CONNECTEDNESS FOR SYNERGY IN SMART ENTERPRISE ASSET MANAGEMENT

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Business and technology leaders are bombarded with information about the elements of Industry 4.0, the fourth industrial revolution. Yet we still lack the understanding and know-how to bring all these elements together in a sound, practical manner to create value in industry.

This article aims to address this challenge.

transforming enterprises into digital business

Contents

1 Executive summary

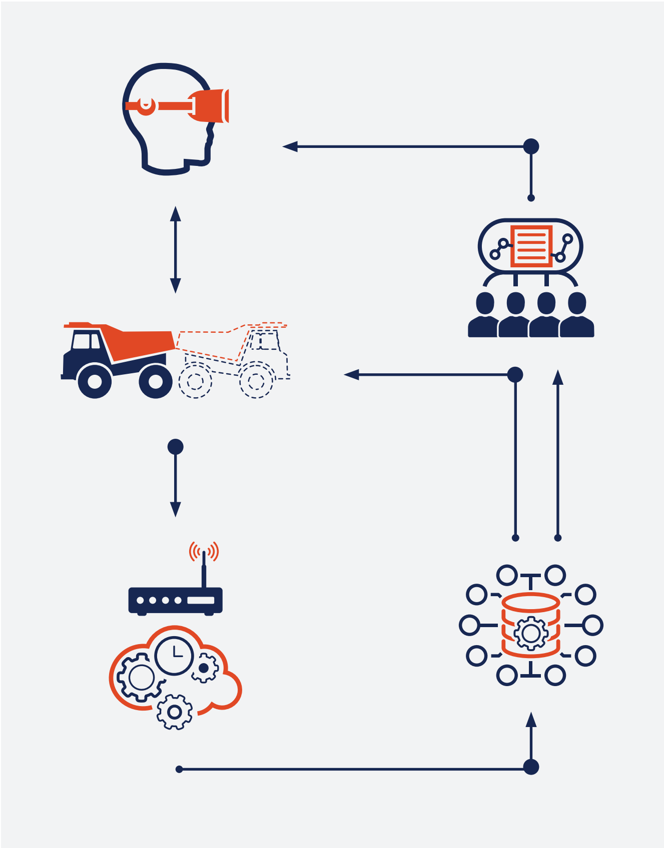
In this article we will help the reader to purposefully employ tools and technologies that provide the platform to connect various elements of a connected asset management system and so create the synergy needed for Smart Enterprise Asset Management (EAM).

Everything we do as asset managers is affected by this connectedness and it will be critical to get this right.

We will take a look at the Digital Twin, the "central nervous system" that represents our real life assets. We will consider how to deploy and manage sensors to give these assets a voice, and how their prompts activate work requests to a distributed work force using mobile devices for speedy and efficient response.

A Smart EAM requires intelligence to detect recurring issues, predict future events, make recommendations and take autonomous decisions. We will consider technologies, such as machine learning, that make an EAM "Smart".

Finally we will look at how technology, such as augmented and mixed reality, can strengthen our knowledge workers and help them to diagnose and repair swiftly and accurately.



A Smart EAM requires intelligence to detect recurring issues, predict future events, make recommendations and take autonomous decisions.

2 The Digital Twin

Importance

The Digital Twin is a dynamic digital representation of a physical asset, or thing, and its associated environment. The Digital Twin promises a more interconnected world which will create more realistic models and representations, and ultimately reduce unpredictability. Core to the Digital Twin is its ability to contain a few or even thousands of data attributes of the physical asset in a dynamic data model.

These attributes are connected with sensors that measure position, temperature, pressure, speed, and many other variables. The Digital Twin also allows for the association of other contextual or static information in order to represent real world operating conditions in the most accurate way.

