It’s just data, right? – How to bring your data to life and unlock the power of AI

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1. Introducing the era of proactive decision-making

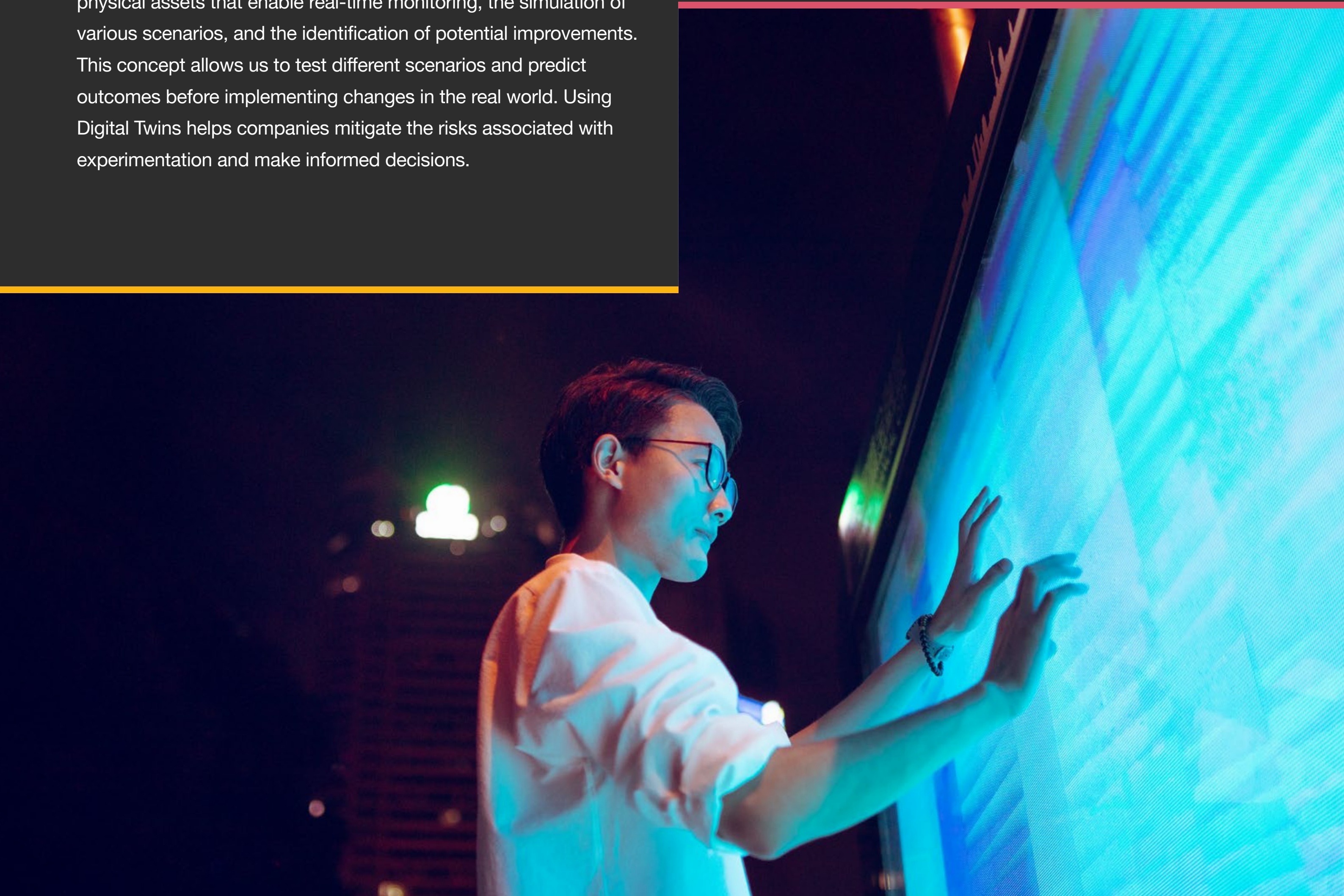
The evolution of data usage has come a long way since its beginning, from the early days of data storage, where data was used primarily for record-keeping and reactive decisions, to the current era, where data is used for proactive decision-making, predictive analytics, and automation. Most companies have realised that data is a valuable asset they can leverage to gain a competitive advantage and increase their efficiency and effectiveness. Businesses need to adopt innovative technologies and techniques to effectively utilise their data, processing it in real-time and visualising and interacting with it meaningfully to unfold these benefits. This way, they can take the right action at the right time.

That said, data without context is of limited value. Therefore, to extract valuable insights from data, it is essential to provide context and identify patterns. And this is where Digital Twins and AI come into play.

Digital Twins are virtual representations of processes, systems, and physical assets that enable real-time monitoring, the simulation of various scenarios, and the identification of potential improvements. This concept allows us to test different scenarios and predict outcomes before implementing changes in the real world. Using Digital Twins helps companies mitigate the risks associated with experimentation and make informed decisions.

At this point, businesses can incorporate another popular technology. AI, particularly Reinforcement Learning, enables them to automate complex decision-making processes and operate with a level of autonomy previously impossible. By combining these technologies, companies can create a powerful ecosystem to test innovative ideas and scenarios with fewer expensive physical prototypes, increasing development efficiency.

