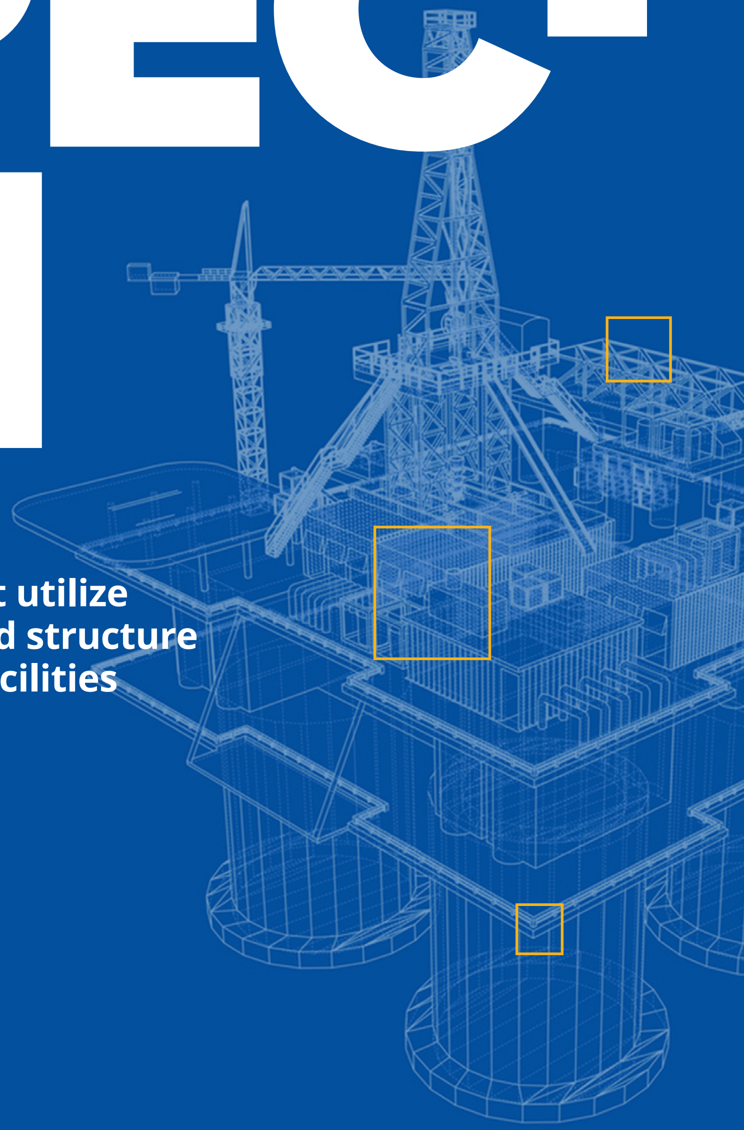
AI FOR VISUAL INSPECTION



How oil and gas companies can best utilize technology to detect equipment and structure defects in off-shore and on-shore facilities

Reading Time: 10-minute read for Managers, Directors, and Engineers of Energy Field/Site, QA/QC, Corrosion, Materials, and Maintenance

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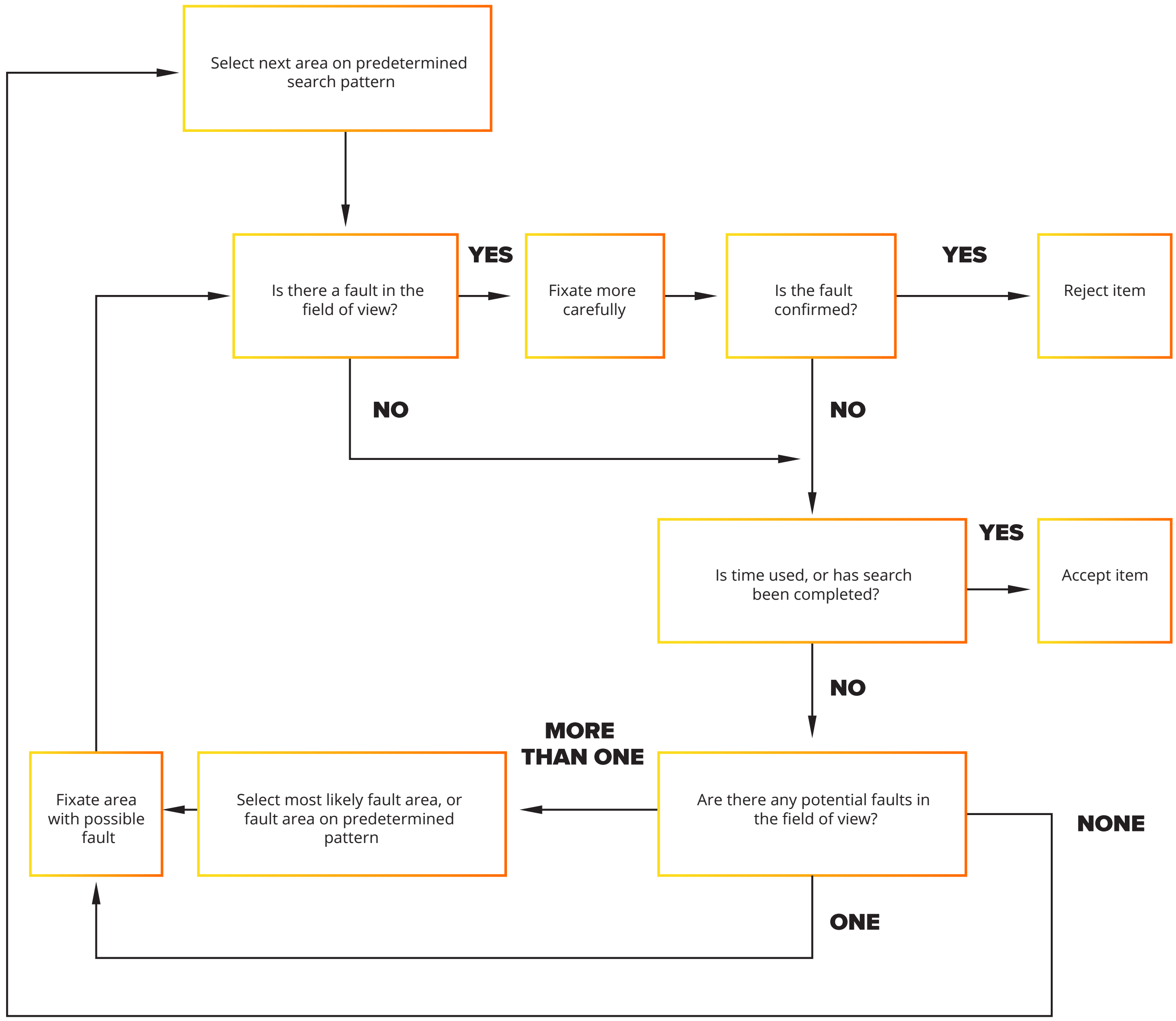
INTRODUCTION

