Use of photographic surveys to enhance safety studies and inspection

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MMI Thornton Tomasetti has been using 360 degree photographic surveys to enhance remotely undertaken safety and operational studies and are in the process of developing automated AI tools to review images and identify areas of damage. This presentation demonstrates benefits seen from MMI Thornton Tomasetti's current photographic methods and looks at future developments in this area.

MMI Thornton Tomasetti have been making use of the Kolor's Panotour software on a number of installations to develop virtual tours. These are similar to 'google' street view and enable a user to remotely walk through plant and process areas. These virtual tours have proven to add value to office based technical studies, with recent examples including PFEER assessments and Passive Fire Protection (PFP) inspection and integrity assessments. The information is used as a means to validate design details, for example the exact location of manual alarm call points, and define potential limitations e.g. whether access to an escape to sea ladder is impaired by a new piece of equipment.

In addition, Thornton Tomasetti is in the process of increasing the use of laser scanning and is developing an AI tool to increase the speed at which defects can be identified in large-scale visual inspection of structures. This uses algorithms that are 'trained' to be able to identify anomalies types in photographs of concrete structures e.g. cracks, spalls etc. MMI Thornton Tomasetti is looking to further develop the tool to potentially cover corrosion and PFP anomalies. In the longer term this has the potential to become an integrity tool of the future. If quick surveys can be developed and then run annually, then comparison of the survey results could be used as a means for tracking degradation in fabric integrity.

It is an English language idiom that a picture is worth a thousand words. However pictures have had little use in safety and asset support, other than as a means to display details of degraded protection barriers and incidents. Until now. The means to take, process and manipulate large numbers of images have been developing. This combined with laser scanning technologies and Artificial Intelligence has the potential to enhance safety and integrity studies. This review looks at what visually based information has been, is and can potentially be used for in support of safety and asset integrity studies and management.

Keywords: 360 degree, photographs, virtual tours, Laser scanning, Artificial intelligence, machine learning, surveys, incident scene recording, forensics, Damage Detection, interaction and immersion, remote studies

Introduction

It is an English language idiom that a picture is worth a thousand words. However pictures have had little use in safety and asset support, other than as a means to display details of degraded protection barriers and incidents. Until now. The means to take, process and manipulate large numbers of images have been developing. This combined with laser scanning technologies and Artificial Intelligence has the potential to enhance safety and integrity studies. This review looks at what visually based information has been, is and can potentially be used for in support of safety and asset integrity studies and management.

This review is restricted to optical imaging of existing assets. It does not include use of 3D and CFD modelling which could be seen as visual information and which can be combined with images to improve presentation. Neither does this review include use of recording in the infra-red spectra. Infra-red can be used for thermal or [gas] release surveys.

Historical use

Previous use of photographic surveys or even basic photographic recording of existing assets, has had limited application to date.

The principal use of photographic material is in the recording of fault and failure evidence such as in in equipment surveys and for recording the details of accidents and incidents. A camera should be a standard piece of equipment for site equipment surveys and audits and as part of the investigation response kit to incidents. Key requirements in obtaining photographic evidence at incident sites should include the following

- Record perishable evidence, including capturing environmental evidence (weather/ lighting) as soon as possible.
- Overview - multiple angles should cover 360deg around incident site.
- Significant element recording (main element of interest)
- Recording of site inventory - before items are removed.
- Close -up. Multiple angles and some form of scale comparison
- Documentation - those documents for which it may not be possible to remove from the incident site
- Exemplar items if available - such as adjacent sites and identical or similar equipment which is not failed.
- Adequate notes to support the images.

Photographic recording has also been used to support visual surveys and equipment audits to record of equipment and structural faults and failures. Using photographs for this fault recording has two advantages. It supports the findings of the fault/failure determination and if date stamped can be used to track the management and rectification of the identified faults. Later surveys can use the initial fault finding photographic information to determine if the fault has been correctly [fully] rectified or in the cause of monitoring of degraded conditions to determine the rate of change of the degradation.

A lesser use of photographic material is either to provide an overview introduction to an asset, such as in safety cases or as supporting information in some safety studies, such as in HAZID and HAZOP studies. Some use of photographic material has been to aid in the presentation of some consequence modelling. This is where modelled release consequences, such as gas plumes or thermal effects, are overlaid on site photographs.