Companies can use these technologies to simulate any system and derive insights from the data collected. By connecting data from various sources and processing them in real-time, they can gain a holistic view of their operations and make data-driven decisions to improve their overall performance and profitability. Ultimately, this will lead to increased productivity, cost savings, and greater customer satisfaction.



2. From data to insights – Bring your data to life

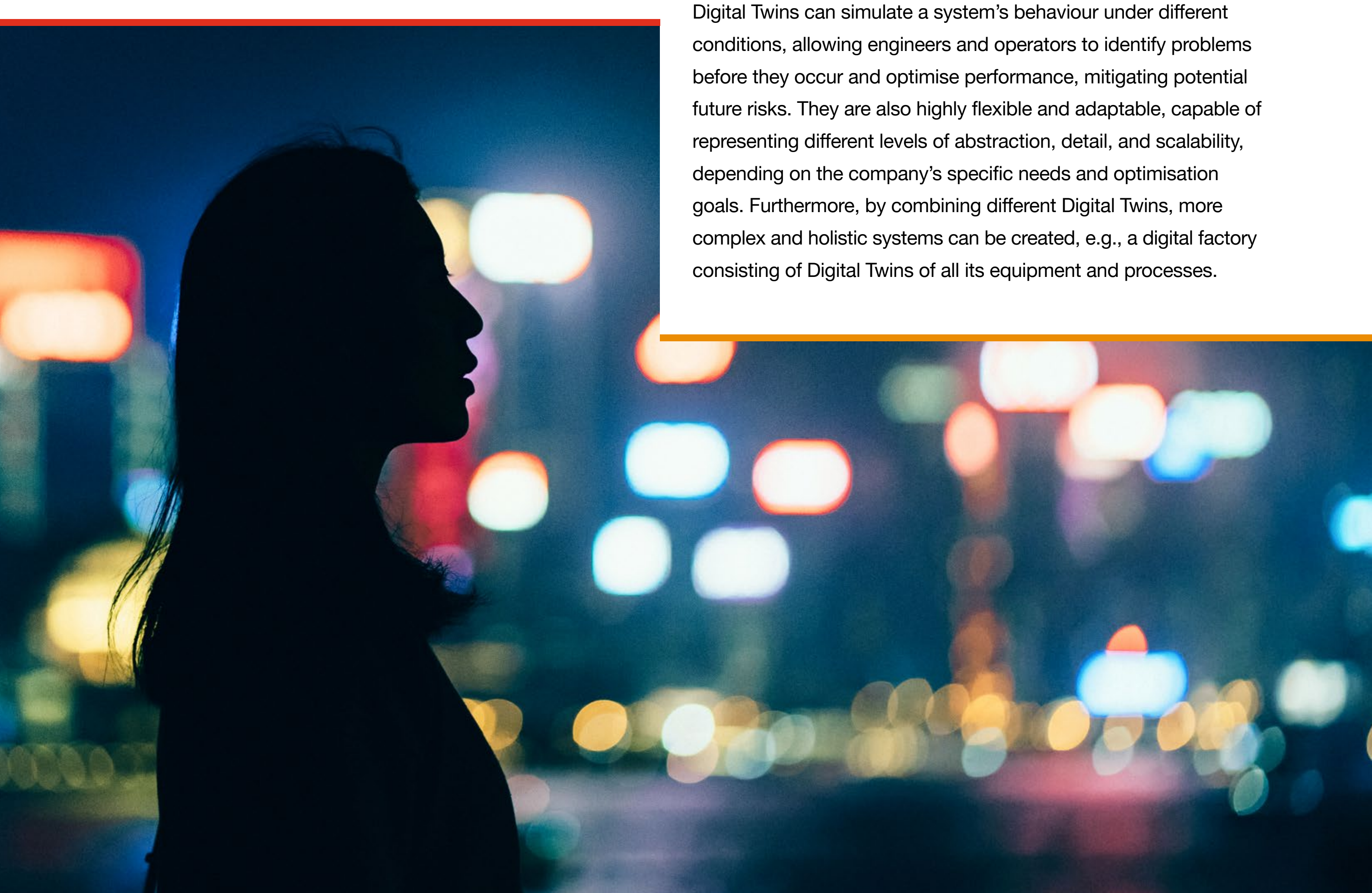
In today's business environment, data has become a vital, if not the most valuable, resource companies can use to gain insights, optimise processes, and drive growth. However, simply collecting data is not enough. To unleash its capabilities, companies must turn it into something more meaningful – a Digital Twin combining explicit data with implicit knowledge.

2.1 Digital Twins – Enabling Next-Generation Monitoring

One of the most critical aspects of future success is the ability to monitor and visualise data in real-time to take the necessary actions as soon as possible. With Virtual Reality (VR), it is possible to create virtual worlds, also called the Metaverse, where companies can visualise and interact with data. In the enterprise Metaverse, products or systems visualised by data allow for a highly immersive and interactive experience. This enables improved planning capabilities, decreasing business risks through early identification.

Figuratively speaking, the engine of any Metaverse is a Digital Twin or a collection of them. Digital Twins form complex and dynamic models that can capture the behaviour of a physical system or process in real time, enabling real-time analysis and prediction. The potential applications of Digital Twins are vast, from improving the efficiency of manufacturing processes to optimising the performance of complex systems such as aircraft engines, power plants and even entire cities.