Visual Inspection—also known as Visual Testing (VT)—is the oldest, most functional and commonly used non-destructive test (NDT) method. Trained and highly qualified visual inspectors apply competence, codes, standards, knowledge of drawings, and experience to evaluate a wide variety of both new and in-service components. Human vision can focus, scan, measure, as well as detect depth, color, and flaws with great precision. Combined with instant, cognitive abilities of the human brain, visual inspection has a very broad application. From coating and insulation defects to welding joints and structural integrity, a visual inspection can help determine equipment defects and elements' conditions.

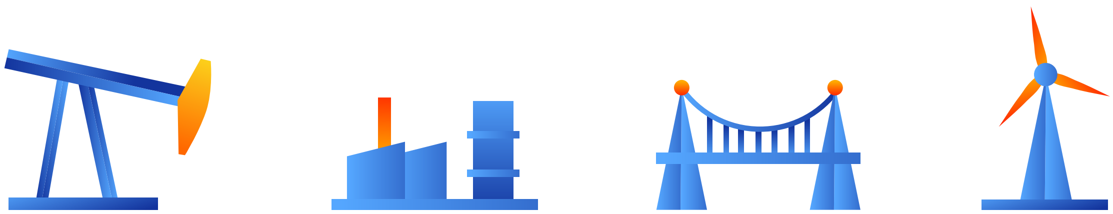
Visual Testing has its advantages and drawbacks. It's labor-intensive, expensive, and in some cases, it can be a dangerous method of inspection and asset management. Most of the time, the equipment and structural elements that need to be inspected are located in difficult-to-access locations—if humanly accessible at all. While some locations may be easily accessed, there are occasionally areas that require greater lengths of inspection time due to the amount of equipment and structural elements.



Flow chart for visual inspection ("Human Reliability in Quality Control" Taylor & Francis Ltd., 1975.)

COMMON CHALLENGES

Visual Inspection is an essential component of asset management in different industries, including: onshore and offshore oil and gas facilities, oil refineries, gas plants, power plants, solar, wind, water renewables, civil construction, chemical plants, and more.



Visual inspection expense is increased when:

- Equipment must be stopped (dry docking vessels, cooling of high-temperature furnaces, reservoir internal inspection, etc.)
- Inspection areas are larger in size (development sites and construction projects)
- There is a lack or high cost of qualified experts
- When the inspection is conducted in highly dangerous areas (hazards, zones of conflict, height, harsh weather conditions, etc.)

Additionally, there is a higher possibility of manual, visual inspection errors, which typically range from 20% to 30% (Drury & Fox, 1975).

OVERCOMING HUMAN ERRORS

Imperfections can be attributed to human error or limitations of space at the inspection site. Manual inspection requires the presence of an inspector or surveyor, who performs the assessment according to his/her judgement—based on industry standards, previous experience, and preexisting knowledge. The mistake and bias in human judgment can lead to varying conclusions by different experts. Also, human eyesight can be imprecise and easily fooled—by optical illusions—so a manual inspection defect can be either missed or incorrectly identified. In either case, significant losses occur in time, causing incorrect maintenance steps to be taken in the future.

