USING MACHINE VISION TO improve construction safety

Everyone working for Shell strives, every day, to achieve the Goal Zero ambition of no harm and no leaks. However, large construction projects such as the Pennsylvania Chemicals complex in the USA continue to present safety challenges. Teams from Shell’s Projects Digital and the Pennsylvania Chemicals project therefore partnered with vendor Detect Technologies to use its T-Pulse digital solution. This is a novel, artificial intelligence (AI) enabled, machine vision solution for identifying construction hazards in near real time. It utilises video footage captured from construction sites and operating facilities, and a proprietary image-processing system to make safety observations and identify hazards in line with industry recommended practices. The T-Pulse solution is now available for deployment at other Shell sites.

Background
Shell has the responsibility to deliver capital projects safely while meeting key promises on cost, schedule and production performance. This drive for excellence imposes pressure on owner teams, which must keep strong oversight of activities on the ground while ensuring the safety of the people working on their projects. Technological advances in computing and sensors have made it possible to increase the breadth of control over complex construction sites.

At the beginning of 2020, the Pennsylvania Chemicals project was at a critical stage of the execution cycle (Figure 1). Every day, 7,500 people came to work at this highly congested construction site packed with process equipment. The tallest column on-site, the quench tower, is about 100 m high, and the loftiest steel structure rises to nearly 130 m above grade (Figure 2). Hundreds of concurrent activities took place at height on any given day and across the entire 156-ha footprint of the construction site.

From a safety management perspective, Shell’s lean owner team was facing a huge challenge: how to focus on preventing the most consequential safety incidents. The project team was keen to identify a solution that would help them to maintain situational awareness site-wide and identify and mitigate high-risk areas.

The challenge: Construction safety risks
Multiple risks must be managed during the execution of capital projects to ensure that everyone goes home safely from construction sites. Owner teams put all the possible controls and barriers in place to ensure that nobody gets hurt while on the job but, unfortunately, incidents happen. Working at height and falling objects remain the top risks.

According to a 2019 report by the US Occupational Safety and Health Administration (OSHA) on cited safety violations across all workplaces, 45% are height related (Figure 3) [Ref 1]. Moreover, the Bureau of Labor Statistics...
indicates that falls account for 39% of all fatalities in construction.

Construction efficiency and safety are intrinsically linked; a safe site is also a productive site. Yet, construction efficiency still trails that of the rest of the economy by a significant margin. However, the availability of a skilled construction workforce in many parts of the world is limited: for example, in a 2018 survey, 57% of contractors in the USA reported difficulty finding skilled workers [Ref 2]. Therefore, many sites rely on apprentices. This may require heightened safety oversight and more interventions.

The solution: Machine vision enabled by AI
Smaller cameras, faster computers and an ever-evolving public library of machine vision algorithms based on vast imagery datasets have enabled many applications that are now familiar. Examples include unlocking a mobile phone using facial recognition and self checkout in stores.

Within Shell, machine vision has been applied at retail stations to identify unsafe actions and behaviours, such as smoking, through a project called video analytics for downstream retail. More information is available in this video.

These use cases rely on very large data sets fed to algorithms, mostly from the public domain, that enable intelligent decision-making. However, for construction sites, the learning data set remains quite limited and the understanding of safety is specific to the construction context. These make AI applications more difficult to implement and the benefits harder to realise.

Machine vision on construction sites
Camera-equipped unmanned aerial vehicles (UAV) can be coupled with an intelligent image-processing system to develop insights that enable the site safety team to identify hazards in hard-to-reach areas, for example, at height, where providing consistent human oversight of activities can be problematic. Such a system can generate actionable safety insights in near real time, thereby efficiently augmenting in-person supervisory trips to elevated work areas.

In the T-Pulse system, UAV video imagery of the area of interest is captured on-site and uploaded to Detect Technologies’ cloud environment. There, the images are processed in less than an hour, and the results are returned to the site safety team.

FIGURE 2
Aerial view of the Pennsylvania Chemicals ethane cracker furnaces area.

FIGURE 3
OSHA safety violations in 2019 [Ref 1].

- Fall protection, 22%
- Hazard communication, 14%
- Scaffolding, 10%
- Lockout/tagout, 10%
- Respiratory protection, 9%
- Ladders, 9%
- Powered industrial trucks, 8%
- Fall protection - training, 7%
- Machine guarding, 6%
- Eye and face protection, 5%
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AI principles
To dive deeper into understanding AI principles, consider how a newborn baby makes sense of the world around it. Initially, there is perception of colours before moving on to shapes that then take another dimension for perceiving depth. A combination of these attributes enables the baby to identify the unique features that help to differentiate objects. Then, when these objects perform actions, the baby can derive inferences.

Machine learning necessitates translating such understanding into binary 1s and 0s. Hence, a coloured image is converted to binary: black and white. When the machine applies a pretrained, weighted rule to convert this binary image into a net sum, it can be compared against a threshold to decide, in binary fashion, yes or no, whether it is a particular colour, shape or feature. This logic is compiled on multiple layers to facilitate feature classification and identification, thus enabling the system to identify objects in images (Figure 4).

Detect Technologies uses computer algorithms to identify and to highlight areas of interest, that is, potential hazards, on the basis of pretrained observation sets. It leverages a “human-in-a-loop” approach for processing the source imagery. In this, the algorithm provides the first pass to generate initial results quickly; these are then vetted by humans with the aim of continuously improving the AI system’s capabilities through machine learning (see boxed text, AI principles).

Human vetting of the results generated by AI helps to improve the algorithm so that it becomes more intelligent with each cycle. Detect Technologies’ safety officer annotates observations and shares the results, along with marked-up images, video snippets and recommendations, with the site team via the dashboard. The site health and safety team then proceeds to assign criticality ratings to the observations, review the recommendations and execute remedial actions. Meanwhile, the AI feedback loop is closed.