Digital Twins can simulate a system's behaviour under different conditions, allowing engineers and operators to identify problems before they occur and optimise performance, mitigating potential future risks. They are also highly flexible and adaptable, capable of representing different levels of abstraction, detail, and scalability, depending on the company's specific needs and optimisation goals. Furthermore, by combining different Digital Twins, more complex and holistic systems can be created, e.g., a digital factory consisting of Digital Twins of all its equipment and processes.



For example,

a Digital Twin of a wind turbine might include highly detailed models of individual components, such as the blades and the gearbox, as well as more abstract models of the turbine's overall performance and power output or the monetary and material flow being used to create it so far. For instance, engineers can use the Digital Twin to simulate the impact of different environmental factors, such as wind speed and temperature, on the turbine's performance.

At the same time, business personnel can analyse the corresponding implications on performance. This simulation allows for proactive maintenance and predictive analysis of potential failures and business risks simultaneously. Moreover, by incorporating real-time data from sensors into the Digital Twin, engineers can test modifications and upgrades to he turbine while getting feedback for future improvements, decreasing development costs and risks.

This form of holistic, data-based Metaverse is highly detailed and provides a wealth of information companies can use to optimise, e.g., design physical products, improve factory layouts, or make informed decisions about business processes like subcontractor supply chain reliability. In addition to monitoring and looking at data, these immersive Digital Twins enable interaction using VR and AR technologies in a highly intuitive and natural way that feels like actual physical interactions. It also allows for collaboration between stakeholders, regardless of their physical location. By sharing the same Digital Twin, stakeholders can debate ideas, troubleshoot problems, and make real-time decisions. This shared access and collaboration decreases a product's time-to-market, giving the business a competitive edge.

The benefits of monitoring and interaction in the Metaverse are numerous. The process itself presents significant potential, allowing organisations to accumulate valuable experiences, gain insights into internal business processes, and instil trust in modern technologies. By creating a highly detailed and immersive virtual world, stakeholders can assess profitable investments, identify issues more quickly, and optimise performance. In addition, the ability to monitor and interact with data allows for better and faster decision-making.

For example,

engineers can use VR to enter the Digital Twin of a power plant and interact with the various components, such as turbines, boilers, and generators, in a highly realistic and intuitive way. At the same time, business personnel can look at the performance KPIs in detail. This enables them to train new employees, identify issues, test solutions, and optimise performance in a safe and controlled environment.

2.2 The whole is greater than the sum of its parts – Introducing Next-Generation Simulations

In today's business world, data is not just about monitoring and visualisation. It is about understanding the story behind the numbers and using that information to make better decisions. Combining data from different sources to provide context can give businesses a more comprehensive view of their operations and help them identify trends and patterns that might not be evident when looking at each data set individually.

One way to achieve this is through the interaction of different Digital Twins – framed as simulations. **Digital Twin-based simulations allow businesses to create virtual environments to test different scenarios and strategies without investing in, for example, physical prototypes or expensive real-world experiments.** This can help businesses quickly identify improvement areas and optimise their operations accordingly.

In this context, the benefits of Digital Twins simulations are significant:

First, simulations help to **identify operational inefficiencies** and find ways to **optimise processes**. A great example is restructuring a company's suppliers. Imagine a retail company that identified significant delays caused by one supplier. Based on the supplier's Digital Twin, the retailer can simulate

1. the impact of changing the supplier or
2. how to minimise the supplier's impact on the business.

This procedure allows the retailer to optimise the process in the most efficient way.

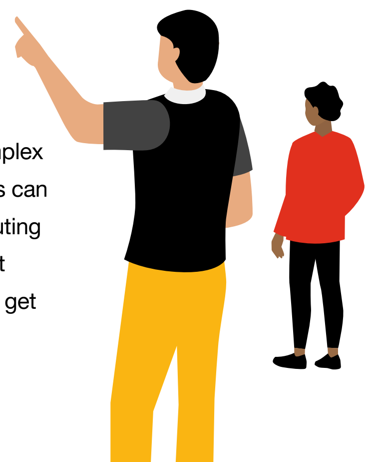
Second, simulations through Digital Twins can help **analyse future scenarios** by providing insights into how operations might be affected by manipulating different operational aspects. For example, a power utility company can simulate its machinery based on Digital Twins to investigate where to install renewable energy sources to maximise production. Digital Twins also enable simulations of emergency measures to minimise potential damages during extreme weather events, such as hurricanes or earthquakes. These examples show how Digital Twin-based simulations help identify potential operational vulnerabilities and develop mitigation strategies.

Finally, Digital Twin-based simulations **reduce business risks** by allowing companies to test new ideas and innovations in a safe, controlled sandbox environment. A great example is testing an aircraft cabin's design and functionality. Here, Digital Twins and a simulation in VR can put design decisions to a practical test at an early stage. This early testing is crucial in industries where mistakes have serious consequences, such as aviation or healthcare. By simulating the impact of new technologies or procedures, businesses can identify potential issues, e.g., problems with building escape routes, and address them before they become real-world problems, preventing costly design changes or project delays.

However, there are limitations to Digital Twin-based simulations. One of the main challenges is the accuracy of the models used. Simulations must be based on accurate and reliable Digital Twins for meaningful insights. If the data used to create the simulation is incomplete or inaccurate, the results might be unreliable. Therefore, balancing having as much detail as possible and as little as necessary is crucial. This simulation-reality-gap should be minimised to ensure the simulation's accuracy and validity.