In HAZID and HAZOP studies the best use of additional supporting material has been made when two screen have been available to project study information. One screen has been used to display the team meeting record the other screen has been used to display supporting information ranging from P&ID through mechanical drawings to photographs of specific equipment items. Particular benefit has been seen when displaying package or vendor supplied units. Such units may be unfamiliar to the majority of the study team. An example is shown in Figure 1 below which shows a vendor package both as a P&ID and as an over view photograph. The visual information greatly aided the team in understanding the potential operation of the new unit.

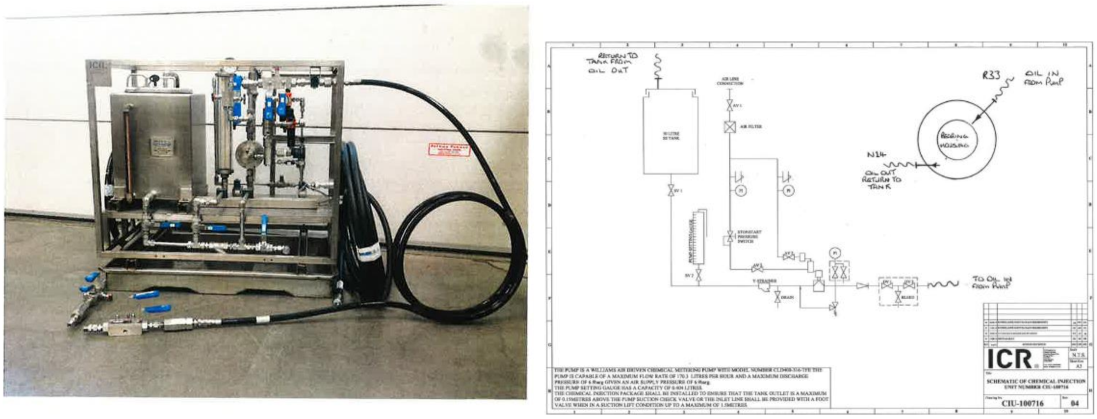

Figure XX - Example of use of a photo to supplement a basic P&ID

However, although useful, photographic information is not critical to undertaking these safety studies.

Present

The largest problem with single image photographic material is that each image has a restricted field of view. This limits the use of the photographic material in later studies unless the later use is also interested in the specific details of the existing image. Even where multiple images of an area may be present it can be difficult to easily determine the context for particular images, such as the location of where the image was taken and view the image is presenting. Each image also has to be opened in turn if there is a requirement to view a wider area or to gain a view of the area under consideration for a different perspective.

As an improvement on packages of individual images, MMI Thornton Tomasetti has been undertaking 360 degree photographic recording of sites and installations. By taking multiple 360 degree shots at numerous locations and then using virtual tour software such as ‘Kolors panotours’[1], photographic virtual tours have been developed. For those familiar with Google’s ‘street view’, these ‘panotours’ can be seen as the process industries site equivalent. Such photographic surveys, if carefully planned, can effectively capture all of the site or installation.

The generated virtual tours, in addition to having significant photographic coverage, can also be interfaced with. Virtual tours can have the following levels of interface

1. An “interactive” element, where the viewer can interact in some way with the content such as changing the viewing angles or zooming in on particular views. And
2. an “immersive” or Virtual reality element. This can be all the way up to full immersion by way of a VR headset. Viewing on a monitor, for general use, would not be considered full VR, but some immersion is provided through the ability to ‘walk through’ as part of a virtual tour.

The MMI Thornton Tomasetti ‘panotours’ have some limited immersion, with the images displayed on a normal 2D screen. However, the viewer is able to ‘walk through’ the presented environment by use of direction arrows. At each view location the viewer is then able to interact by rotating the view and also to be able to zoom in on the selected view. This interaction and walkthrough ability enables the user to quickly establish their position and context within the location. This enables quick positioning relative to the area and equipment of interest and is both easier and faster than trying to use a number of individual photographic images. Virtual tours are a very powerful means for providing a remote over view of an installation.

Use of these virtual tours has been used in support of remotely undertaken studies particularly by individuals and teams that may also be unfamiliar with the assets. An example of their use has been in the review and updating of information in support of PFEER assessments [2] and compliance. These were conducted as remote projects using existing documentary information on the location and provision of safety related equipment in sources such as the safety cases. This used drawing data as a basis for the study. By combining with the virtual 'panotour' it was possible to identify features that could easily have been missed from the review of the drawing information. Figure 2 provides an example of where the original build included a small heat shield. The presence of this shield was no longer fully detailed in the documentary information, due to a number of reasons. However, in the visual 'panotour' the heat shield was easily identifiable and its presence still confirmed. This allowed the review of escape provisions to include this shield as a potential option.