Applying artificial intelligence (AI) models to detect cracks, corrosion, coating breakdown, and other defects on structures can reduce required working hours, eliminate manual errors, increase safety, and extend areas of inspection operations—while ultimately saving lives and protecting the environment.

In this whitepaper we present a step-by-step, multi-year vision on how to build an end-to-end AI solution for visual inspection—relevant for any inspection application.

END-TO-END SOLUTION ARCHITECTURE

First, our visual architecture for the ideal solution:

3D MAPPING

Create a 3D map of a site (interior and exterior)

- LIDAR or photogrammetry-based 3D mapping technology

IMAGE/VIDEO ACQUISITION AND LOCALIZATION

Use UAVs, ROVs or other remotely controlled or autonomous unmanned vehicles inspect the site collect and localize the media on a 3d map

- NanoMap, Monocular Camera Localization, or alternative navigation and localization technology
- Simultaneous localization and mapping (SLAM)

IMAGE/VIDEO ENHANCEMENT

Using specific AI/ML models to enhance images (Reducing blurriness, improving lighting, etc.)

- Generative Adversarial Networks (GANs)
- Convolutional Neural Networks (CNNs)

IMAGE/VIDEO ANALYSIS

Use ML models for identification (detection, segmentation, etc.) of structural elements and defects. Connect the results of structural and defects analysis to derive the condition for each structural element class

- Deep Neural Networks (DNNs)
- Conventional Computer Vision

RESULTS AGGREGATION

Aggregate multiple predictions to derive the coating condition for each unit and the site overall

- Image Stitching
- Multitask Learning
- Regression Analysis
- Conventional Computer Vision

PREDICTIVE MODELING AND MAINTENANCE

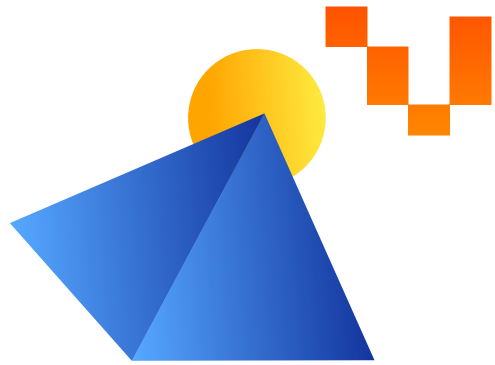
Collect the results in a time series manner to see degradation patterns and predict the future states for each area, unit and the site.

Use those predictions to plan repairments way in advance.

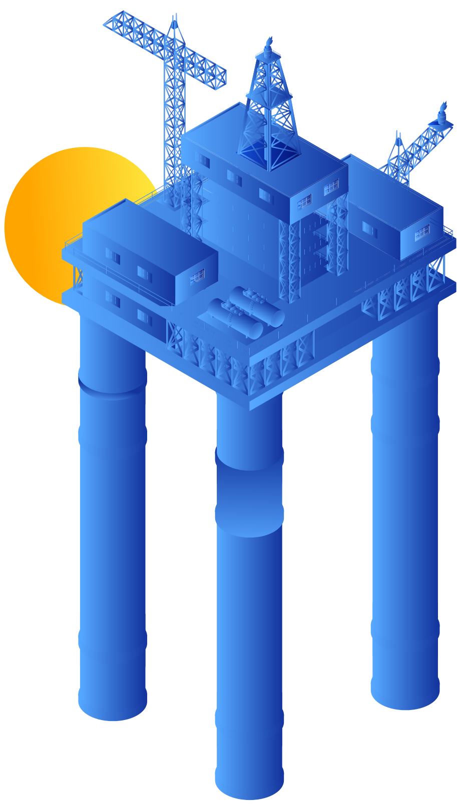
- Predictive Modeling Techniques
- Regression Analysis

STEP 1. CREATING 3D MODEL OF THE SITE

The very first step in the process is to create an accurate 3D map of the site or object under inspection. An accurate map speeds up the navigation and collection of images and videos, as well as allows defects to be tracked in real-time.



Multiple photogrammetry or Lidar based algorithm families—such as Structure from Motion (SfM) and Simultaneous Localization and Mapping (SLAM)—provide the ability to create an accurate map of intricate unknown environments.



STEP 2. IMAGE/VIDEO ACQUISITION

SLAM, NanoMap, and other efficient navigation technologies allow Unmanned Aerial Vehicles (UAV), remotely operated underwater vehicles (RoV), or other autonomous agents to navigate through a site and collect images and video.