It should also be acknowledged that increasing the amount of data is not a universal solution. This approach can lead to higher computing power requirements, increasing time and costs. Moreover, indiscriminately adding more data can introduce additional noise, deteriorating the quality of the analysis. Hence, careful consideration is needed to determine the optimal data granularity and completeness level for achieving reliable and meaningful insights that inform decision-making. The complexity of Digital Twins can also present challenges when combining them with simulations.

As Digital Twins become more detailed and closer to reality, it may be more difficult to simulate complex scenarios accurately. Overcoming this can require a significant amount of computing power or expertise. This is where best practices and experiences are vital to get to the profitability sweet spot.



2.3 Trust is the foundation of every successful technology

As we've seen, Digital Twins can provide a wealth of insights and value, but only if they are worth our trust. Here, trust grows through combining fundamental principles such as security, safety, privacy, and reliability, demonstrated through positive immersive experiences. In the context of Digital Twins, this means ensuring that the data used to create a Digital Twin is accurate and up to date, secure and protected from unauthorised access, and operates reliably and consistently. These principles, among others, are precisely defined and considered in regulations, criteria catalogues, norms, and standards such as the AI Cloud Service Compliance Criteria Catalogue (AIC4)[1], the Cloud Computing Compliance Controls Catalogue (C5)[2], the EU AI Act[3], and other standards of different countries. You can find more detailed information about these principles in Section 3.3.

Therefore, **in the context of digitisation, we define trust as the confidence individuals, organisations, and society have in the safe, secure, and ethical use of user-centric digital technology**. It is the belief that digital products and services will function as intended and deliver the expected outcomes, and only them.

One proven and experience-backed approach to building trust in Digital Twins is a "trusted-by-design" ethos. **This ethos means integrating security, privacy, transparency, and reliability into the design from the start rather than trying to retrofit them later or after deployment**. A trusted-by-design approach involves taking a holistic view of the Digital Twin, considering the Digital Twin itself and the systems and processes surrounding it, such as the data sources, cloud infrastructure and organisational framework.

Transparency is another crucial aspect of building trust in Digital Twins. Users must understand how the Digital Twin was created, what data it uses, and how it operates. Clear documentation, open communication, user-friendly interfaces, objective support, and independent system audits can achieve this. Ultimately, building trust in Digital Twins is essential to realising their full potential. Only by ensuring their accuracy, security, and reliability can we fully leverage their insights and value to drive innovation and growth across different industries.

1 https://www.bsi.bund.de/EN/Themen/Unternehmen-und-Organisationen/Informationen-und-Empfehlungen/Kuenstliche-Intelligenz/AIC4/aic4_node.html

2 https://www.bsi.bund.de/EN/Themen/Unternehmen-und-Organisationen/Informationen-und-Empfehlungen/Empfehlungen-nach-Angriffszielen/Cloud-Computing/Kriterienkatalog-C5/kriterienkatalog-c5_node.html

3 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52021PC0206

3. From simulated insights to AI-enhanced automation

Digital Twins provide a powerful tool for providing context to data and enabling new insights. But what if we take this concept further and create a smart simulation of our entire business or supply chain? This is where the concept of a Digital Twin combined with AI-enhanced simulation comes in. By creating a smart simulation, we can experiment with different scenarios, test hypotheses, and actively explore what-if scenarios - just as a biologist does with cultures in a petri dish. This can be incredibly valuable for businesses in all sorts of industries, from manufacturing to supply chain management to healthcare.

3.1 When the system learns to operate itself – Next-Generation Automation

Combining Artificial Intelligence with Digital Twins truly unlocks their potential. AI can help analyse the vast amount of data structured through Digital Twins and provide valuable insights for improving businesses and increasing efficiency. One use case for blending AI with Digital Twins is the ability to create predictive models to identify patterns and predict events.

Using Machine Learning (ML) to enhance Digital Twins allows the identification of anomalies and data patterns that would be difficult or impossible for humans to detect, especially in complex systems where emerging patterns and sudden tipping points often occur. For example, by implementing predictive maintenance systems, companies can identify potential issues before they become major problems, decreasing unscheduled and expensive downtime. Digital Twins provide real-time representations and generate data, such as asset degradation, that the predictive maintenance algorithm can use.

Integrating Reinforcement Learning (RL) proves to be particularly suited to amplifying the potential of Digital Twins further. RL's ability to learn through trial and error, combined with the real-time representations provided by Digital Twins, identifies intricate patterns and tipping points that often occur in complex systems. RL explores data in virtual environments and is often used in situations where there are complex and dynamic states of a system with many possible actions. It learns to make good decisions guided by a value (reward) that indicates to what extent the decisions lead to good overall performance.

To make good decisions, RL learns to understand the rules underlying the simulation (Figure 1). After training, the model is deployed in the production environment, where it interacts with the real-world asset or operation, provides insights and recommendations, or even takes action itself. A significant advantage of RL is that it enables systems to learn to operate without regular human intervention. This decreases the reliance on highly skilled personnel, enables real-time process adoption and increases overall efficiency.