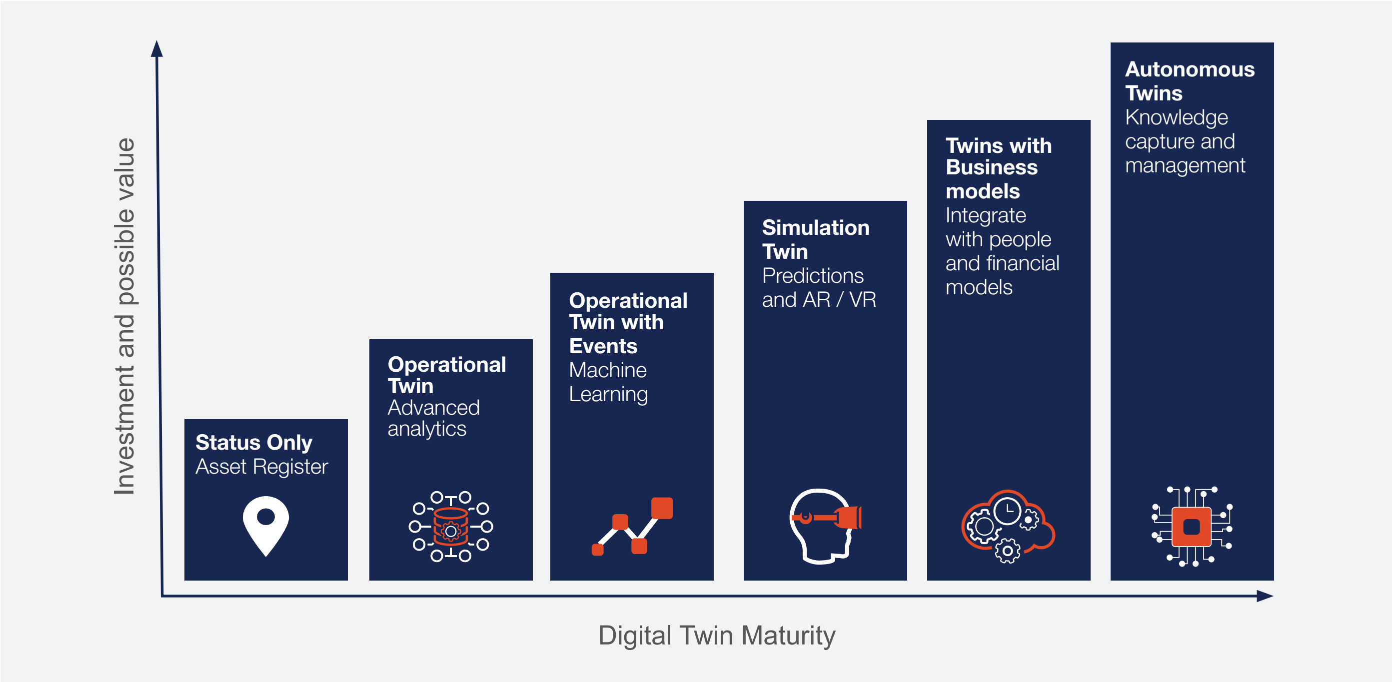
With this connectedness to the asset and its context, the Digital Twin is able to detect changes to the asset's condition quickly to allow for superior awareness and responses to the traditional analytical methods. The responses can lead to improved performance of the asset or lowering of operational expenses.

With the information gathered throughout the lifecycle of the asset, the Digital Twin can optimise the lifecycle stages of the asset with improved calculation of remaining useful life and replacement decisions.

Key to the emergence of the Digital Twin is the rise of the Industrial Internet of Things. But the second driving force is that of the modern workforce's increased awareness of information availability and allowing it to change behaviour of people or assets' actions.

Different Types of Digital Twins

Source: Image adapted from Kalwani, S., 2017



2 The Digital Twin

Different Types of Digital Twins

Digital Twins evolved in stages, and many organisations have unknowingly started the Digital Twin maturity journey. Most responsible asset operators will have the most basic form of the Digital Twin in place, called the Status Twin. The Status Twin is a fixed schema representing the asset's current operating conditions, like position, speed, flow, etc. A SCADA system is a good example of a Status Twin in the industrial world.

Operational Twin

To exploit advanced analytics, the Digital Twin needs to have a flexible data model where data is stored and fetched by analytics applications. The model needs to be able to scale vertically to allow for many different types of measuring points, but also horizontally to allow for analysis across many different assets. Selecting the right platform to contain the Operational Twin is very important because it becomes the foundation for all future versions of the Digital Twin.

Operational Twin with Events

Once the Operational Twin is in place, the next challenge is to connect events to data sets. This labelled data is called "supervised data" and unlocks machine learning capabilities.

Simulation Twin

The Simulation Twin simulates the operations of an asset through physics, prediction and process models. The output can be in the form of a prediction or a simulation of events, or in the augmentation of the asset's reality through Augmented Reality or Virtual Reality.

Twins with Business Models

The next step is to connect those improvements to the income statement and balance sheet. To improve profitability and reduce risk, the relationship between the financial drivers and the people processes needs to be incorporated into the Digital Twin. This will ensure change in people's behaviour and the generation of value.