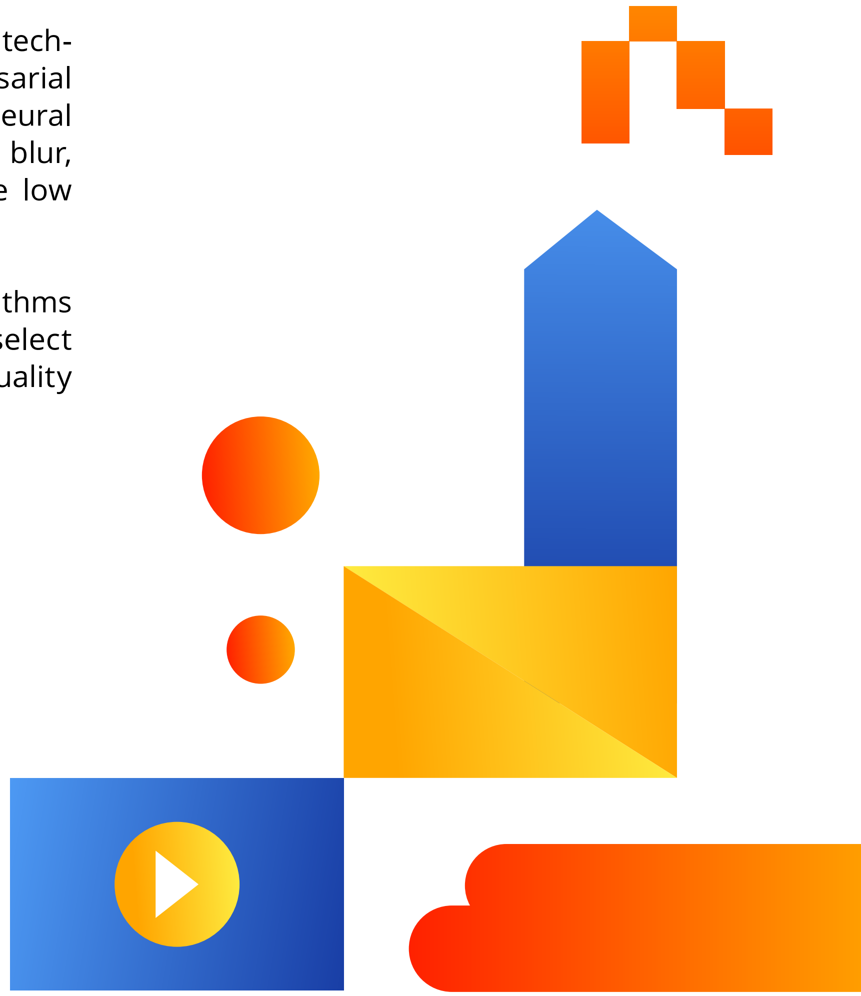
Efficient preprocessing is done on a device to reduce the amount of data being transmitted. More media is kept for areas requiring closer attention and less for those likely in satisfactory condition.

STEP 3. IMAGE/VIDEO ENHANCEMENT

Often times, inspectors, surveyors, or autonomous agents are working with limited equipment and in harsh, low-light conditions. The combination of those factors could lead to low media quality and poor prediction accuracy.

Luckily, powerful image enhancement techniques based on Generative Adversarial Networks (GANs) and Convolutional Neural Networks (CNNs) can reduce motion blur, increase image resolution, or reduce low lightning impact.

Additionally, fast image forensics algorithms can filter video files and pictures to select only the most informative, highest-quality files for detailed processing.

