DIGITAL TWINS AND AI FOR CONTAINER TERMINALS

"SIMULATION TECHNOLOGY HAS SUCCESSFULLY TAKEN ITS PLACE IN THE PORT AND TERMINAL INDUSTRY."



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Recent years have again shown how vulnerable global supply chains are when it comes to disruptions. Different situations, such as terminal lockdowns, the Suez Canal obstruction, and Brexit, led to situations where major bottlenecks occurred at container terminals. At the same time, container terminals are under pressure, forced to serve bigger and bigger vessels with more cargo per arrival in shorter times. And, what's more, requirements regarding environmental sustainability are rising.

While enhancing the productivity in container terminals, new means to improve resilience and eco-friendliness are more important than ever. The use of digital technologies can significantly increase transparency and, together with Artificial Intelligence (AI), forms an important basis for operational and strategic decisions. The digital twin is considered as key concept and enables physical systems to be represented in the digital world. This builds a basis for various use cases supporting harsh day-to-day operation at the terminal.

DIGITAL TWINS

What is a digital twin? Digitalisation has taken big steps in the industry in previous years. More and more sensors are plugged into machines to provide data of the current state of each single component of the system. But how to make use of large amounts of data in daily operations?

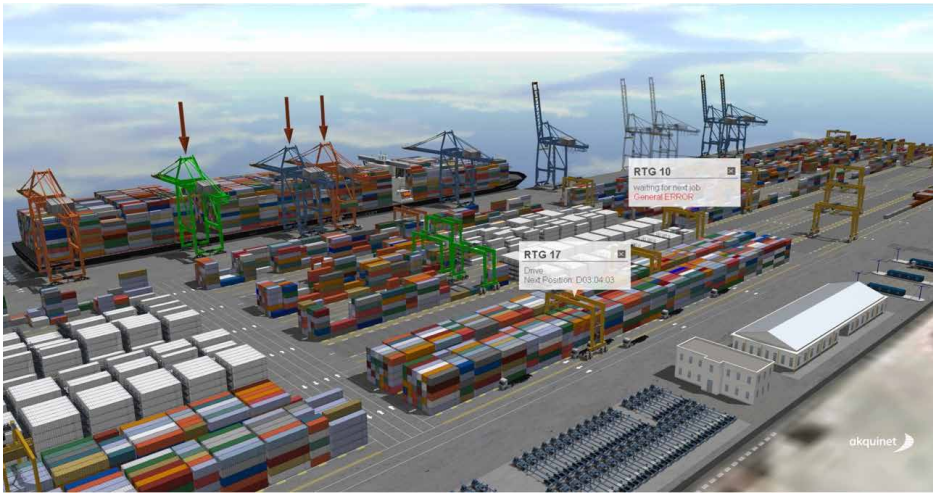
According to VanDerHorn and Mahadevan (2021), a digital twin is a virtual representation of a physical system (and its associated environment and processes) that is updated through the exchange of information between the physical and virtual systems. Essential is that there is a constant and bilateral data connection between the physical and virtual systems. That is, digital twins are able to represent real-time data, such as in forms of visualisations, but are also utilising data from different sources to have an impact on the operational processes by analysing data and providing decision support. The association of the environment and processes is crucial for this symbiosis, achieved by applying sensor technologies and connecting operational systems.

But a digital twin not only allows to represent the current state of a physical system. By using modern data storage systems, we are able to jump back in time and learn from past processes and even project future scenarios using predictive analytics. And now comes the clue: we are able to even adjust operational parameters and circumstances in a way that we can ask questions like "What would have happened if..." and get certain answers from our digital twin who can visit other places and situations, get back, and share those experiences and learnings with his physical twin.