Autonomous Twin

The end state is an Autonomous Twin focused on being the overarching twin to control the asset through software control and decision making. This completes the evolution of the Digital Twin from being a supporting actor in the decision making process to taking full control of the decision making.

It will not make economic and business sense for all assets to be deployed as Autonomous Twins. The investment to achieve a successful Autonomous Twin is significant and the operation and maintenance cost associated with the Autonomous Twin is often underestimated. It is important for asset owners to understand the different Digital Twin maturity stages and which is the desired state for each asset class.

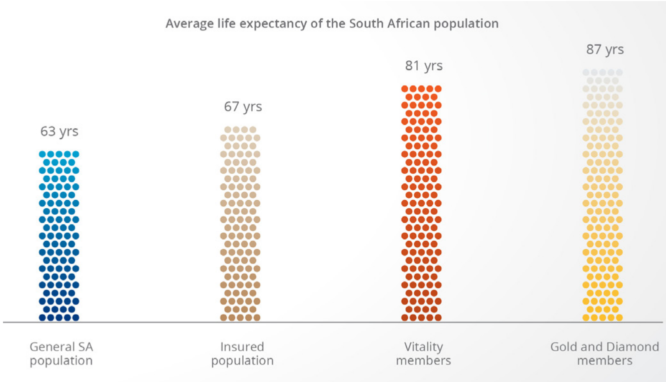
2 The Digital Twin

Digital Twin Example

One of the best Digital Twin examples in South Africa does not come from the asset management fraternity, but from the health and life insurance industry. Discovery Health, a health insurance provider, has built a Digital Twin ecosystem through its Vitality programme where most of its "assets" (the people insured) are equipped with sensors by means of a smart watch, which is actively monitoring crucial performance measures, and an edge device in the form of a mobile phone.

They have also been able to partner with technology providers, retailers, doctors, hospitals and financial institutions, all of them contributing to the completeness of the Digital Twin. The two aspects that are most impressive are, firstly, the scale at which the health insurance provider is able to deliver this Digital Twin model. Secondly, they have clear evidence of how the Digital Twin is changing "asset" behaviour through the right instructions and incentives.

In this example the ROI model is clear: by changing human behaviour to make healthy and safe life choices, the health insurance provider is reducing the risk of an unexpected catastrophic failure and decreasing ongoing medical expenses to keep the person healthy. This is a very good example of Digital Twins with business models.



Source: Based on the Vitality Diamond Zones research paper, 2016.

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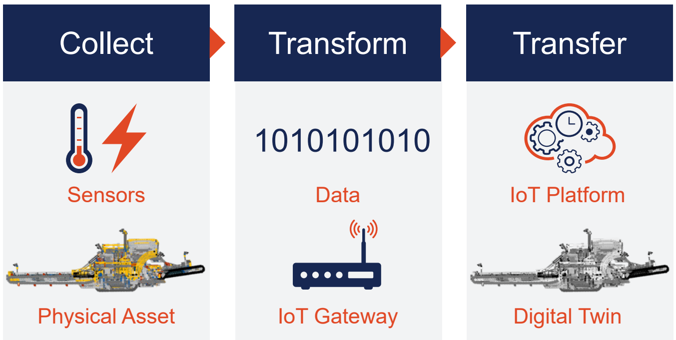
3 Edge to Cloud Connectedness

Edge to Cloud Architecture

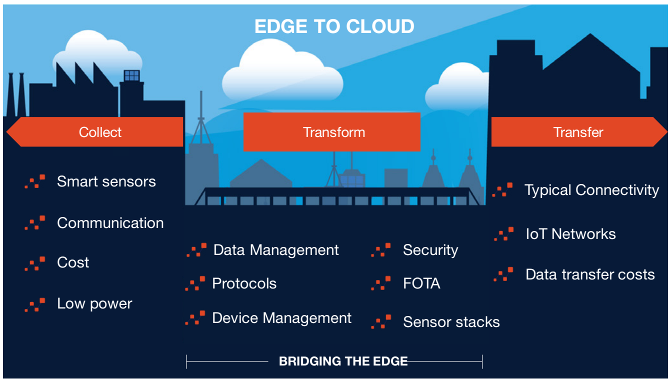
Three main steps are required to accomplish this Edge to Cloud journey, where the "edge" refers to the area which is near the source of the data (typically sensors on assets) and the "Cloud" is the IoT platform where data is stored, displayed and processed. This brings the assets alive and keeps the Digital Twin in sync with its Physical Twin. The steps to connect the "things"/physical assets that are located on the edge level to the Cloud are: (1) collect its perception of its performance, health and surroundings through the use of sensors, (2) transform raw data to meaningful information encrypted for secure transmission and (3) transfer the transformed data to the Cloud platform as illustrated in the diagram below.



