ADDRESSING AI CHALLENGES IN CONTAINER DAMAGE SURVEYS: A NOVEL SOLUTION FRAMEWORK

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International commerce heavily relies on shipping containers, which are frequently damaged by weather, repeated movement, and continuous strain. Evaluating these containers for damage, or their "health," is vital for everyone in the shipping process, especially port operators.

Terminal operators perform container damage surveys primarily to protect themselves from liability and to make informed operational choices. Damage can harm cargo and reduce a container's utility. By documenting damage upon arrival, terminals establish responsibility. Additionally, damage assessments determine suitable handling equipment and storage locations, impacting downstream processes.

While ISO_9897 provides a definition and standardised system for classifying these damages—defining type, location, and severity—its practical interpretation and consequences differ significantly between stakeholders. Each terminal, for instance, operates under its own specific guidelines, leading to inconsistencies in damage assessment and handling. This lack of uniformity creates a major challenge in consistently assessing container condition.

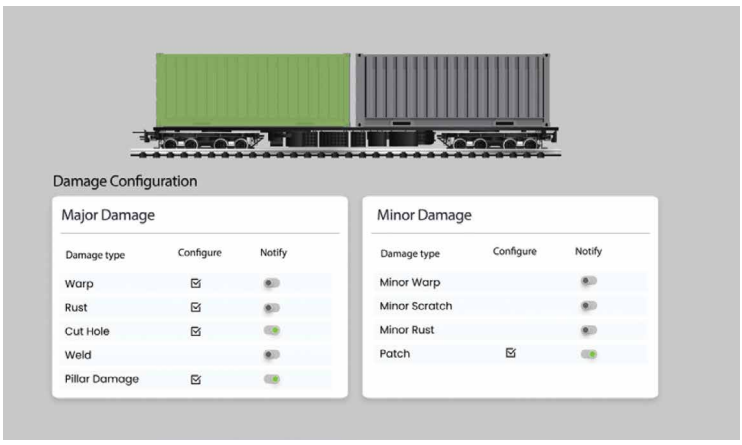
While manual inspections are time-consuming and have implications for personnel safety, the lack of consistency in operational interpretation is a major challenge to automated damage detection.

AUTOMATED DAMAGE SURVEY EVOLUTION AND CHALLENGES

Initially, damage surveys were performed manually, with

surveyors physically examining containers from all sides and recording findings on paper, supplemented by photographic evidence. To enhance efficiency, systems were developed to provide live video feeds to operators at workstations, using image stitching or line scanners to create complete container views due to spatial constraints.

The advent of computer vision and deep learning has enabled further automation, where AI algorithms analyse stitched images to detect and classify damages, generating reports and minimising manual documentation. Despite these advancements, AI-based solutions face significant challenges. They often struggle with consistent



and comprehensive damage detection and lack adaptability to changing conditions, requiring extensive retraining. These limitations stem from insufficient training data and the absence of reliable, digitalised ground truth for real-time validation. Terminals mitigate some of these issues with strict operational and installation procedures, like controlled container movement and precise camera placement, along with extensive data reconciliation efforts. However, the lack of standardised damage definitions across the industry further complicates matters, hindering the on-the-ground practical applicability of ground truth data used in training.

SMART CONTAINER DAMAGE SURVEY - A NOVEL SOLUTION FRAMEWORK

ATAI has pioneered a distinct methodology that leverages computer vision and deep learning to create an effective and intelligent container damage survey system. This novel solution successfully bypasses the previously outlined obstacles and delivers practical results in real-world scenarios.

Key fundamental changes in our approach include:

FRAMEWORK TO DEFINE DAMAGE-DRIVING UNIFORMITY IN DAMAGE DEFINITION

ATAI has developed a solution that empowers terminals to define damages precisely to their standards, using ISO_9897 as a foundation. This framework enables terminals to define damage types, assign localised classifications, specify the impact of damages, and establish handling protocols. This approach ensures comprehensive damage capture and enables terminals to react according to their unique operational requirements. By maintaining a complete container health history, efficiency is maximised, with action taken only when necessary. Furthermore, the framework's flexible configuration allows for rapid adjustments to damage definitions and procedures.

ABOVE
Synthetic data creation – 3D rendering to environment creation

RAW IMAGES VS STITCHED IMAGES

Historically, damage detection algorithms relied on stitched container side images due to operational space limitations and the need for damage localisation. Stitching, however, is computationally demanding, especially considering the real-world scenarios where container speed and distance from the camera vary, leading to image distortions. These distortions can cause detection errors, false alarms, or misclassifications of damages.