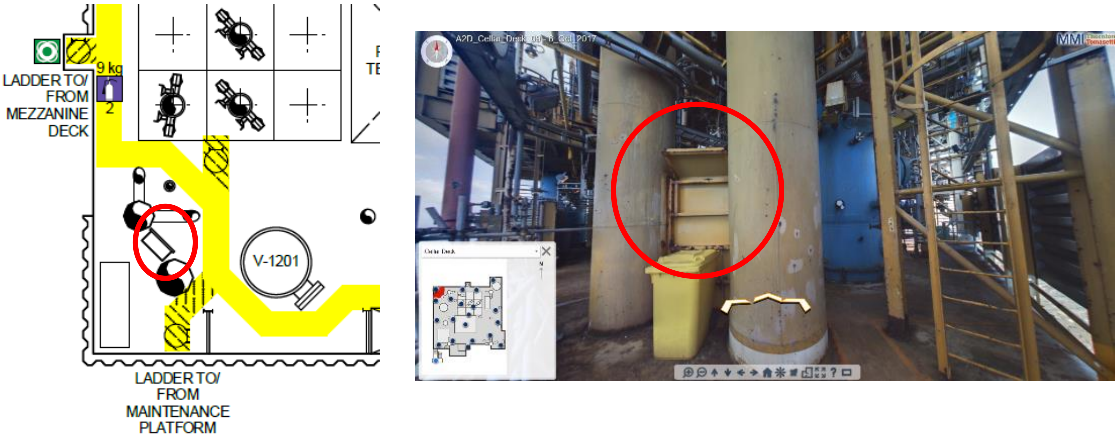

Figure 2: - Example of exiting layout drawing and extracted 'panotour' image of same area. Identification of heat shield

Other cases where the 'Panotour' information was used as evidence to confirm 'as built' details have included

- Identification of restrictions to escape routes, and creeping changes on the use of some rooms.
- Reviews of F&G systems and call points locations and functions. The existing drawings were identifying some call points as fire alarm MAC (Manual Alarm Call point), but in a review of the Panotour images the actual call points were confirmed as ESD buttons. These would provide both an ESD shutdown as well as alarm signal and the F&G data could then be up dated. In other cases detector locations were not as indicted in the drawings.

Another tool for virtual tours is in the use of embedded hotspots. The basic function of these is to allow the virtual user to transition from one 360 image location to the next, thereby providing the slightly immersive nature of being able to walk through a location. These hotspots can be included directly within the tour images and provide a mouse click link to open other supporting files and information. This is a powerful presentation tool. An example of a hotspot in use is presented in Figures 3 and 4 which display a pantour image without embedded hotspot (figure 3) and with embedded hotspots and opened supporting information (figure 4). This is from a review of PFP (Passive Fire Protection) at a site.

Figure 3: Image from standard 'Panotour'

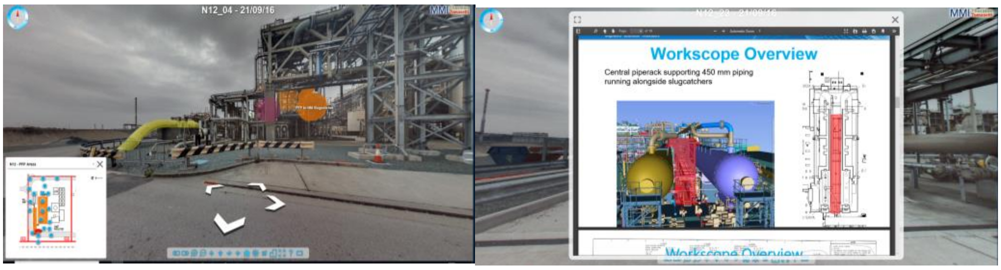

Figure 4: Image from 'panotour' with emended data hotspot, and example of opened data

The ability to access 360 degree 'virtual' tour information has had the following uses:

- Provision of easy to access 'as built' information remote from the installation. This has been used extensively by site personnel and office based personnel and reduces need for personnel to go onto site. This has also been used by third party consultants working remotely, similarly reducing the requirement to visit the installation and hence costs.
- Means to confirm site information for difficult to access sites. This has been especially beneficial for offshore Normally Unmanned Installations. In these cases it is not possible to easily obtain specific information at short notice of ad hoc information. The use of virtual tours speeds up information access and reduces cost and risks associated with the need for trips to such locations.
- Having 360 virtual tour information improves the ability to remotely familiarise personnel and contract staff with asset and installation layouts prior to actual on site visits. This can reduce learning times and exposure to site hazards with cost and performance improvements.
- Improves requests to site personnel for site information and in the undertaking of asset management audits /surveys. Images from the virtual tour can be extracted by remotely based individuals and attached to site requests for additional data. This aids the site in identifying the exact locations associated with site information requests. Embedded hot spot information can also be used to support audit surveys by identifying survey points and possible requirements.