IMPORTANT FUNCTIONS AND USE CASES IN CONTAINER TERMINALS

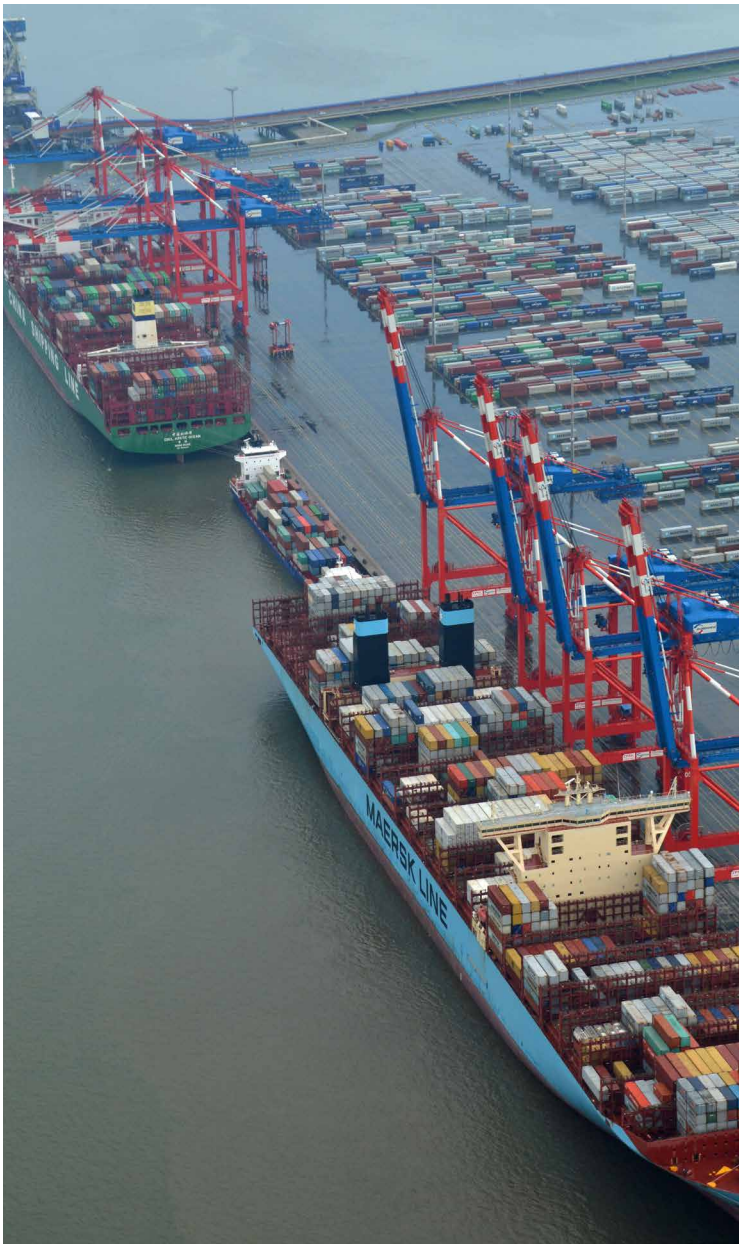
Visualisation and Monitoring

Most people think in pictures instead of bits and bytes or tables. Thus, for humans, providing a view based on pictures will be the perfect view of the current operation at the terminal. 3D-Animations – known from the



BELOW - FIGURE 1
CHESSCON Live-View

"3D-ANIMATIONS... HAVE MADE ENORMOUS DEVELOPMENTS IN RECENT YEARS, WHICH ALLOWS THE USE OF THIS TECHNOLOGY FOR REAL-TIME VISUALISATION OF ALL PROCESSES AT THE TERMINAL."



LEFT
CSCL Arctic Ocean, Unifeeder Spirit and Marie Maersk at EUROGATE Container Terminal Wilhelmshaven
Source: EUROGATE

gaming industry – have made enormous developments in recent years, which allows the use of this technology for real-time visualisation of all processes at the terminal as a "Live-View" (see Figure 1).

