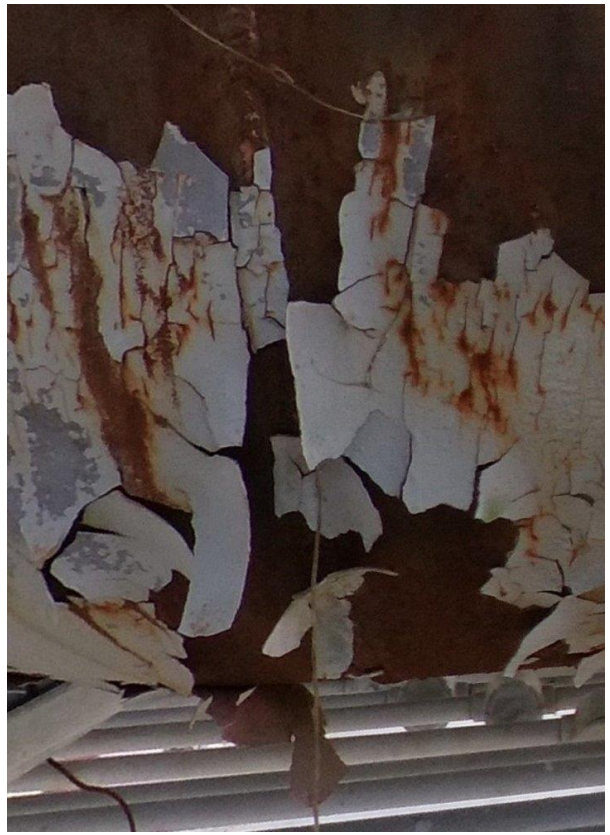
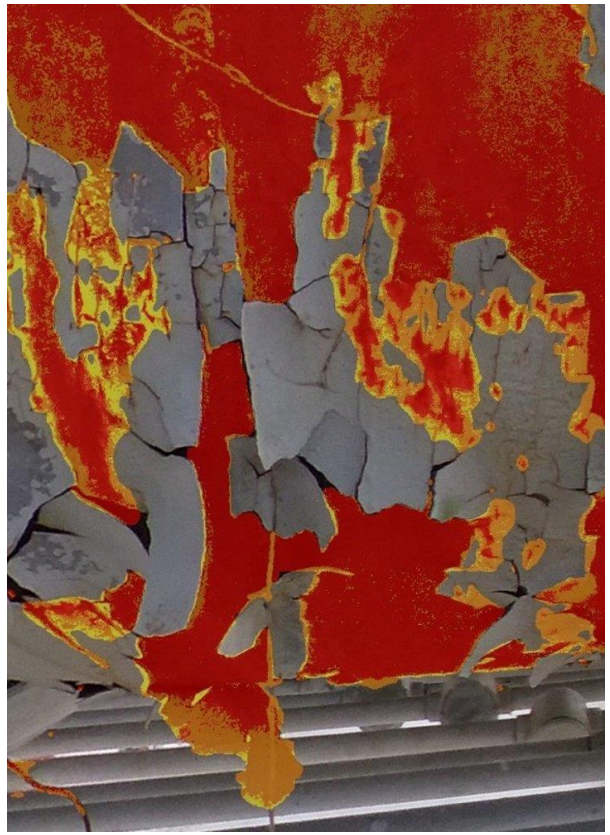
Impact of Imaging Analytics in Corrosion Management

Corrosion management, inspection, and reliability forecasting play a key role in financial planning as well as safety and reliability management.

With annual corrosion costs estimated at billions of dollars, cost-efficient and robust corrosion assessment and mitigation approaches are required to prevent asset failure and downtime.

However, switching from reactive to proactive corrosion management creates a need for excessive amounts of data collection, processing, and interpretation, making the adoption of Robotics, AI, and other emerging technologies a key priority.





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Inspection Challenges

Often, when an inspector completes an inspection, they only spend 40-50% of their time in the field actually completing the inspection activity. The remaining 50% of their time is often spent gathering the documentation, creating the work package, identifying the location, and other administrative tasks.

Human subjectivity also impacts the quality of inspections. For example, an inspector may go into the field and make a recommendation to code align to a damage mechanism. However, even if missing paint and light surface oxidation is observed during an SME review, the SME's recommendation may not result in a direct action to address those issues.

Computer imaging software and image analytics can help eliminate this human subjectivity.