In summary Virtual tours have the following benefits: Easy check of physical details. Availability of multiple perspectives. Reduces required site presence with reduced cost and reduce risk exposure required in order to review site locations and as a presentation tool though use of embedded hot spot details. The only adverse aspects associated with Virtual tours are that if not updated, information can become outdated, and the time and effort requirement to undertake site scans and the stitching of the images together.

Present and near future

Standard 2D optical single and 360 degree images are being superseded in surveys by the use of Laser scanning technology, e.g. use of Faro scanner [3].

Benefits of laser scanning

- Collect data accurately in a short time.
- Accuracy 1/16th of an inch down to 1/32nd of an inch depending on various factors
- Collect data that would be difficult to acquire otherwise. Laser scanning using drones is being applied

The biggest use to date of laser scanning has been in incident recording and investigation, also known as Forensic use.

Incident site use of laser scanning captures millions of data points in a 3D point cloud. This point cloud provides an accurate 3D representation of the evidence such as burn patterns, equipment orientations and fragments, skid marks, vehicle positions etc. This documenting of visual and dimensional evidence is also undertaken in half the time it takes with traditional methods.

Large amount of very accurate dimension measurements can be used to identify minor variations over large areas. These can be enhance to identify damage patterns that are not visually obvious. The image in Figure 5 shows the scan of a building façade which had suffered cracking. The determination of defection patterns was used to determine where support design had been insufficient, rather than specific external (scaffolding) induced loadings causing damage.

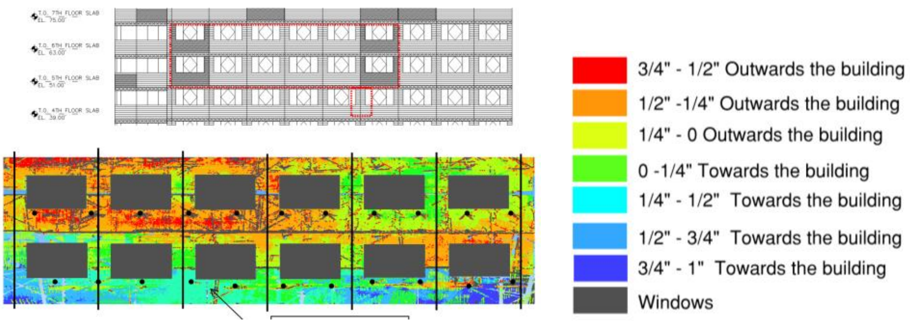

Figure 5:- Scan of damage to façade showing defection patterns

Laser scan data can also be used to generate 3D models. These post incident 3D models can then be compared to pre-incident design to define the exact location and extent of incident damage. The post incident 3D models can also be further manipulated as part of incident re-enactment and damage determination. Figure 6 shows a photograph of a damage section of a bascule bridge (sometimes referred to as a drawbridge) and the resultant laser scan. Figure 7 shows the manipulation of the laser scan to indicate the extent of distortion in addition to the obvious collision damage.

Figure 6: Photo (left) and Laser scan (right) of a damaged Bascule bridge.

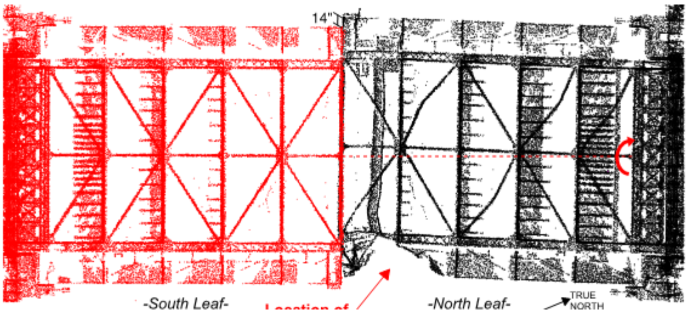

Figure 7: Manipulated 3D scan model to provide rapid determination of distortion extent.