Edge to Cloud Challenges

Industry is faced with a multitude of challenges in each one of these data acquisition steps. The diagram to the right highlights some of the building blocks in the next section.

Source: Diagram adapted from IoT.nxt marketing material.



Collect

Evolving technology has made sensors more accurate, cheaper, smaller and reduced their power consumption needs. When choosing sensors, make sure that they fit your data acquisition needs and that they are smart – i.e. the transducer/actuator must be combined with processing and communications functions.

A low power footprint is important in cases where industrial applications are far from the control centre and battery power is crucial for the sensor to last for years.

Transform

Typically, your IoT gateway is responsible for this function, but some smart sensors can also perform this role. To address some of the typical issues faced in the industry, six different IoT gateway features are discussed:

- **Data Management** includes data streaming, filtering and storage. Be clever about choosing which data must be sent to the Cloud as this can have a significant impact on data transfer costs.

3 Edge to Cloud Connectedness

- **Protocols** involve the language spoken between your edge device and the Cloud, and include protocols such as MQTT, CoAP, XMPP and AMQP. Protocols are selected based on the amount and frequency of the data that is sent to the IoT platform.
- **Device Management** ensures that the gateway is easily configurable to manage all connected sensors, its parameters and access control. Scalability needs to be addressed during device management where device provisioning is performed to effortlessly connect an array of devices to your choice of platform.
- **Security** is very important and needs to be addressed in every layer of the IoT value chain to reduce vulnerability against hackers.
- **FOTA** (Firmware Over The Air) ensures that the security of the gateway is continuously updated and it maintains device integrity.
- **Sensor Stacks** are the software layer responsible for the communication between the sensor and gateway device and this is where the term "interoperability" also becomes really important. Your gateway should be able to interface and communicate to any type of sensor such as legacy, wireless or PLC connected. Protocols in the Sensor Stack include Bluetooth, Modbus, CAN bus, Profibus, I2C, SPI, 4-20mA and many more.

Transfer

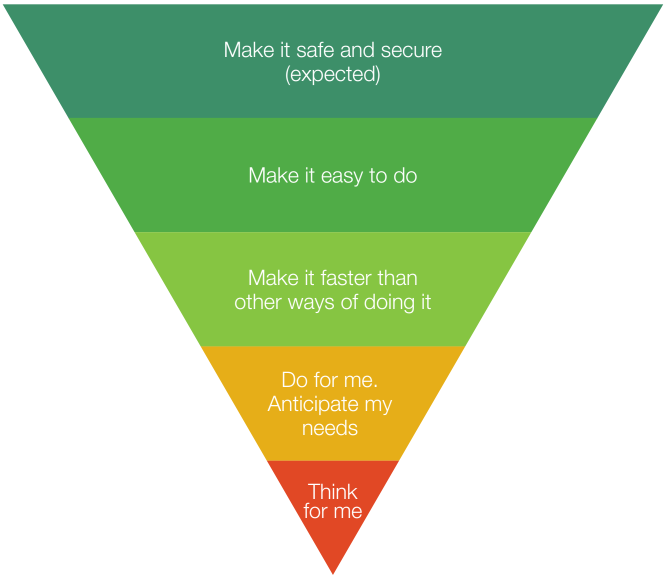
The transfer of data can be costly and should be limited to only that which is required for decision making and analysis. Most edge gateways have built-in intelligence, and if sensibly configured, can analyse and aggregate data or apply rules to determine which data should be transferred over the network for processing. The typical connectivity methods include Ethernet, 4G, 3G and Wi-Fi, and with remote applications that don't enjoy the perks of an established IT infrastructure you can make use of IoT specific networks such as Sigfox, LoRaWAN, RPMA and Vodacom's NBIoT.

> Your gateway should be able to interface to any type of edge device irrespective of its protocol or communications interface, such as CAN Bus or TCP/IP for example.

4 Big Data and Machine Learning

There are great expectations and by now proof of potential to improve the performance, cost and risk associated with our assets by having an accurate and up to date digital representation of their current and historic condition, performance and operating context. This information improves asset owners' or other stakeholders' ability to "see into the future" and thus make more informed decisions about the manner in which asset owners acquire, operate and maintain them.