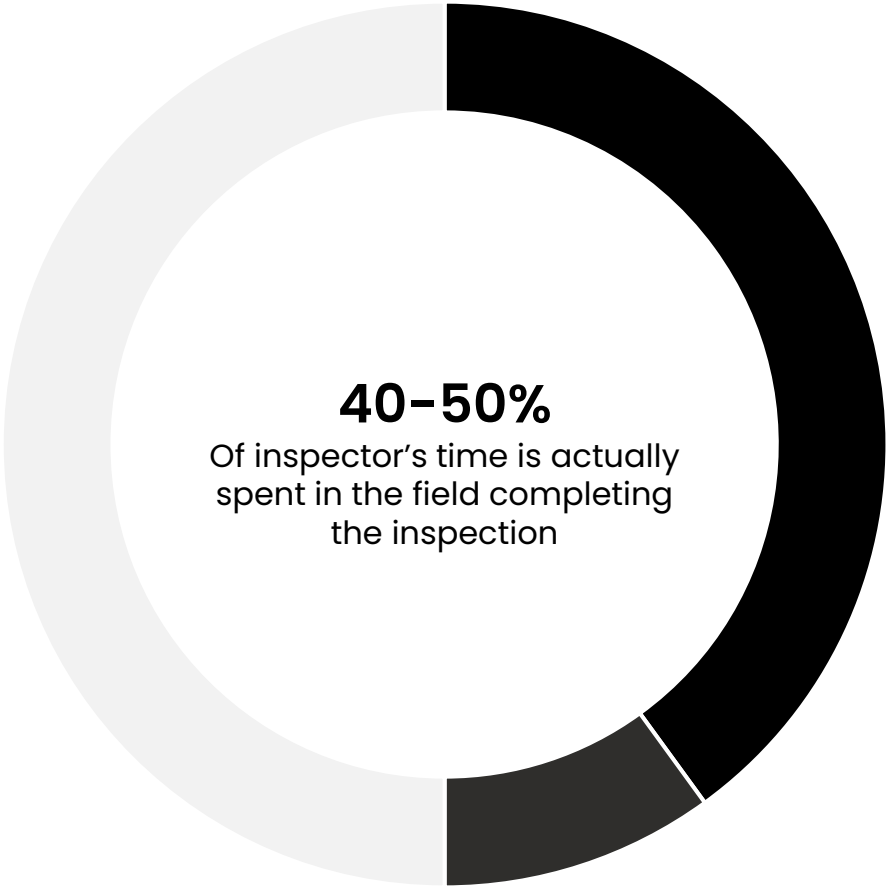

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Image Analytics
Proof of Concept (POC)

Two facilities with limited resources and tight inspection schedules were looking to create efficiencies to reduce costs and create staffing efficiency. Pinnacle teamed up with SoftServe, a global, cutting-edge software and technology company, to pilot an image analytics proof of concept (POC) and build the computer vision algorithms needed to investigate how panoramic or 360-degree handheld images with corrosion labels can be used to train a machine learning (ML) model to automatically detect corrosion and calculate corrosion coverage.

The goal of this POC was to prove the feasibility and business value of a computer vision-based approach for detecting and classifying three severity classes of corrosion on panoramic images taken by handheld cameras during a facility inspection.

Further piloting, development, and scaling of the solution can bring business value by:

- Inspection automation
- Data-driven decision making
- Assets monitoring and forecasting
- Operations planning

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Workflow

Phase 1 Photo Collection
Images and videos were collected in the field using a Ricoh Theta Z1 360-degree camera. Equirectangular images with 6720x3360 resolution were gathered to conduct the analysis. Equirectangular images are single images stitched together from a 360-degree horizontal and 180-degree vertical view.

Phase 2 Photo Preparation for Model Processing
Pinnacle used online tools for manual object labeling for inspections. Each photo was saved with metadata including circuit, photo ID, labeled objects, and asset tags for mapping.

Phase 3 Corrosion Detection
As part of a labeling workshop, the Pinnacle and SoftServe teams developed image analytics to evaluate distribution and calculate the statistics of coating damage and corrosion. SoftServe tested several fully convolutional networks for corrosion segmentation with the UNet-like architectures. During the hyperparameter tuning process, SoftServe tested several parameters of the segmentation pipeline, such as model architecture, model encoder, loss function, number of epochs, batch size, input size, and image input method. This allowed the teams to find the optimal configuration of the pipeline.