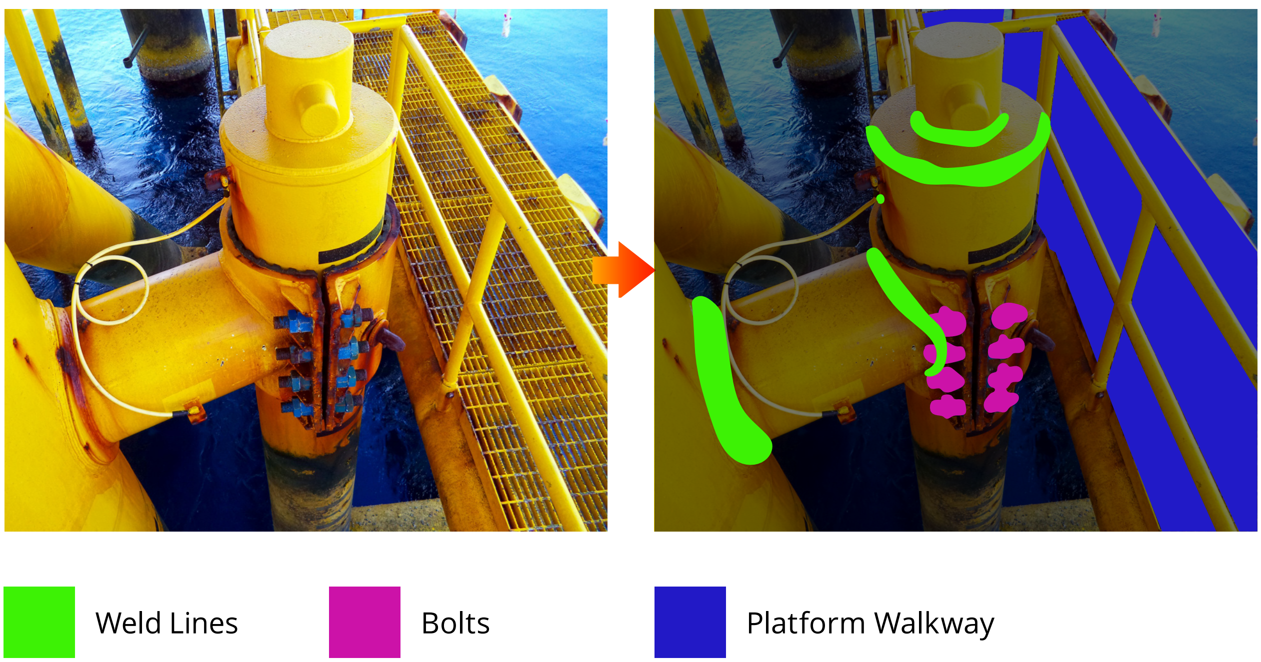


STEP 4. IMAGE/VIDEO ANALYSIS

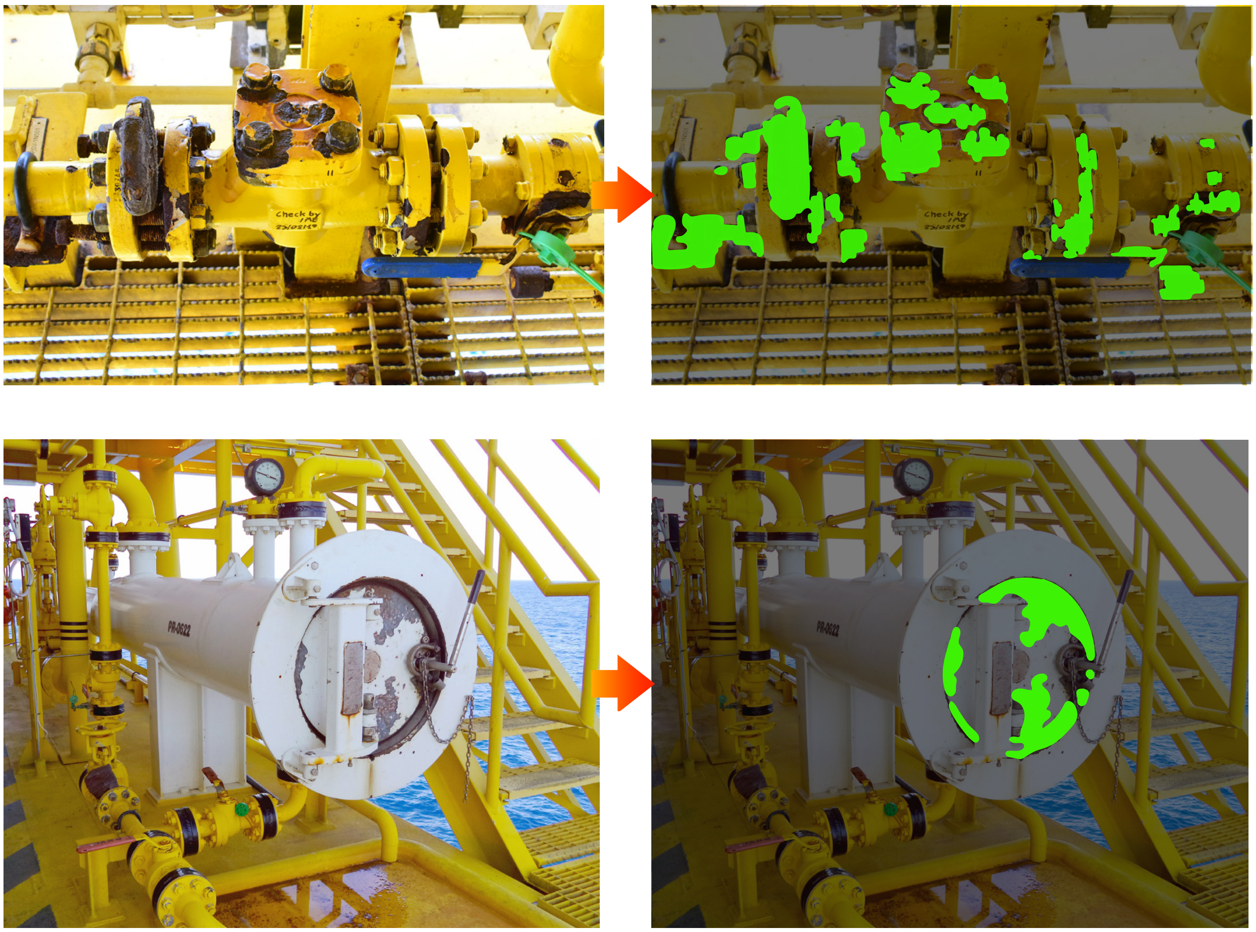
During the visual inspection, identification of defects is often not enough, as surveyors and owners need to best understand the impact of those defects on the different structural elements.

Therefore, the following approach is taken for image analysis:

1. Use conventional and deep learning (DL)-based computer vision for identification of different structural elements on images (Weld Lines, Plates, Holes, Edges, Stiffeners, etc.)