As outlined in the preceding sections, the technologies to acquire huge volumes of asset related information are becoming much more affordable, and the opportunity to apply intelligent, data driven decision making for more and more of our assets is becoming possible. But our reliance on humans' ability to process all this data in time to influence decisions is becoming an ever increasing problem.



Source: The Financial Brand.com, February 2016

Natural Human Intelligence

Human expertise and intelligence has always been used to make predictions, evaluate these predictions and then decide on taking appropriate actions to mitigate risk, optimise cost or improve performance of our assets. Humans are "noisy thinkers" though and easily get distracted, influencing their ability to consistently make accurate predictions or good decisions. Humans are also relatively slow in processing data; to compensate for this they simplify matters by using approximations, limiting the scope of input data, etc. All these simplifications prevent them from taking all factors into account or seeing subtle correlations between trends in large data sets. Another approach to deal with our slow processing speed has always been to focus individuals on specific problems and then employ more staff to deal with the other issues. This is clearly not a sustainable solution, and also does not yield the optimum integrated solutions modern business requires.

4 Big Data and Machine Learning

Artificially Augmented Human Intelligence

These benefits of Artificial Intelligence (AI) are recognised in all modern businesses and statements are made that the “Artificial Intelligence” revolution could be equated to the “Mobile” revolution of the first half of this decade. AI is technology that appears to emulate human performance typically by learning, coming to its own conclusions, appearing to understand complex content, etc. AI algorithms are especially good at performing repetitive data processing tasks, detecting patterns in data, identifying anomalies, and many other tasks. The inverted pyramid on the previous page provides a simple illustration of the progressive abilities of AI from where the initial goal is just to make things simpler and safer for humans, all the way through to thinking for them.

Artificially augmenting human intelligence addresses many of the aforementioned challenges with human intelligence, and some of the clear advantages include:

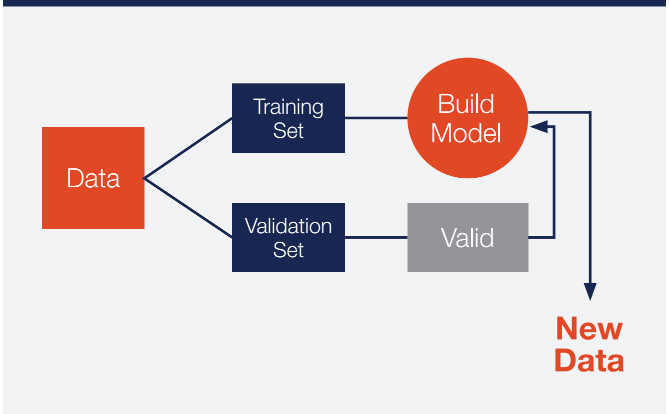
- Machines do not get distracted by their surroundings, emotions or personal issues and are thus much clearer thinkers than humans.
- They can easily be replicated to scale up their processing capacity.
- They are quick and can give answers in near real time.
- They can be precise and can consistently perform well.
- Since intelligent machines are quicker, they can also consider more inputs in their decision making process, i.e. they could be more comprehensive.

Artificial Intelligence through Machine Learning

Machine Learning (ML) is one way to emulate human intelligence. We can teach machines to recognise good from bad, forecast sequences, detect patterns, etc by showing them data, selecting certain features to examine in the data and then “training them” about the deductions they can make from the data. Once trained, they can interpret new data based on the learnings we’ve transferred to them. This method of training an ML algorithm is called “Supervised Learning”. A good example of Supervised Learning would be the SPAM filter used in many e-mail applications, where the algorithm detects and replicates user behaviours such as repeatedly deleting messages from certain

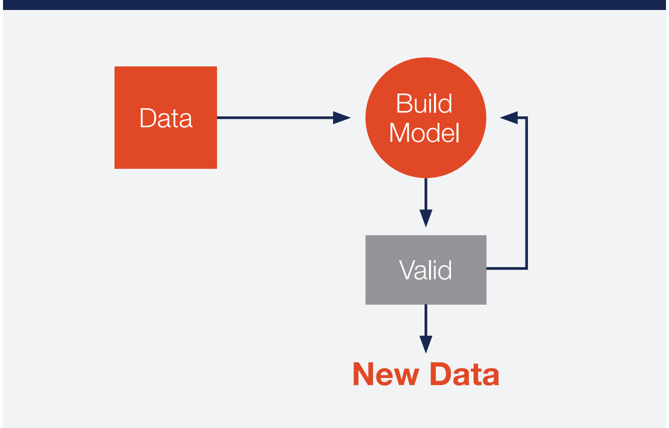
4 Big Data and Machine Learning

Supervised Learning



senders. But as with children, we could also expose ML algorithms to too little information, or transfer our own biases (stereotypes) to them, which will lead to poor forecasts and bad decisions. For example, if we show the algorithm 100 red sports cars and "teach" the algorithm that is what a fast car looks like, it is very likely that it will see a red tractor as a fast car rather than a black Lamborghini. We thus need to be very careful with the process of training these