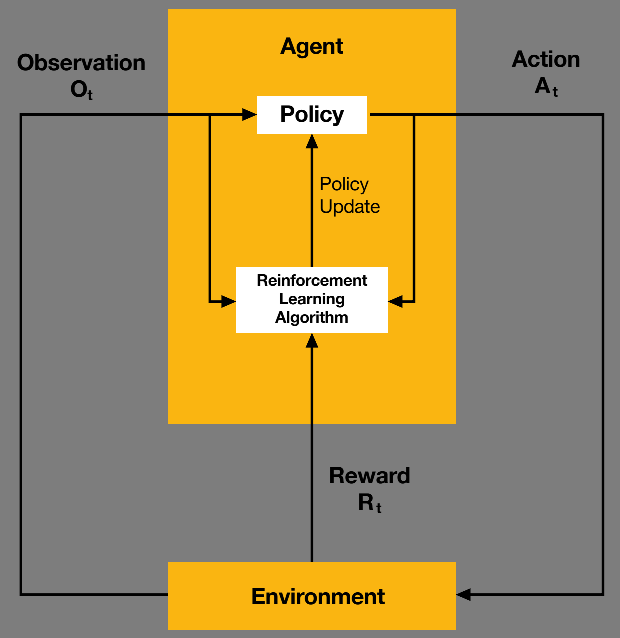
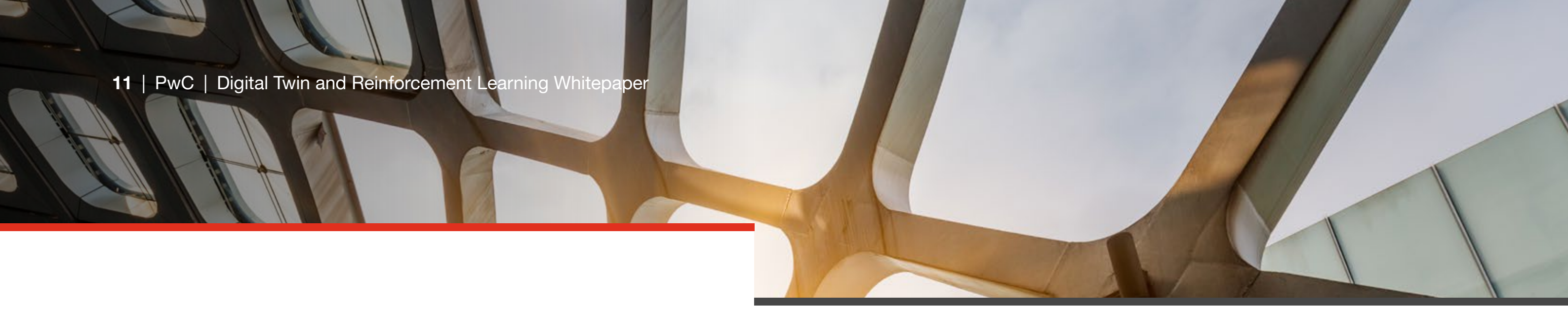


Figure 1: Reinforcement Learning architecture

Implementing RL in a manufacturing context requires a detailed and structured approach that leverages tools and best practices such as MLOps. The MLOps framework is a streamlined process that combines machine learning and DevOps practices to develop, deploy, and maintain machine learning models efficiently. It involves several steps:



MLOps emphasises version control, automation, and collaboration among data scientists, software engineers, and operations teams. It also integrates Continuous Integration/Continuous Deployment (CI/CD) pipelines, automated testing, and infrastructure management tools. By adopting MLOps, organisations can accelerate the development cycle, ensure model reliability, and effectively manage ML systems at scale, decreasing the time-to-market and development costs while enabling structured portfolio enhancements.

ML also provides a framework for deploying, monitoring, and scaling RL algorithms in production environments. This framework ensures the algorithms perform as expected and deliver valuable insights to optimise operations and improve efficiency. To ensure the algorithm provides valuable insights over time, operators can adjust the RL algorithm based on these metrics, which means going through another development cycle in the AI lifecycle loop (Figure 2).

In manufacturing, deploying RL algorithms using MLOps is a powerful way to optimise operations and improve efficiency while ensuring trust along the development process. By leveraging MLOps tools and best practices, decision-makers can confidently deploy and scale RL algorithms, knowing they deliver valuable insights and improve performance over time.

Implementing RL systems can be challenging due to the various aspects to consider during development. Organisations should establish robust governance frameworks to ensure RL systems' safe and ethical operation, incorporating principles such as fairness, transparency, and accountability. Regular audits and oversight mechanisms can help detect and mitigate any biases or unintended consequences.

Despite the challenges, organisations continue to explore the capabilities of RL because of its potential benefits in enhancing decision-making and driving business performance. As technology advances, RL is becoming an increasingly important tool for optimising complex systems and improving product development through informed decision-making. The gained knowledge gives a competitive edge to the business implementing the disruptive potential of RL and Digital Twins.