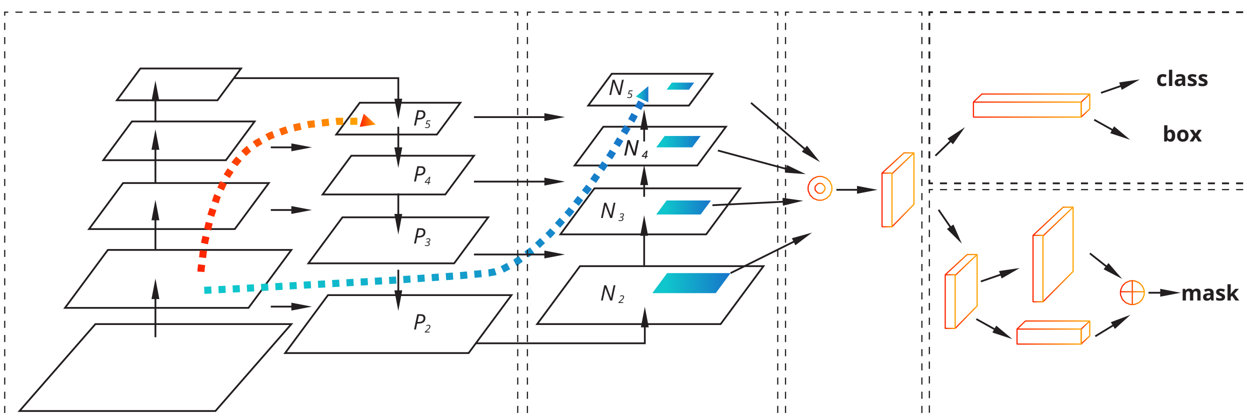


2. Use DL for detection and segmentation of different structural faults and coating failures



Tech Note: Feature-Pyramid Networks are best fit for defects segmentation, as they are doing a great job in handling objects of different scales.

Such NN (neural network) architectures as ESPNet, PSPNet, FPN assure the best trade-off between segmentation quality and computational recourses, so most of the models could be deployed even on mobile devices.



3. Combine results from the first two steps to assess the condition of each class of structural elements.

STEP 5. RESULTS AGGREGATION

After media analysis, it's crucial to derive the state of the separate units and site overall.

Image sticking techniques are useful to remove overlaying areas and create composite panoramic images from multiple pictures and videos.

Regressive analysis and multitask learning help to aggregate results from composite images for larger units and site overall.

STEP 6. PREDICTIVE MODELING AND MAINTENANCE

Individual media, composite images, and aggregated results are localized on the 3D map and organized in a time-series format.

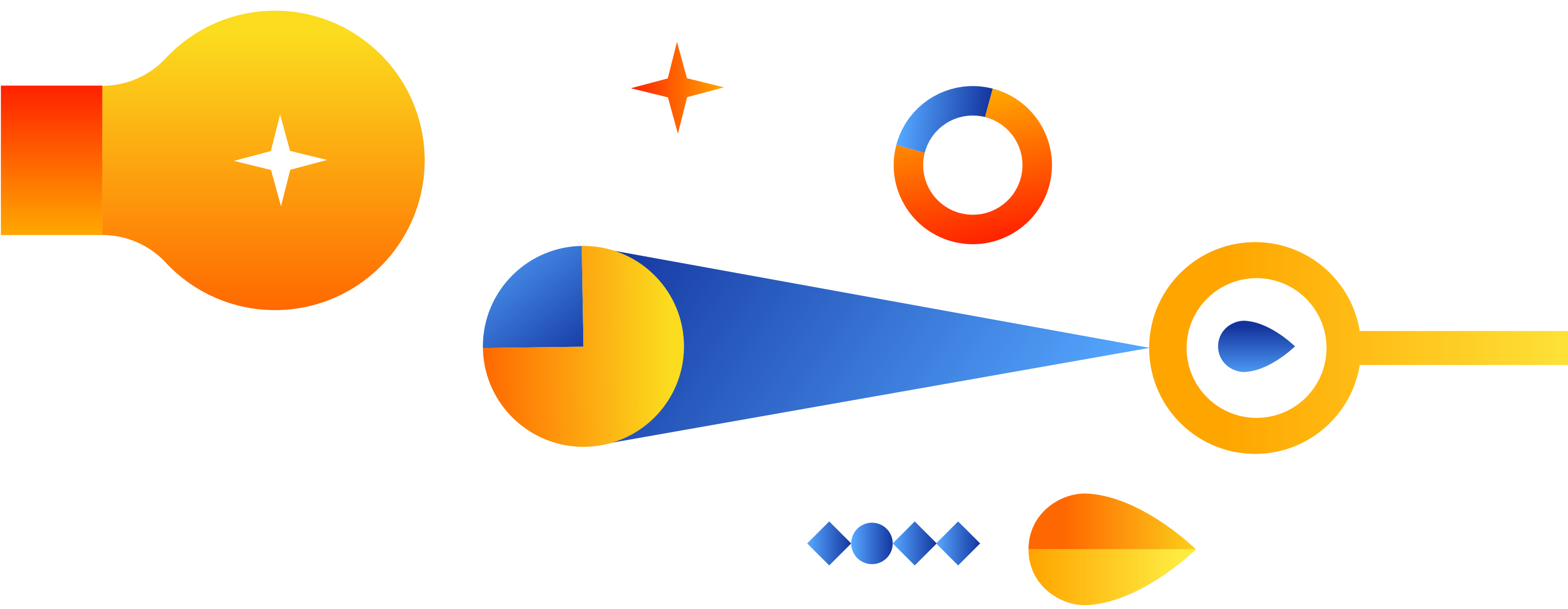
With a growing number of historical data samples, predictive modeling applied to unravel new insights, such as structures' deterioration rate, forecasted conditions, and future required maintenance.