Phase 4 & 5 Report and Results Preparation and Feedback
The teams built a report that outlined the chosen approaches and techniques for building the pipeline and incorporated the results of the POC with the provided conclusions and potential improvements for future development.

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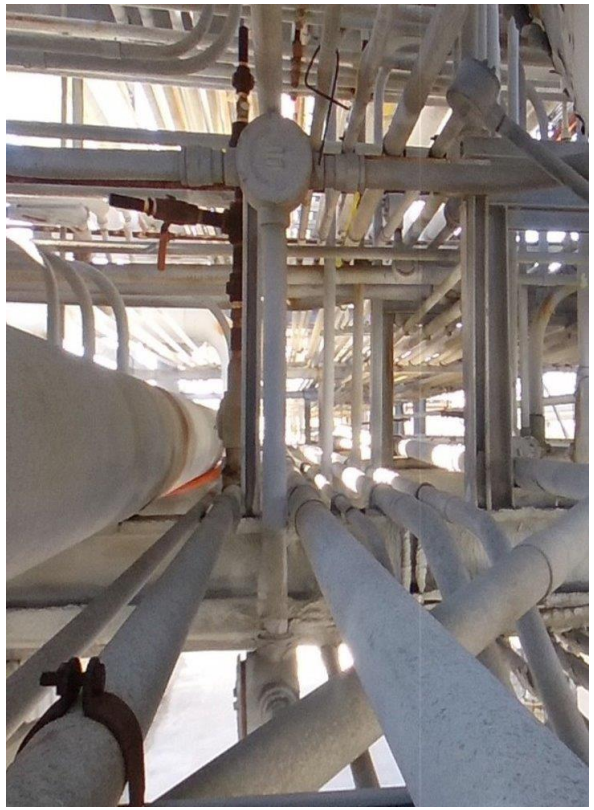
Corrosion Segmentation Results

Segmentation results are promising, and preliminary results show that machine-segmented images largely agreed with human annotations, even with limited training data.

However, it's important to note two things:

1. Attention must be paid to the difference between false positives and false negatives.
2. There can be disagreement between human annotators, and it is possible for people to miss corrosion.



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Heatmap: Conceptual View

This POC created a heat map to identify areas of interest. It can pull up the associated image along with your GPS coordinates and give a graph percentage of what kind of damage it sees. Here's an example of a conceptual view of a heatmap. All images with GPS coordinates are plotted on the actual facility satellite view as circles. The relative size of the circle corresponds to the relative area of the corrosion compared to non-corroded are on the image. Color is responsible for the most popular type of corrosion found on the image.

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Imaging Results: Facility #1

Image analytics can help us standardize corrosion detection and drive the right actions to optimize costs and resources. At the conclusion of the POC, each facility received:

Corrosion Segmentation Model:
This model outlines the detection of corrosion and rust stains on images taken by a panoramic camera.

Texture Classification ML Model:
This model outlines the detection of paint defects, rust staining, light, and severe corrosion on close-up images of the stationary equipment.