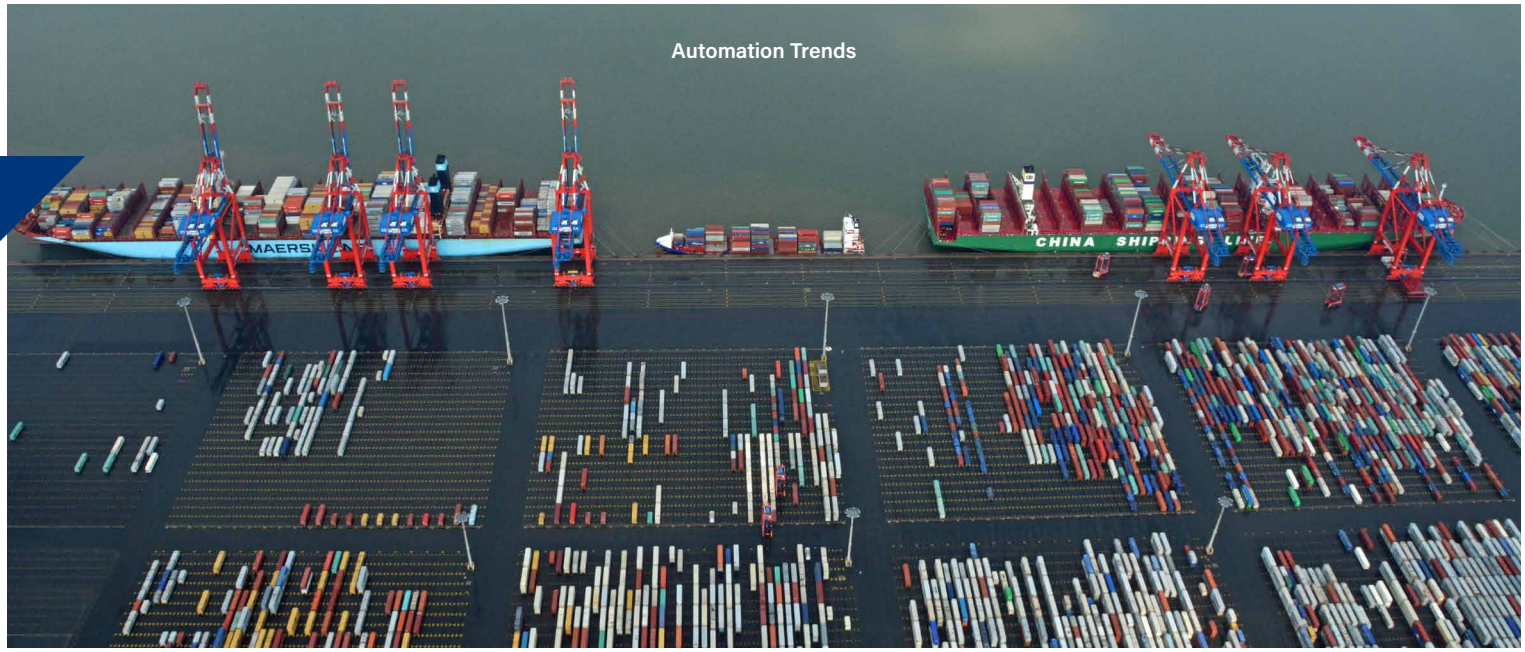
The first idea that comes to mind is that we need to show the same view as looking out of the window from the control room. But, the use of Augmented Reality (AR) or even Virtual Reality (VR) functions will allow the highlighting of specific activities and states additional to the real world view and can be also used for training purposes.

Other views for terminal staff may be dashboards, showing on one view the current state of all machines of a specific equipment type or aspects from operational processes. By selecting a specific piece of equipment in the 3D-live-visualisation or in the dashboard related properties can be shown which may be different, for example, for yard planners or maintenance staff. Planners might be further interested in contextual information, such as in which process the Container Handling Equipment (CHE) is currently working and what the next jobs are.

Monitoring is used to analyse the recent past and shows the results in a dashboard with pre-defined KPIs. It allows to trigger notifications or even processes in case pre-defined thresholds are exceeded. Moreover, we can monitor the current utilisation of CHE to support the best selection of equipment based on sophisticated algorithms. It further allows to track the conditions of superstructure, especially CHE, in order to estimate when maintenance should be performed.