The insights collected can be integrated into the assets management system and widely spread through the company, allowing businesses to plan their operations, maintenance schedules, and costs way in advance. Such a proactive position leads to production optimization and cost cuttings as well as significant improvements in the safety of personnel and assets.

DATA AND MACHINE LEARNING ALGORITHMS ARE KEY CHALLENGE

Magic wouldn't happen without a wizard casting a spell. Luckily—in our case—we are dealing with much more reliable Machine Learning (ML), yet probabilistic stuff. To let the ML magic happen, we need to prepare a perfect mix of algorithms, data, and computing power. With the aforementioned, it's possible to run a 'training' exercise—otherwise known as a process when the machine is trained to act as a human would in the same circumstance. The most obvious component of the mix is computing power. This is also where cloud computing serves to be the primary option. With a cloud provider, computing power and information consumption is both easily scalable and accessible.

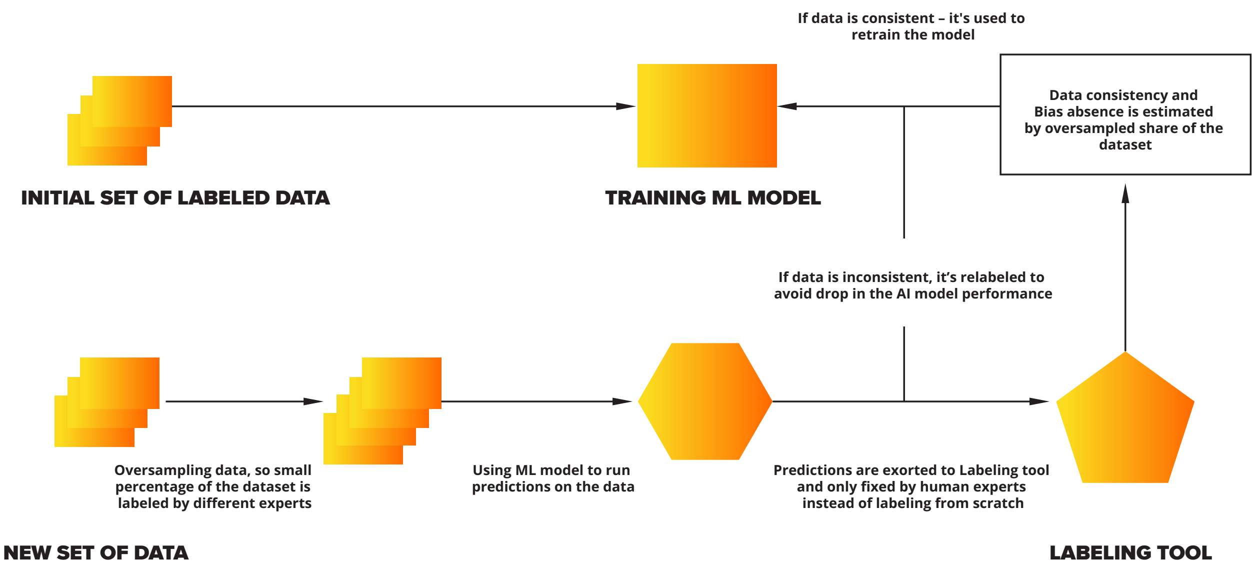
Through proven methodology and academic support, it's possible to determine which algorithm works best, what is the best way to train it, and what is the most efficient way to make it work. Although it takes some effort to adopt academic's solutions to the real world, it pays off quickly through agility, adaptive-learning, and high-performance. The last and usually most important part of the ML mix is data. In most cases there is no one to help here to ease the data acquiring process, and it's the organization's responsibility to design the process of acquiring and ingesting the right data. While algorithm and computing power impact performance (you may not be that accurate by using old approaches) or runtime (you may be a bit slow while train or predict), the data plays a critical role in the overall solution efficiency.



The very first challenge in building any ML solution is acquiring the right data, as quality and quantity of data is a crucial factor in the model success.

Current state-of-the-art approaches in machine learning (ML) allow users to extract even the most intricate patterns from the data, generalize them, and use to process new samples. However, the power of these ML models relies on properly labeled data.