In addition to the use in incident recording and investigation Laser scanning is also being used as a build check. If there is good design information, sufficient to support 3D model construction, then 3D models developed from Laser scanned data have been used to compare and identify construction discrepancies. This is shown in Figure 8: which compares 3D scan model against a 3D design model.

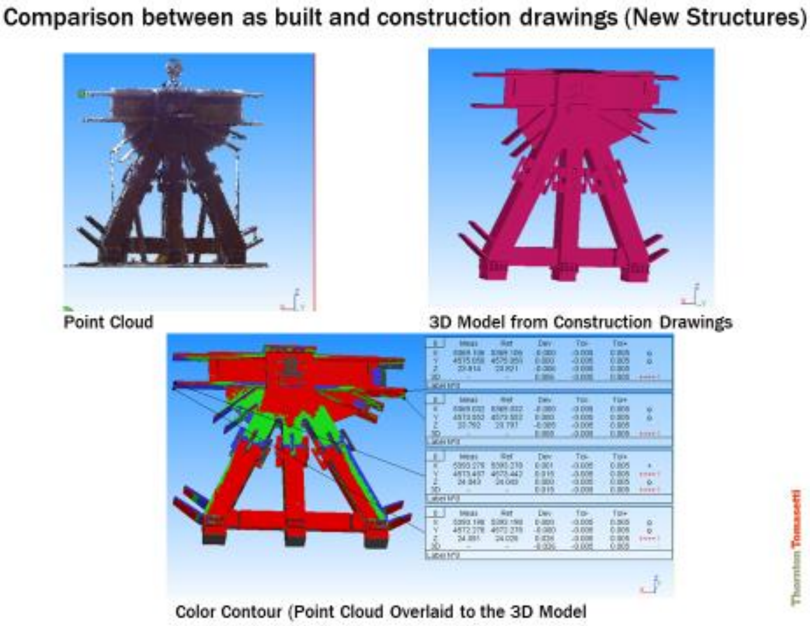

Figure 8: As built vs design comparison

Similar comparison models are also possible using scan data taken at different times. This comparison ability may be used as another means for tracking know degradation. This may be where degradation is identified but that immediate repair or replacement was not determined as being required. Instead ongoing monitoring of the condition is applied as the integrity management tool. The ability of Laser scanning to measure and differentiate colour as well as physical 3D parameters (it has been used in crime scenes for the recording of blood patterns and at fire scene for burn patterns) could enable the measurement and monitoring of fabric degradation, e.g. PFP damage, in addition to physical degradation over time.

With photo augmented laser scanning camera it is also able to generate much more interaction than the 360 degree photo developed 'virtual' tours. As such 3D laser scan models can be expected to replace 360 degree 'virtual tours' for sites and installations.

Further future developments

An internal development by Thornton Tomasetti is the potential application of Artificial Intelligence in the visual identification of asset damage. This so far has been limited to the visual identification of three types of concrete damage, namely spalling, cracks and exposed re-bars (reinforcing bars) and has been called Thornton Tomasetti Damage Detection T2D2. Figure 9 shows examples of exposed rebar and crack types of concrete damage.

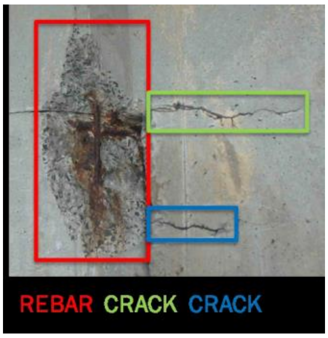

Figure 9: exposed rebar and crack - basis for AI tool

Using Google based AI tools [4], a mobile (android) tool has been developed to automatically identify and classify three types of concrete damage. The initial AI tool development uses Machine Learning (ML) based on several hundred images of concrete damage. The initial AI damage determination results are then reviewed and validated as part of an iterative process to update the Machine learning parameters. This provides error data to the machine learning in order to improve the AI selection. Figure 10 shows some latter stage examples of the comparisons of AI tool inferenced damage extents comparted to manual 'ground truth' extents.