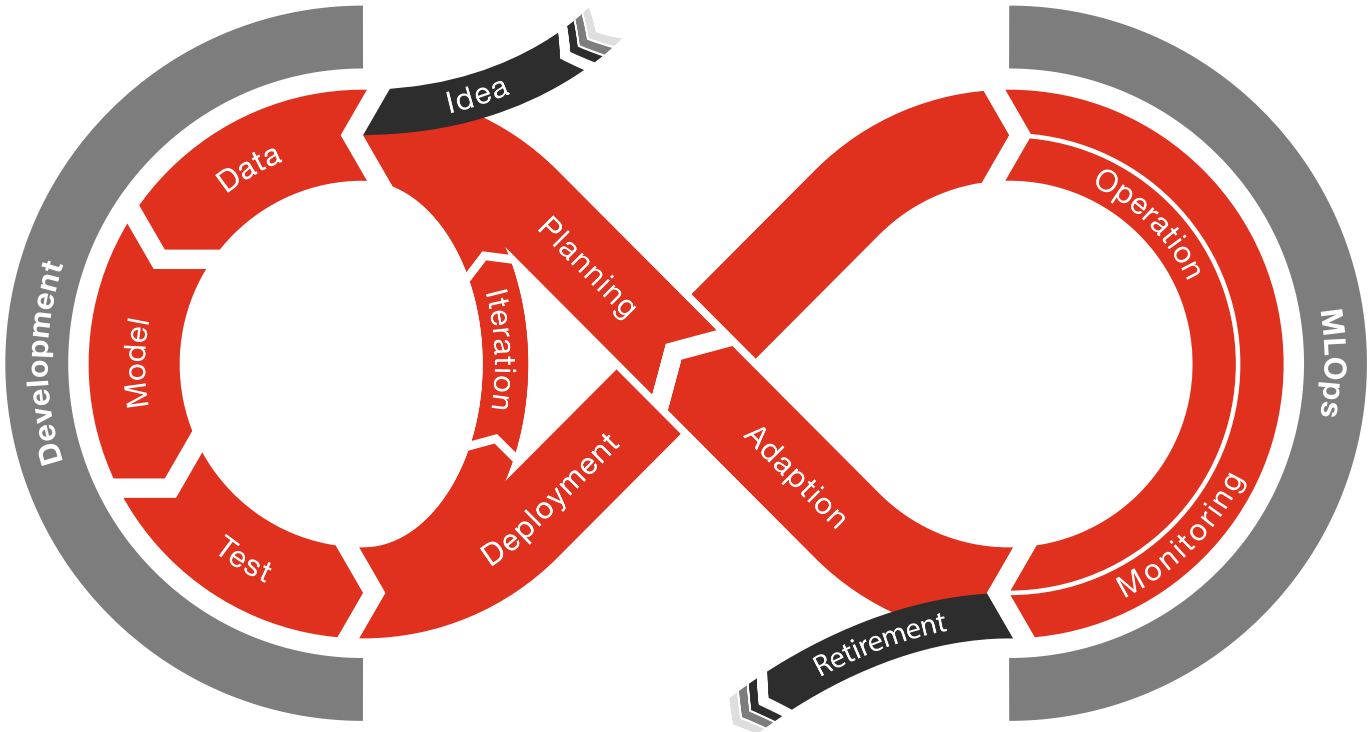
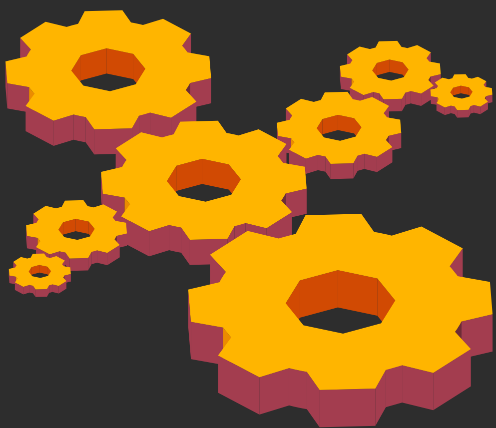


Figure 2: AI lifecycle

3.2 How technology is changing the way we work

In **manufacturing**, for example, RL agents can optimise performance and minimise waste and downtime by continuously monitoring the production environment and adjusting actions based on feedback. A leading packaging solutions manufacturer for the food industry uses RL to optimise production plant control. The RL agent adjusts the production parameters within seconds according to the available material properties and external parameters, such as the current temperature and humidity of the production hall. This enables high-quality parts to be produced even from defective materials.

In **logistics**, RL is a powerful tool for optimising supply chain operations. In a Digital Twin of a warehouse, for example, an RL agent could learn to optimise the placement of goods based on demand patterns while considering factors such as space constraints, frequency of use, and delivery schedules. Further, RL can optimise control systems by analysing real-time data from sensors and other sources. An RL agent could decide how best to adjust operations to maximise efficiency and minimise waste.



RL can also enable automatically guided vehicles to learn to optimise dispatching tasks in matrix production systems. RL agents can adapt to changing market conditions and improve efficiency and profitability by learning to make routing, inventory management, and scheduling decisions. Through continuous learning from experience, they can identify the most efficient and effective ways to manage supply chain operations, minimising costs and maximising output.

In **healthcare**, Digital Twins coupled with RL hold great promise for personalising treatment plans and improving patient outcomes. By creating virtual replicas (Digital Twins) of patients and continuously learning from data and feed-back on individual patient characteristics and medical histories, RL agents operating within Digital Twins can optimise treatment plans, identify new treatments and therapies, and adapt to each patient's unique needs, maximising the chances of successful outcomes. By leveraging Digital Twins and RL, personalised medicine has the potential to revolutionise the healthcare industry, delivering better patient outcomes, fostering trust through transparency and reducing healthcare providers' costs.