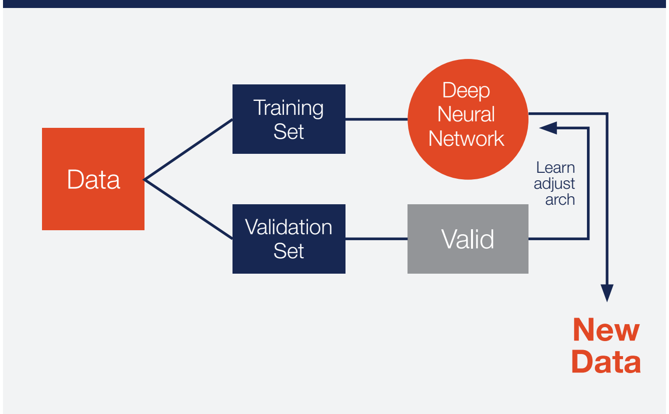
Unsupervised Learning



algorithms and make sure we employ suitably skilled humans to do so.

Machines can also decide which features to look for in data themselves and then use these features to classify data. In its simplistic form this is called "Unsupervised Learning". This approach is good for simplistic classification problems such as image classifications and could be put to good use in many industrial applications.

Deep Learning



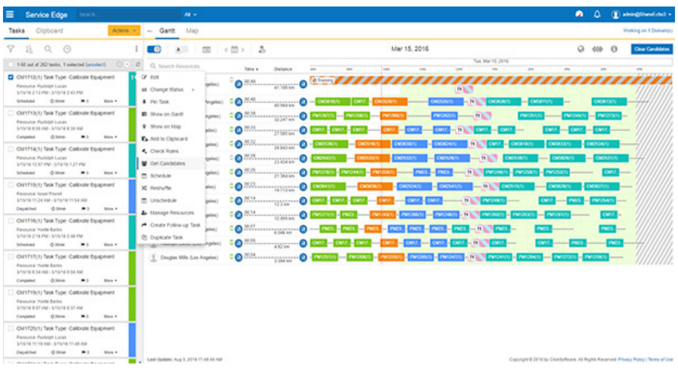
More complex problems require a technique called "Deep Learning" which will look at data from multiple angles in a sequence of "Layered" learning steps. This approach is often used to perform natural speech interpretation.

Examples of Machine Learning applications in EAM

There are many examples of the application of ML techniques in the EAM world, several of which focus on detecting equipment health or performance anomalies or predicting assets' Remaining Useful Life to support optimal maintenance tactics. Although very valuable, it should be recognised that AI can be applied in many other areas of EAM. Two examples below illustrate the potential for using ML in work and safety management applications.

Work Management and Resource Allocation

A large percentage of work management activities centres around the interpretation of work requests and required follow-up actions to assign the correct resources to the work for execution.



Source: ClickSoftware

Using Text/Sequence analysis, ML algorithms could perform much of this work in a more consistent manner by:

- validating and classifying work requests, removing duplicate requests and determining the level of urgency and likely resources required to perform the work;
- planning and optimally scheduling the work by assigning the correct resources to work orders and optimally scheduling the work based on priority;
- optimally allocating work to field service engineers based on their workloads, routes, traffic conditions, availability of assets to be worked on, etc;
- analysing textual feedback on work to initiate appropriate follow-up work or other administrative tasks to close out a work order.

Feedback analysis could also classify completed work and detect any anomalies relative to other similar work completed in the past.

Image Recognition (Machine Vision)

The application of machine vision in EAM has great potential to replace/improve all activities that involve visual observations to trigger actions.

Some examples include:

- detecting unauthorised access or activities based on facial recognition;
- detecting staff fatigue based on analysis of their facial expressions;
- detecting good/bad part or asset conditions.

Source: NEC

5 Virtual, Augmented and Mixed Reality

Virtual, Augmented and Mixed Reality technologies assist humans to use information stored in a two-dimensional format in a three-dimensional world to make better decisions and operate more efficiently by having the right information shared with them in a non-obtrusive, easily accessible manner.