Simulation

Simulation technology has successfully taken its place in the port and terminal industry mainly for planning, testing and training tasks. Based on a digital twin it currently supports day-to-day operations at the terminal.



There are mainly two fields of applications:

- Based on the whole information saved in the recent past, "re-plays" of historical scenarios are possible. The control staff may re-run the scenario from a recent shift and replay the operation to analyse occurred bottlenecks or inefficiencies. Furthermore, the planners may run exactly the same scenario with another set of planning parameters to understand and learn how to act better next time.
- Terminal operators may also use simulation technology to forecast the upcoming operation. Based on the current state of the terminal and all its components, the scenario for a simulation run is more or less fully defined. Additional to the states of the yard and all pieces of equipment, the current state of the planning parameters out of the TOS has to be provided to the simulation. This preview functionality can be be started by the terminal staff, but it may also run in a scheduled way. In this case warnings will automatically be generated, if pre-defined milestones (such as when a vessel service is finished) will not be achieved. Thus, either the control staff or – in a more automated way — the Terminal Operating System (TOS) may rethink the current planning and adapt it to the results of the preview.

Both applications of the simulation technology, the "re-play" of historic scenarios as well as the "preview" of the upcoming operation, support the terminal operator and the algorithms in the TOS to find the best decisions and improve the planning of the operation, which will lead to more productive and more efficient processes.

Predictive analysis based on AI

Another upcoming trend in the port and terminal industry is the field of AI. Again, the data collected within the digital twin is used as a base for AI methods. These methods analyse the big amount of data available and detect correlations between various parameters as well as patterns leading to specific situations. These insights are incorporated in sophisticated optimisation algorithms that automatically and dynamically support planning decisions (such as allocation and dispatching of CHE, assignment of yard storage locations, and on) in order to optimise certain objectives, like the utilisation of equipment, empty trips, and environmental impact.

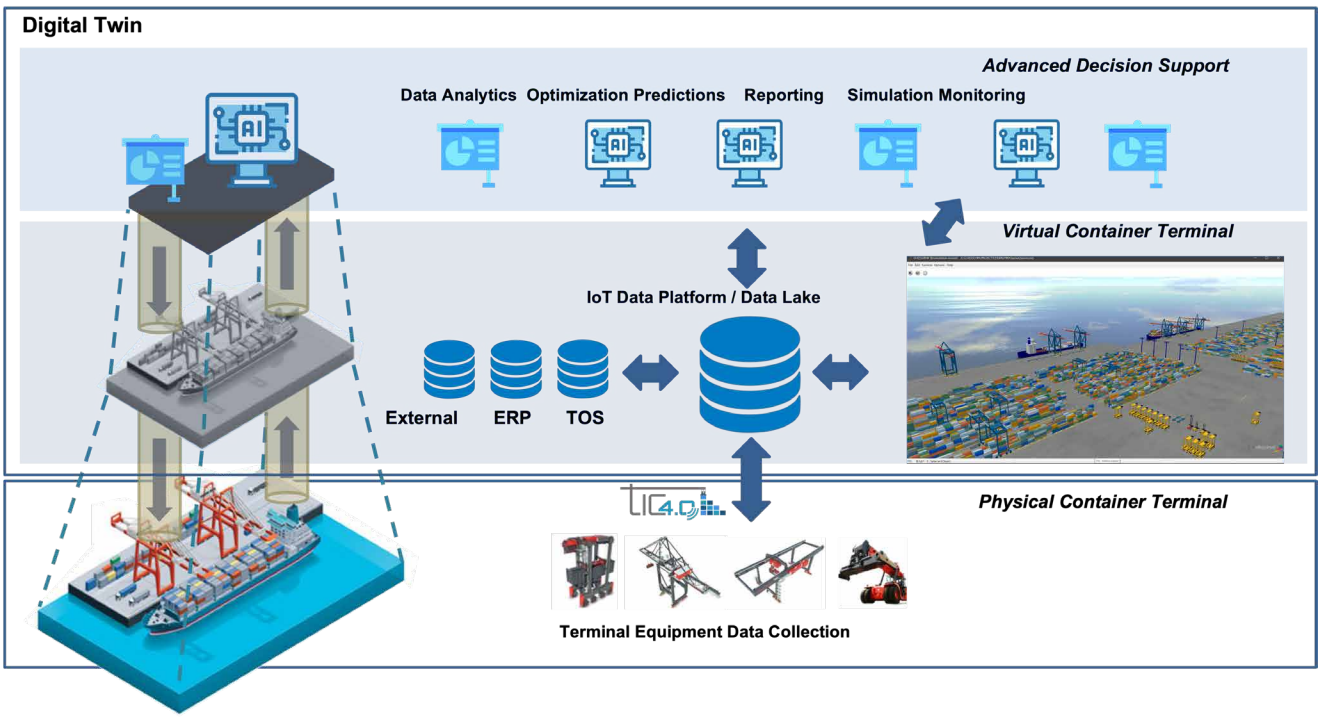
Another application is predictive maintenance: in this case patterns of sensor data are detected which lets terminal staff know to expect a break down of the device within the next hours/ days and maintain the equipment condition dependent instead of fixed time intervals only. This can be used to better align operational and maintenance processes in order to be more resilient against breakdown-related disruptions.