In contrast, ATAI has developed a novel method that accurately maps and localises captured imagery onto the overall container. This innovation allows the algorithm to process raw damage frames, resulting in improved detection and classification accuracy. Furthermore, ATAI's approach enables the utilisation of images from multiple camera angles, which were previously discarded in traditional stitching methods. These additional images enhance training data considerably and provide multi-perspective damage evidence.

"ACCURATELY AND RELIABLY CAPTURING CONTAINER ID IS EQUALLY IMPORTANT TO KNOW CONTAINER LOCATION."

ABOVE & BELOW
Damage detection for swap bodies, semi-trailers, and tank containers

"ATLOCATION CAN TRACE A CONTAINER IN THE YARD EVEN WHEN THE CONTAINER NUMBERS MAY BE DAMAGED/ERASED."

ACCURACY VS MISS

While the terminal industry typically prioritises overall AI accuracy, container damage detection demands a distinct strategy. This is because damage datasets are heavily imbalanced, with far more instances skewed towards undamaged containers vis-à-vis damaged containers. Furthermore, false positives, which necessitate manual intervention, are costly. Therefore, training algorithms for damage detection should emphasise precision and sensitivity over general accuracy.

ATAI's system reflects this, prioritising the reduction of missed damages over simply maximising accuracy scores.

TRAINING DATA SET – REALISTIC SYNTHETIC DATA CREATION FRAMEWORK

Obtaining adequate training data for container damage detection is difficult, requiring extensive raw data collection, accurate ground truth creation, and sufficient representation of all damage types. This process is lengthy and susceptible to environmental and location variations, impacting algorithm performance.

While synthetic data offers a potential solution, it struggles with realistic damage representation and information loss during 3D-to-2D conversion, further affected by environmental factors. ATAI addressed these challenges by developing a 3D damage dataset that incorporates environmental and location-specific variability. Using an AI-driven framework that combines image processing and 3D rendering, ATAI creates a highly authentic dataset. By working with raw damage frames rather than stitched images, lossy transformations are minimised, and multi-perspective damage views enhance dataset robustness.

DAMAGE VALIDATION MECHANISM – ABSENCE OF GROUND TRUTH

Typically, AI systems use probabilistic methods and require digital ground truth for validation. However, container damage detection cannot rely on real-time

digital ground truth for identifying exceptions; therefore, every detected damage must be evaluated.

ATAI's solution addresses this by (1) optimising algorithms for high precision to prevent missed damages, and (2) providing a comprehensive historical record from previous inspections, irrespective of the terminal's specific damage definitions (using our damage definition framework). This strategy significantly reduces the need to handle false positives.

STATIC MODEL VS CONTINUOUS LEARNING

A key distinguishing feature of our container damage survey solution is its ability to incrementally learn and improve through continuous feedback, comparing detected damages to the actual ground truth. This learning framework enables us to utilise standardised models across various terminal operations, such as quay, gate, and rail surveys. Beyond continuous learning, this framework ensures consistent results throughout the terminal while also providing the flexibility for individual terminals to customise the algorithms to their specific requirements.

BEYOND ISO CONTAINERS: SWAP BODIES, SEMI-TRAILERS.

ATAI has extended the applicability of container damage survey system beyond ISO containers and extended the system to non-ISO containers, such as swap bodies, semi-trailers and other container types. This novel framework allowed us to deploy and use common models across various types of terminals, including intermodal terminal, RoRo terminals, inland container depots and barge terminals, thus gaining the benefits of data richness.

CONCLUSION

With its innovative approach and thorough understanding of both customer needs and technology, ATAI's smart container damage survey solution has become a leading solution for container damage survey.

ATAI's customer-centric approach ensures real-world applicability, setting new standards for efficiency, accuracy, and adaptability in terminal operations.

ABOUT THE AUTHOR

Kishor Arumilli, Vice President of Engineering at ATAI, has over 28 years of experience spanning from platform design to full solution development. At ATAI, he oversees product development from concept to production. With global experience in the IT industry working in various industry domains, he is a key member of ATAI's senior management. His research focuses on smart IoT, edge computing, applied AI, distributed data and compute, and enterprise servers and storage.

ABOUT THE COMPANY

ATAI is at the forefront of digital transformation in the maritime, logistics, and supply chain industries. Their pioneering efforts focus on optimising productivity and recognising opportunities for sustainability and cost efficiency through innovative business models. ATAI achieves this by streamlining current processes with comprehensive problem-solving applied AI solutions. Their capabilities are enhanced by AI algorithms, sensors such as cameras, location sensors, wireless mesh networks like LoRa and 5G, as well as lidar and radar technology. As a result, ATAI has successfully tackled numerous operational hurdles across various market sectors.