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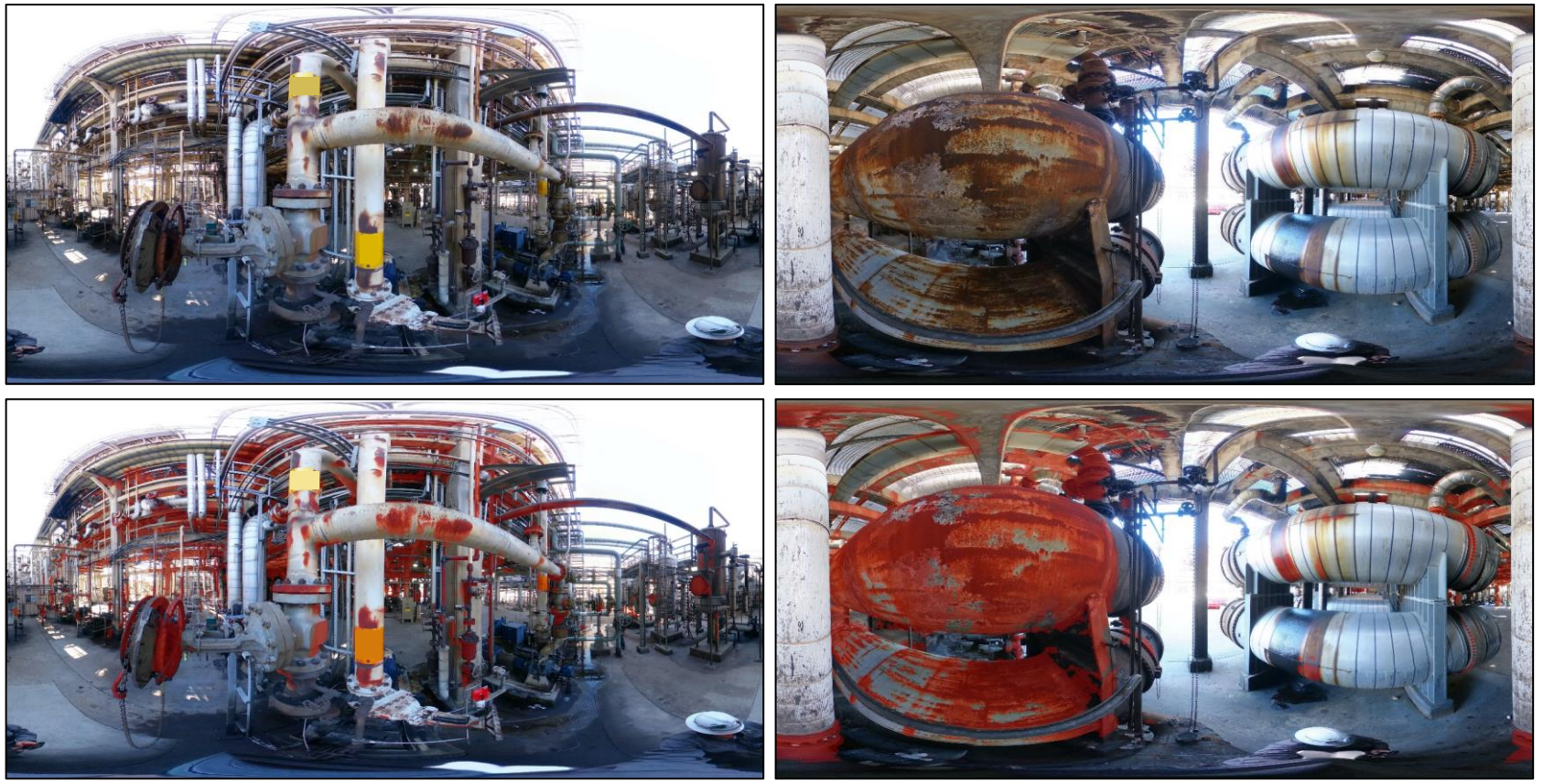
Imaging Results: Facility #2

User Interface (UI)

Browser application hosted on the secured virtual machine (VM), allowing users to tune processing parameters, run ML models in real-time on the selected images, and see the big picture on the map.

Technical Report

The report outlines the chosen approaches and techniques for building the pipeline and incorporates the results of the main experiments with provided conclusions and potential improvements for future development.



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Results

Ability to Generalize & Scale

The model is consistent in the cases from the new facility, which are similar to the data it was trained on. The model is less accurate in the cases from the new facility, which exhibit differences in appearance and catches most of the visible corrosion, even its light forms.

Robustness

The model is sensitive to changes in lighting conditions. Using simulated data did not significantly help.

Solution

The solution consisted of forming a diverse validation dataset from different facilities and conditions to ensure the model is stable. The solution also included iterative model retraining and periodic model monitoring by careful experts reviewing samples of images processed by the model.