ABOVE
Marie Maersk, Unifeeder Spirit and CSCL Arctic Ocean at EUROGATE Container Terminal Wilhelmshaven
Source: EUROGATE

"WITHIN A FOUR-LEVEL ARCHITECTURE A 3D LIVE VISUALISATION WILL BE PROVIDED, SHOWING THE WHOLE TERMINAL WITH ALL ITS OBJECTS AND PROCESSES."

TWINSIM: DIGITAL TWIN AT EUROGATE

At the end of 2021, EUROGATE Group and the University of Hamburg initiated the project 'TwinSim' and invited akquinet port consulting to join with the aim of developing a digital twin of processes and equipment in container terminals. The three-year joint project is sponsored by the German Federal Ministry for Digital and Transport (BMDV) within the Program for Innovative Port Technologies (IHATEC) and has a grant of €3.65 million ($3.74 million).



ABOVE - FIGURE 2
TwinSim Generic Architecture

The scope of the project is to build a digital twin for supporting operations and maintenance at the EUROGATE Container Terminal Hamburg (Germany). In the first project phase, main use cases were identified in workshops and interviews, following a structured approach and value benefit analysis. Key topics include the digitalisation of equipment (mainly quay cranes, straddle carriers, rail cranes), deriving operationally relevant key figures and insights from data, equipment monitoring and predictive maintenance, and decision support for operational handling processes using AI. As shown in Figure 2, the digital twin will support all types of functions – from 3D visualisations over control to advanced decision support with simulations, business intelligence and AI.

EUROGATE will implement the required technology on the terminal equipment, such as IoT and edge devices, to establish the physical layer. Moreover, a central datalake and ETL processes will be established to process data from the physical layer, integrate it with planning and process data from the TOS and external systems (such as weather stations), and further connect with the Enterprise Resource Planning (ERP) system to automate support processes, such the ordering of spare parts in the context of predictive maintenance. For the integration of the terminal equipment, Terminal Industry Committee (TIC) 4.0 specifications are adopted.