This section considers the role of Virtual, Augmented and Mixed Reality in the Smart Asset Management landscape. Terminology for these technologies is often used interchangeably – the next paragraphs attempt to clarify the differences:

- **Virtual Reality** (VR) is a computer generated environment into which users are immersed. VR is often applied to virtually position (immerse) users in hazardous or remote locations where they cannot easily operate. This has good applications in training, design and remote control settings.
- **Augmented Reality** (AR) is an environment where digital information is superimposed over the real world in real time. This technology is useful to display useful information about the physical world over the user's own visual observations of the world. Good examples of AR are a virtual route marking and displaying equipment performance and health parameters. In other words, VR replaces the real world whereas AR enriches or adds to the real world.
- **Mixed Reality** (MR) is a combination of the two where computer generated objects are added to the real world. This could again be useful in design applications where design changes can be overlaid over the current physical world. This technology also allows the placement of "virtual" controls on physical assets, only visible and accessible through MR headsets.

It is important to keep in mind that all the static and dynamic asset and environmental data displayed in a virtual environment or overlaid in the physical environment has to come from somewhere. Apart from data originating from sensors in the VR, AR or MR devices, the dynamic information would often be relayed from sensors fitted to the physical world. Having a suitable edge to Cloud data transfer and processing solution available that can forward/make data available to the VR, AR or MR technology cannot be avoided. This dynamic data will often be meaningless if it cannot be combined with accurate master data such as equipment design information, work history and recorded equipment geospatial information. This is where an accurate asset register and custodian of the Digital Twin comes into play.

Applications of VR, AR and MR

There is a wide variety of applications of AR in industry. Some examples are briefly outlined below.

Safety

- Safety information about assets and environments can be overlaid onto them to steer artisans, operators and engineers clear from potential incidents.
- Work that requires a permit can be locked by the device and only displayed once the proper documentation is in place.

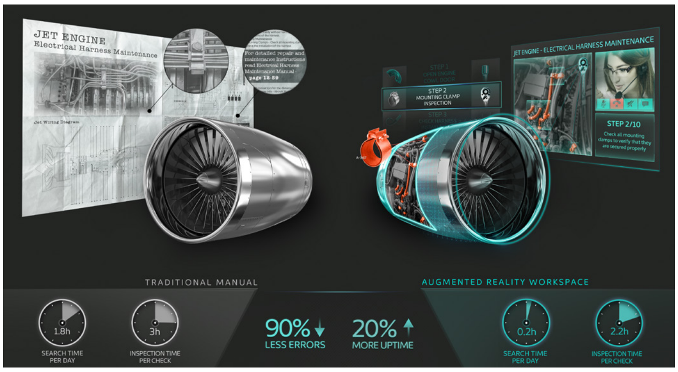
5 Virtual, Augmented and Mixed Reality

- Workers can be given training in a safe and controlled virtual environment that simulates the real world, but does not have any of the dangers of working on site.

Source: New Equipment Digest

Training

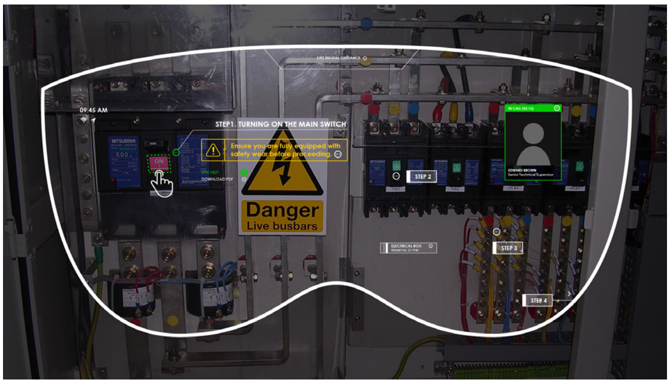
- An asset's anatomy can be understood without disassembling a single part or component.
- MR will also allow businesses to provide training without the physical asset being present.
- Following on this, it also means that you can provide training to employees scattered all over the world without having to have everyone in the same location.