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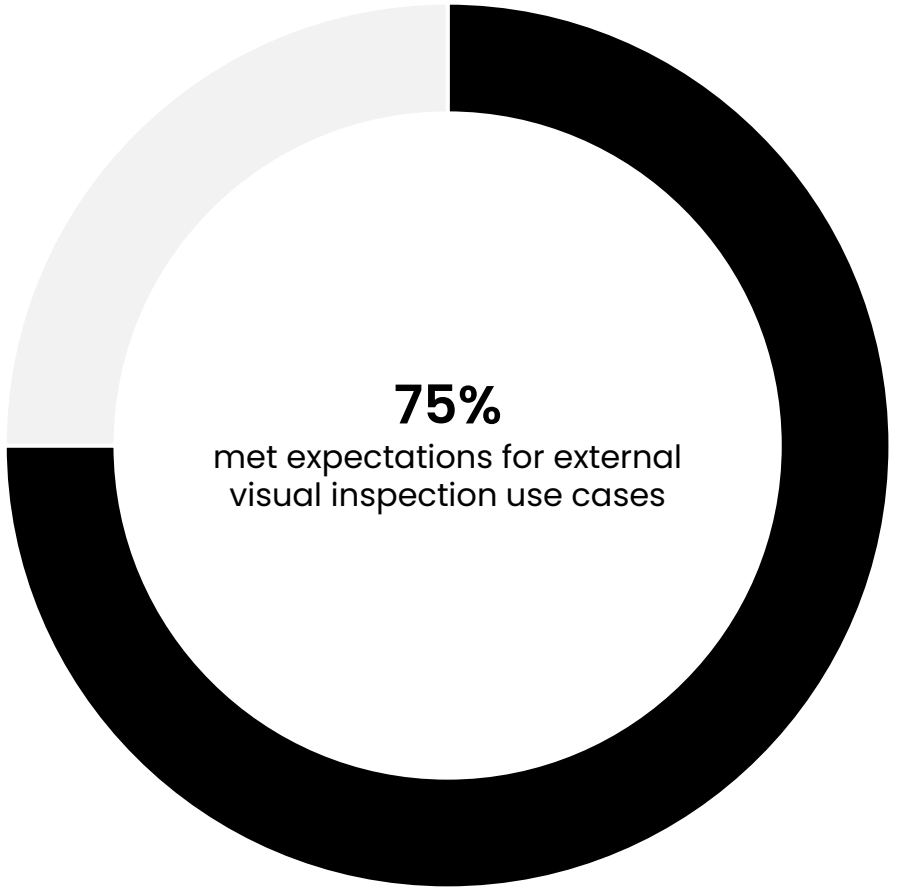
Results Validation Process

The results validation process was a semi-quantitative process with four SMEs (3 APIs & 1 NDT Tech Lead). These results were tested on images from crude units from two facilities and 75% met expectations for external visual inspection use cases.

During the validation process, areas of anomalies were manually highlighted by SMEs using the same criteria as in training set for external visuals and was compared against machine learning model results. A qualitative response on whether the machine learning model results met API expectations was also included.



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Potential Enhancement

From a visual perspective, there are three main objectives for reliable and trustworthy corrosion detection and segmentation:

1. Object on which it is detected
2. Coloring
3. Texture

No machine learning approach on its own could fully replace ultrasound scanners to estimate the depth of corrosion, but texture analysis will be able to prioritize zones and areas of more severe corrosion.

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Limitations with Computer Vision

Input information for processing is limited by what type of image was able to be taken, how the image was taken, and the conditions in which the image was taken.

Some limitations of the images include:

- The objects of interest will always be only partially visible
- Perspective will play a decisive role in the results
- Shadows, excessive illumination, occlusions, and other distortions will impact the results

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Conclusion and Takeaways

Image analytics can help facilities reduce waste and overall costs by reducing the overall variability and uncertainty in external corrosion due to human subjectivity in inspections. The cameras and computers in this POC capture everything in the frame, not just the asset that is being inspected. An inspector can capture multiple assets simultaneously and perform a basic screening in one click. From there, an SME can then evaluate it to pinpoint precisely what assets need additional attention.

The next phase of this POC is to leverage a similar solution for Thermal Corrosion Under Insulation (CUI) anomaly screening, structural anomalies, and other advanced screening methods.

Major Takeaways:

- Image analytics can help you improve your inspection plan
  - Reduces overall variability and uncertainty in external corrosion
- Image analytics limit the human subjectivity that occurs in inspections
  - Also creates opportunity for staffing efficiency and reduces wasted inspection costs
- Image analytics are a cost-effective option for conducting more accurate inspections
  - These specific cameras enable facilities to inspect hard-to-reach areas that laser scanning can't access as easily.

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Contact Us

Headquartered in Pasadena, Texas, Pinnacle is exclusively focused on helping industrial facilities in oil and gas, chemical, mining, and water and wastewater better leverage their data to improve reliability performance, resulting in more production, optimized reliability and maintenance spend, and improved process safety and environmental impact. For more information, visit pinnaclereliability.com

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