T-Pulse on the Pennsylvania Chemicals project
The T-Pulse solution was first demonstrated to the project team in late 2019 in a one-off trial that generated serious interest in the technology. That led to an extended pilot study that started in February 2020 but was soon interrupted by the COVID-19 crisis. The pilot study eventually concluded in September 2020.

The objectives of the pilot phase were to:
1. measure the value of the T-Pulse solution for improving safety in construction;
2. explore the ability to adapt the algorithms to site-specific conditions through a continuous feedback loop for increased automation of the process;
3. align T-Pulse reporting with the International Association of Oil & Gas Producers IOGP 577 recommended practices; and
4. assess the scalability of the solution across Shell projects and operating assets.

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The pilot’s footprint involved an area of about 32 ha covering the ethane cracker unit, the polyethylene manufacturing units and the cogeneration plant (see Figure 5). These areas were characterised by the highest intensity and complexity of concurrent construction activities. UAVs were deployed to the pilot-study area for 2–3 h/d, when the weather was appropriate, and recorded site activities from a safe distance.

The data collected were anonymous, i.e., not identifying any individuals; this was deliberate to...
mitigate data privacy concerns. The imagery was shared with Detect Technologies’ team for processing and first-pass analysis. In about 2 h, the classified and annotated observations were delivered to the health and safety team on-site for a thorough review. The results were presented in a web dashboard aligned with the IOGP 577 reporting categories (Figure 6).

Pilot-study results
Figure 7 shows an example of a fall-hazard observation detected by T-Pulse: an individual is dangerously overreaching across the safety barrier to receive tools from another person. Through this observation, the safety team was able to provide the necessary coaching to the work crew.

In another example, T-Pulse observed an exposed, open grating (Figure 8(a)). Safety barriers were installed before work was allowed to proceed in this remote, elevated area (Figure 8(b)).

Through using the feedback loop during the study period, the following types of observations became completely automated:

- human and machinery activity detection;
- basic personal protective equipment compliance;
- open gratings;
- smoking;
- social distancing; and
- face mask compliance.

Further value can be realised in a semiautonomous way, that is, by human vetting of the AI analysis. This could include the detection of loose objects, loitering, exposure of people to suspended loads, observation of the three-points-of-contact...
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rule, provision of safety barricades and netting, the presence of excavations and interference with construction traffic.

It is only a matter of time, and the acquisition of a sufficient AI training dataset, until these semiautomated observations can also be generated autonomously. Eventually, further and more complex observations will be added to the toolset.

During the 50-d pilot, T-Pulse generated 141 insightful safety observations (see Figure 6 for examples), of which 24 were classed as high or very high risk by the health and safety team. The timely identification and resolution of these hazards enabled by T-Pulse may have prevented serious safety incidents.

Conclusion

In the final months of 2020, the number of activities performed at height was gradually reducing. At the same time, seasonal changes were limiting the ability to observe work from the air, so the window of opportunity to use T-Pulse on the project was starting to close.

The pilot study has established T-Pulse as a viable tool with excellent potential for managing safety risks in construction. For example, it was proved that a 2-h aerial drone survey, enhanced by 2 h of post-processing by T-Pulse, was equivalent, in terms of coverage and ability to provide insights, to 60 h of surveying the same 32-ha plot on foot. The ability of T-Pulse to observe work and detect hazardous conditions at height is unrivalled.

The journey ahead for T-Pulse in Shell

After the successful completion of the pilot study at the Pennsylvania Chemicals project, the project’s digital innovation steering committee decided, in late 2020, to make T-Pulse available for deployment at Shell sites. Currently, a new service is in development to cater to demand at green- and brownfield projects as well as turnarounds.

Technology trends

Future capabilities in AI, machine learning, robotics and sensor hardware are extremely enticing. This is an era of increasing use of unmanned aerial, land and underwater vehicles to achieve remote insights. Keeping construction safety in mind, the vision is to have a system that combines sensor data and edge processing on devices to provide real-time alerts to avoid potential hazards.

Achieving this will require a complex interplay among on-ground infrastructure (the Internet of Things), including fast internet connectivity and appropriate sensors, and an integrating system that provide relevant insights to an individual in the field via a personal device. The near-term target is to reduce the time from the observation to the insight reaching the associated individual through increased automation of recognisable observations and edge processing of footage close to where it is collected.

A pivot application of this technology during the ongoing COVID-19 pandemic has been to help identify actions for the real-estate team to ensure safe social distancing and face mask use through interventions on the basis of insights from remote monitoring cameras.

Relying on external suppliers

“We are incredibly proud of our collaboration with Shell, which has been one of our strongest stakeholders during our journey. Close collaboration with the Shell teams on-site and in the global technology centres has enabled us to mature and evolve the product offering significantly to be of large value to the energy sector globally. Together, we will continue to push the boundaries of technology and implementation in the space of AI and commercially deployable machine vision for the industry.”

Daniel Raj David, chief executive officer, Detect Technologies

Detect Technologies is a Chennai, India, based start-up catering to the energy industry through its patented products for providing intervention insights. The company was part of the first cohort for Shell E4, a start-up accelerator programme run by Shell India.
Several other Shell sites have already introduced T-Pulse. For example, the LNG Canada project at Kitimat has agreed a long-term contract with Detect Technologies to assist in managing construction safety at its site that started in 2021. The Shell Chemicals plant at Singapore’s Jurong Island successfully used T-Pulse during a month-long major turnaround in late 2020. Meanwhile, other use cases are being explored and trialled, for example, for asset inspection and flare monitoring.

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REFERENCES


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