Source: Reflekt

Maintenance task execution

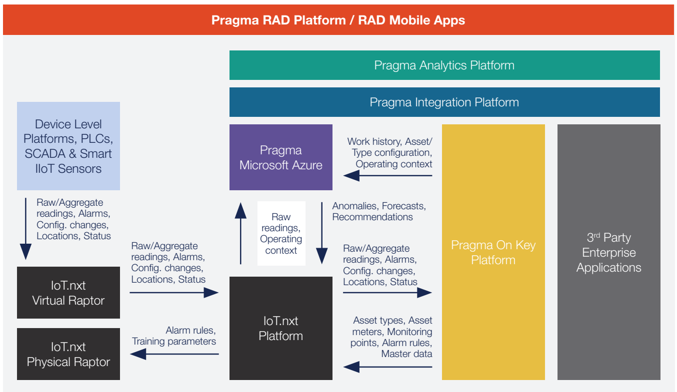
- Step-by-step task instructions will be projected onto real-world assets to assist artisans and engineers. This will ensure that maintenance tasks are being performed in the way they were designed to, resulting in less rework and damage to assets.
- The execution of a task can be recorded and reviewed if there was an unexpected breakdown, forcing workers to take responsibility for their work.
- In future, the end state of a component or asset after a maintenance task can be saved and near real-time image processing can be done by AI to ensure that the work was done in the way it was intended.
- Finally, the concept of experience leveraging will also start playing a role. Experts can assist less experienced workers remotely by either walking them through a task or making annotations on their real world views.



Source: Soluis Group

6 Pragma products for a connected SMART EAM landscape

With the rise of Cloud computing, micro service based architectures, blockchain and other information management technologies, the days of single source monolithic business applications to address EAM needs are numbered. In this platform based EAM system landscape, an accurate Intelligent Asset Register (IAR) acting as the custodian of the Digital Twin master data is crucial to realise a truly connected EAM landscape working off a single version of the truth with regards to asset master data. This IAR should host all asset information, maintenance plans, links to sensors, equipment manuals, resource requirements, etc required by other EAM system components to make forecasts, manage work, detect trends and manage costs. Pragma, through its On Key platform and solutions built on other partner platforms can provide such an integrated EAM system. Content in some of the platforms, such as AI algorithms, is still evolving, but the diagram alongside illustrates typical data flows made possible between the different components of Pragma's integrated EAM system.



The functions of the different components from partner platforms are described in more detail in the table below.

Pragma On Key Platform	Primary/master system used to configure asset types, assets, resources, maintenance plans, meters, monitoring points, asset configuration options, etc. On Key will also serve as primary system to manage all work triggered by other systems.
Pragma RAD Platform / RAD Mobile Apps	Host rapidly developed custom and standard native mobile and web apps to integrate with multiple underlying platforms that provide end users with fit-for-purpose apps which avoids duplication of data.
Pragma Integration Platform	Integrate different business applications incapable of direct integration to facilitate data transfer automation, data transformations, etc.
Pragma Analytics Platform	Provide a single platform from which data across different sources can be used for reporting, data mining, analysis and modelling.
Pragma Microsoft Azure	Store and perform advanced real-time processing of incoming IIoT data to detect anomalies, perform forecasts recognise patters (incl. machine vision).
IoT.nxt Platform	Perform IIoT device management, link up IIoT devices and sensors data streams to logical endpoints from where data can be processed through basic functions before being pushed to real-time visualisations and 3rd party systems.
IoT.nxt Physical Raptor	Interface to legacy sensors and equipment to collect data. Provide local data processing, aggregation and rule application before forwarding data on to IoT.nxt platform for further processing and integration with 3rd party systems.
IoT.nxt Virtual Raptor	Interface to digital data sources and systems. Platform local data processing, aggregation and rule application before forwarding data on to the IoT.nxt platform for further processing and integration with 3rd party systems.
Device Level Platforms, PLCs, SCADA & Smart IIoT Sensors	3rd party smart and digitised data sources such as LoraWAN and Sigfox platforms for smart IoT devices, legacy industrial measurement and control systems, OEM device platforms for Smart Assets, etc.
3rd Party Enterprise Applications	3rd party enterprise systems relying on information or actions originating from data collected through the IIoT solution.

7 Conclusion

The evolving connected Smart EAM landscape offers much opportunity to improve the performance of assets while keeping costs and risks in check by means of improved information based decision making and actions. This connected world does not come without its challenges though and a pragmatic approach to establishing the appropriate integrated technology platforms that can deliver on these promises is crucial.

Technology alone will not solve the complex challenges industry is faced with and a clear digital transformation strategy that considers business processes, people and technology will be required. The asset management aspects of this digital transformation need to be aligned with industry standards and best practices. Pragma, with many years' experience in asset management consulting, service delivery and product development experience along with our technology partners can guide clients on this journey to ensure success.

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