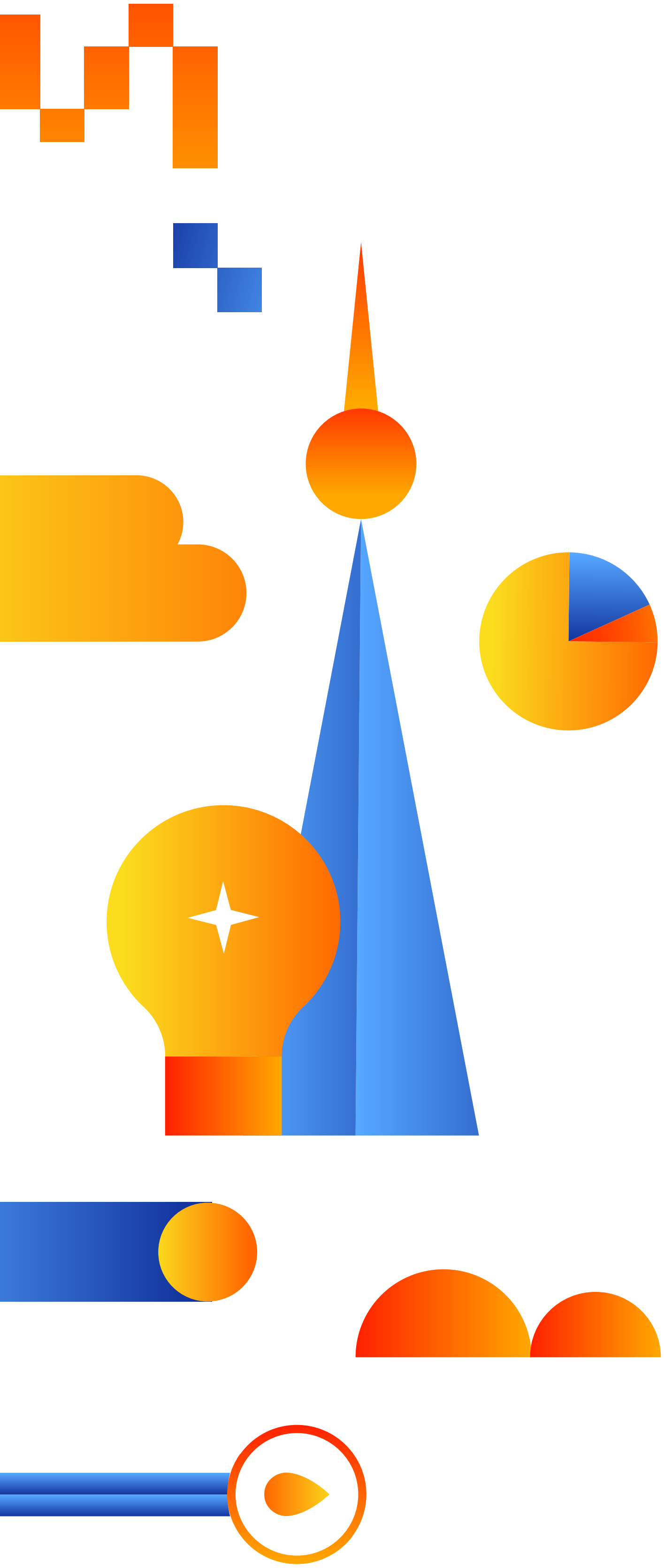
Usually, data labeling is a prolonged and manual process done by human experts in the field. Still, biases in experts' judgments are one of the main challenges in remote inspection. Therefore, it's crucial to set up the right process around data labeling, which will assure maximum efficiency and avoidance of any biases



Data Labeling is a process when human experts—in a software-assisted mode—annotate data samples in a machine-readable format. In visual inspection, data labeling means identifying and highlighting visual defects and structural areas on the image.

This process allows users to implicitly capture experts' knowledge and experience in the labeled dataset, which is later used to train ML models.

At SoftServe, we utilize the latest achievements in ML and decades of engineering experience to create a framework in which the data labeling process will be fast, bias-free, require minimum amounts of data, and lead to the best results.



LEARNING TO LIVE WITH AI

AI is changing the way people live and work, adopting it is essential. AI agents for visual inspection will have cognitive capabilities that can learn how inspectors or surveyors make decisions. Later, these cognitive agents can begin to make their own decisions about how the process of inspection should operate or when the assets, constructions, or equipment units should be maintained. The expert (inspector or surveyor) role will still be critical. However, it will become more of a supervisory position rather than an active-participant. The key role and ability of the company will be to have a supporting technical environment that allows room for innovation—through cognitive agents.

SUMMARY

The insights provided here are based on solutions that SoftServe has already developed successfully. We can build a custom version of such visual inspection solution on any platform for future clients. At SoftServe, we have a global team applying our AI/ML, Big Data, and DevOps expertise to solving the biggest challenges facing different industries—while partnering with the most trusted cloud providers in the world. Where are you in your asset management journey? Contact SoftServe today and let's talk about first steps in saving you time and money in your visual inspection and predictive maintenance operations.

ABOUT US

SoftServe is a digital authority that advises and provides at the cutting-edge of technology. We reveal, transform, accelerate, and optimize the way enterprises and software companies do business. With expertise across healthcare, retail, energy, financial services, and more, we implement end-to-end solutions to deliver the innovation, quality, and speed that our clients' users expect.

SoftServe delivers open innovation, from generating compelling new ideas, to developing and implementing transformational products and services.

Our work and client experience is built on a foundation of empathetic, human-focused experience design that ensures continuity from concept to release.

We empower enterprises and software companies to (re)identify differentiation, accelerate solution development, and vigorously compete in today's digital economy-no matter where you are in your journey.

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