Digital Twins and RL can improve **risk management** in highly regulated business processes such as accounting. By creating a Digital Twin of the accounting system, RL can be trained to make decisions based on real-time feedback. The RL agent can learn to identify potential fraud, detect anomalies, and optimise risk mitigation strategies. This approach enables proactive risk management, reduces human error, and enhances the accuracy and efficiency of accounting processes, ultimately ensuring financial integrity and compliance.

A **property letting** agent can utilise a Digital Twin to optimise energy consumption, improve tenant experiences, and enhance space management. The company can identify inefficiencies, adjust systems, and save energy costs by monitoring and analysing data from various sources (e.g., sensors) in real-time. The Digital Twin also empowers tenants to control their space, request maintenance services, and access building information, increasing satisfaction and engagement.

3.3 How to enter the future from a business's perspective

While combining Digital Twins and AI has great potential, it is essential to recognise the risks involved. These risks range from technical issues to ethical concerns and must be carefully considered and addressed. For example, risks arise from flawed data used for training AI models, leading to inaccurate predictions and unsafe decisions. High-quality, up-to-date data and involving subject matter experts are crucial to mitigate this. Companies can also address biases arising in ethical concerns by designing transparent and fair AI systems. Moreover, blind trust in automation increases the risk of following the wrong AI recommendations, possibly with unintended consequences. This highlights the need for human supervision and control.

To mitigate the risks associated with combining Digital Twins and AI, enable a trustworthy holistic AI transformation, ensure profitability and improve efficiency, businesses can integrate AI and Digital Twins into operating systems successfully by taking these six steps.

1. Readiness Check:

Assess the components and approach needed to integrate AI and DT, e.g., data, IT, security, and ethical considerations. Provide a clear understanding of where the company stands and develop a customised guidance plan for becoming AI/DT ready.

2. Strategy:

Identify the necessary competencies, decisions, and guidelines while focusing resources on efficient and agile implementation. Develop a tailored, comprehensive strategy to leverage the potential of AI/DT.

3. Use-Case Ideation and Prototyping:

Define and develop relevant use cases and establish an innovation process and a customised implementation plan. Then test your ideas by building a prototype and a minimal viable product.

4. Concept and Development:

Select algorithms and tools, guide positioning, advise on architecture, and provide guidance on developing the AI lifecycle. Establish systems that meet business objectives.

5. Trusted-by-Design MLOps:

While developing AI systems, consider security and robustness, performance and functionality, reliability, data quality, data management, explainability, transparency, and ethical principles. Rely on best practices and standardised pipelines to confidently implement trusted and reliable AI systems.

6. Governance and Compliance:

Throughout the process, consider the applicable regulations and develop a governance transformation plan to make the company AI and Digital Twin ready. A plan helps support and ensure compliance and mitigates potential risks.

This holistic approach provides a clear understanding of the company's current status. Considering the business's key performance indicators, it builds a customised plan for AI/DT readiness to develop and operate the most promising AI/DT services. This way, companies can realise the technology's maximum potential and guide the AI lifecycle, positioning, architecture, and development. Following these steps, businesses can confidently implement trusted and reliable AI systems and play a leading role in this rapidly evolving field while maintaining their focus on the overall vision:

REDUCING COSTS | **IMPROVING EFFICIENCIES** | **ENABLING TRUST THROUGH DATA**

3.4 Trusted-by-Design – Embedding trust into the entire system

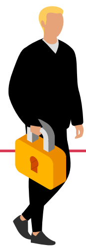
The rapid adoption of AI technologies has led to the emergence of AI-enhanced Digital Twins and simulation models that offer rapid insights, fast decision-making, and high reactivity across industries. However, as systems become increasingly complex and integrated, trust becomes critical in their successful deployment. Building trust in the system ensures decision-makers can rely on an AI-enhanced Digital Twin model's insights and recommendations.

Expanding on the trusted-by-design principles introduced in Chapter 2.3, it is imperative to approach system design with knowledge and experience of the relevant principles, with security, reliability, ethics and data integrity at the forefront. This approach means these principles must be woven into the system's fabric from conception to implementation. Trusted-by-design systems have built-in safeguards that prevent malicious actors from tampering with the data, ensuring that decision-makers can rely on the system's accuracy and authenticity.

Companies can take concrete measures to establish trusted-by-design principles for AI-enhanced systems. These measures include:

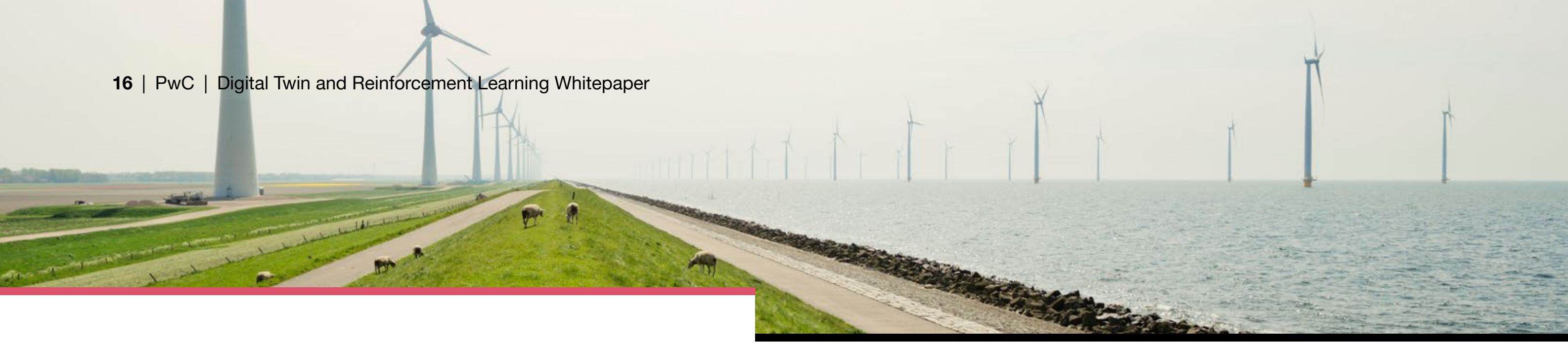
1. Data Integrity:

One of the most critical factors in building trust in AI-enhanced systems is data integrity. Data integrity means ensuring data is accurate, complete, and consistent throughout its lifecycle. Companies can achieve this by implementing data validation and verification mechanisms, such as checksums, digital signatures, and encryption. Ensuring that the data sources are reliable and trustworthy is also crucial. Trusted data sources can be identified through data provenance and data lineage techniques, which provide a complete record of how data was collected, processed, and analysed.



2. Secure Infrastructure:

A secure infrastructure is essential to an AI-enhanced system's security and reliability. This includes implementing secure network and communication protocols, access control mechanisms, and storage systems. It is also important to see that the system's hardware and software components are reliable and trustworthy. Trusted hardware is achieved through hardware-based security mechanisms such as secure enclaves, hardware root of trust, and secure boot mechanisms. Start with a thorough analysis of the system requirements and use cases; this should consider the system's technical requirements and the potential risks and vulnerabilities that may arise.



3. Explainability and Transparency:

Explainability and transparency are essential for establishing trust in AI-enhanced systems. Decision-makers are interested in understanding how a system arrives at its recommendations and insights. Companies can achieve this to a certain degree through explainable AI techniques, which provide a clear and interpretable explanation of how the system arrived at its output. They can also achieve transparency through data visualisation and reporting, which provide a clear and accessible view of the system's performance and outputs and through open-source releases of the different development stages.

4. Human Oversight:

Human oversight is crucial for the reliability and trustworthiness of AI-enhanced systems. Humans are needed to interpret and contextualise a system's insights and recommendations. Companies can achieve this with human-in-the-loop systems, where humans provide feedback and guidance on the system. Designing the system with human-centred principles and considering end users' needs and requirements is essential.

5. Continuous Monitoring and Improvement:

Continuous monitoring and improvement are essential to maintaining AI-enhanced systems security, reliability, and trustworthiness in evolving conditions. This includes monitoring performance, detecting and mitigating security threats, continuously improving system capabilities and functionality, regularly assessing the system's security posture, and automated testing tools and techniques to identify potential vulnerabilities. By adopting a proactive approach to monitoring and testing, designers can quickly identify and address potential issues before malicious actors can exploit them. Again, it is crucial to establish a feedback loop where users can give feedback on the system's performance to improve its accuracy and reliability.

Building trust in AI-enhanced systems ensures that decision-makers can rely on the insights and recommendations provided. Proven trusted-by-design principles and hands-on experience help establish trust by designing systems from the ground up with security, reliability, and data integrity in mind. Only then can businesses unfold the true potential of Digital Twins, simulations, and Reinforcement Learning.

4. Conclusion

Digital Twins and AI are transforming industries and opening new possibilities for businesses. By bringing their data to life, organisations can improve decision-making, reduce risks and costs, and increase efficiency. The potential benefits of using Digital Twins and AI are enormous, and these technologies will continue to evolve and improve over time.

Through the evolution of data usage and the power of Digital Twins to create virtual representations of physical assets, they demonstrate the potential of monitoring and visualising real-time data through Digital Twins, leading to enhanced insights and decision-making.

Combining Digital Twins and AI enables organisations to create simulations that aid their understanding of complex systems and preparations for the future. Trust is a fundamental aspect of Digital Twins and AI, as it ensures the success of data and technology projects. By prioritising trustworthiness in designing Digital Twins and AI systems, organisations can instil confidence in their technology and benefit from reduced costs, improved product developments, automation, and enhanced trust in technology.

DT and RL have applications across various industries, including energy and manufacturing, facilitating streamlined operations and unlocking competitive advantages. Use cases in manufacturing, logistics, and healthcare exemplify the impact of these technologies on businesses, such as reduced downtime and improved product quality. Looking ahead, it is evident that Digital Twins and AI will continue to be crucial drivers of business transformation.

Organisations that embrace these technologies can gain a competitive edge by enhancing operations, minimising costs, and accessing new possibilities. However, it is imperative to approach these technologies comprehensively, with a clear strategy and a focus on trustworthiness.

We invite you to learn more about Digital Twins and AI and explore how these technologies can benefit your business. Our team of experts can provide guidance and practical support to help you implement these technologies effectively and realise their full potential. With the right approach, Digital Twins and AI can revolutionise your business and drive success in the years to come.

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