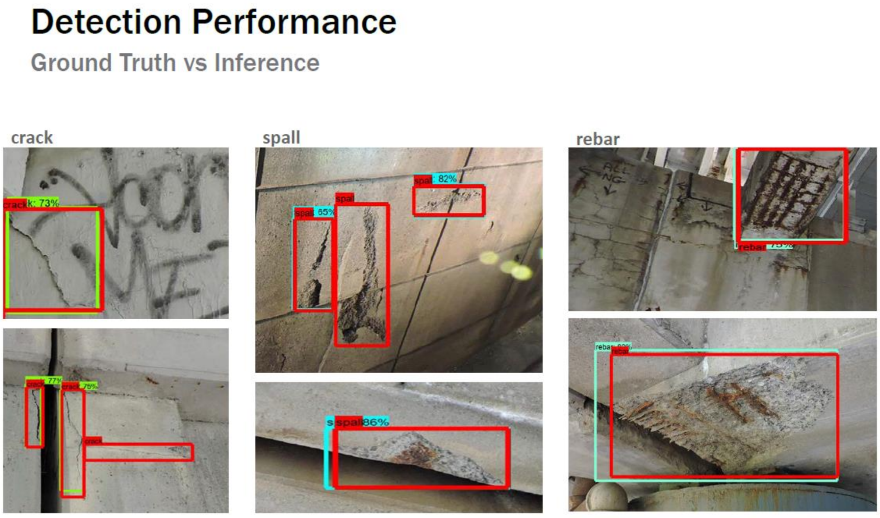

Figure 10: AI tool development - examples of validation stage comparisons

The end result is a mobile application that has the potential to quickly identify the current three types of concrete damage. Figure 11 shows the resultant trail tool being used to survey the damage present in some concrete paving.

Figure 11: Use of Damage Detection (T2D2) AI on android mobile

Although at an early stage and still only very basic this AI technology has the following potential:

- Scans can be undertaken by inexperienced individuals as part of an initial screening survey. The need for selective more detailed surveys and the need for greater expertise can then be determined. These initial screening surveys may also be conducted faster than manual surveys, which have to stop, photograph, and record individual areas of detected damage.
- Surveys of areas difficult to access. For example by using drones on high structures. Drones are currently being used for optical and laser surveys of difficult to access structures.
- Extension to other types of visually identifiable damage. For example areas of surface corrosion could be defined and included in the detection algorithms.
- Extension to other systems. MMI Thornton Tomasetti is looking to determine if this AI tool could be used for damage surveys of Passive Fire Protection materials and systems.

Another potential development would be use of the tool as an asset monitoring tool, similar to that discussed for the laser scanning technology. As a monitoring tool the initial scanning results could be compared against laser scan surveys and the changes used to define the rate of change of any degradation. This monitoring using an AI tool could be undertaken quickly and by inexperienced personnel. This is where a prioritisation systems has been applied to detected areas of integrity degradation. If more frequent scanning is possible then areas which previously may have been repaired or replaced, may instead be placed under AI based monitoring. This could have benefits in both limiting survey costs and repair and replacement costs.

What further areas of development using AI? Potential use of Infra-red thermal surveying, mobile acoustic surveys etc. Let us know. 'We will be back'.

Summary

Until now photographic information was a very useful tool incident sites and in fault/failure recording. Photographic information had some limited use in providing support to and enhancing safety studies. New tools and developments in photographic recording of assets can significantly aid in enhancing safety and asset integrity management.

Virtual tours have the ability to quickly provide site 'as built' information to remote users. These have an interactive interface which enable remote users to easily and quickly confirm site details, particularly compared to the effort of having to wade through folders of existing photographs. Remote access to this information has also been of increased value for sites which are difficult to access e.g. unmanned installations and where access to the virtual information can reduce the need for data gathering site visits. The virtual tours can also be used as presentation tool with the ability to embed hotspot links to other documents within the tour.

Laser scanning (with photo overlay) is becoming increasing used in the recording of incident locations. With the ability to be able to capture large amounts of dimensional data which can then be used to define damage in detail. The 360 degree nature of the laser scanning could also replace 'standard' 360 degree photographic imaging for virtual tours, and has the ability to provide design vs construction checks and monitoring of degradation conditions.

AI could be used to developed simple integrity scanning tools. This has a twofold benefit. It can allow for inexperience personnel to undertake quick [visual] screening surveys of an asset. This can be used to determine the need for more detailed surveys or investigations. And secondly there is also the potential for AI tool to be used to monitor for further degradation of damage.

References

[1] Kolor - WWW.Kolor.com , Note, Kolor ceased trading in 2018. Other virtual tor software is available.

[2} HSE, Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) regulations 1995

[3] FARO technologies , inc. https://public-safety.faro.com/en/

[4] Google AI - https://ai.google/