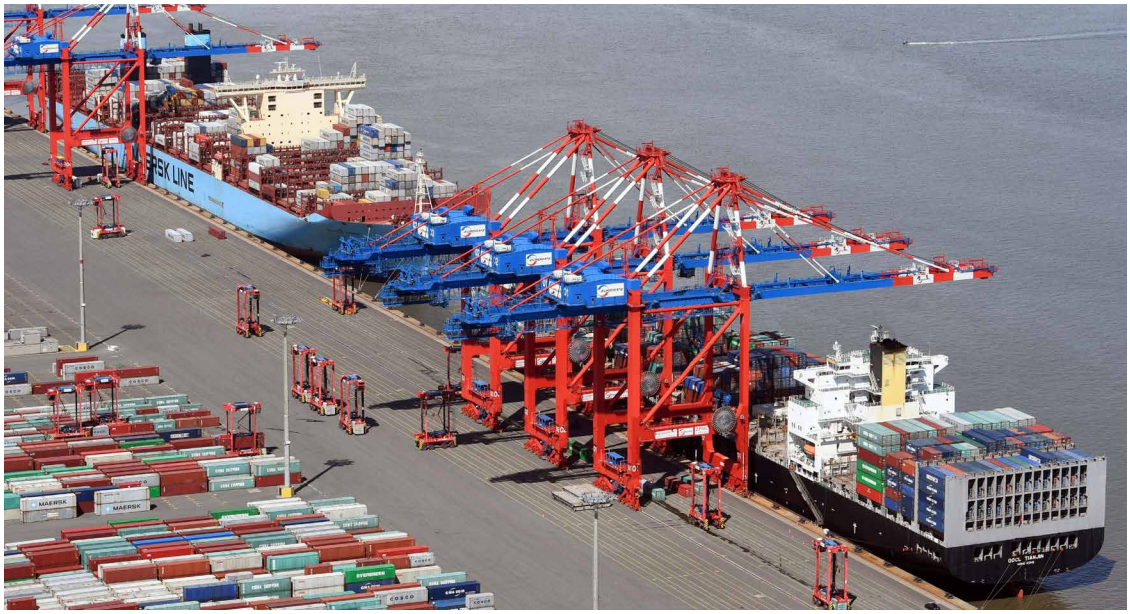
TIC 4.0 is an initiative which plans to standardise the communication between equipment, systems and subsystems at a container terminal by establishing a common data language and definitions (syntax and semantic) among the companies involved in the cargo handling industry.

"The TwinSim project done by EUROGATE with the project partners from akquinet and University of Hamburg is one of the big pilot implementations of TIC 4.0 standards currently undertaken. It – again – shows the importance of standards when integrating data from different sources to have one unified view on this. Talking TIC becomes more important," said Norbert Klettner, Vice-President of TIC 4.0.

The research group at the University of Hamburg will analyse the data with means of AI to optimise the planning and processes, further taking into account and optimising the environmental impact of operations and individual activities.

Visualisation and Monitoring will be based on akquinet's 3D-Visualisation "Live-View", which is part of the CHESSON family. Within a four-level architecture a 3D Live Visualisation will be provided, showing the whole terminal with all its objects and processes. In parallel, dashboards for all types of objects will be provided, showing an overview of all devices of this type. By either clicking on the object in the 3D or selecting a special device in the dashboard, detailed information of the piece of equipment will be shown. Beyond this overview, monitoring data and timelines may be selected and shown. Based on the CHESSCON Sim – and Emulation family, simulation applications – as described above – will be configured to support retrospections and what-if analysis.

Overall, this will lead to a high operational transparency and data-driven and situation-based optimisations, improving processes with respect to efficiency, productivity, resilience, and environmental impact of container terminals.



RIGHT
Mayview Maersk und OOCL Tianjin at EUROGATE Container Terminal Wilhelmshaven
Source: EUROGATE

ABOUT THE AUTHORS

Dr. Leonard Heilig is Co-Founder and CTO at driveMybox and research project leader in the project TwinSim. In those roles, he leads the research and development in the areas of simulation-based optimization, machine learning and cloud computing. He holds a B.Sc. (University of Münster, Germany) and a M.Sc. (University of Hamburg, Germany) in Information Systems and received his PhD at the University of Hamburg. He spent some time at the University of St Andrews (Scotland, UK) and at the Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, Australia. In the last years he published more than 50 scientific articles and books in the areas of maritime logistics, operations research and cloud computing, served as guest editor in several peer-reviewed journals and worked as consultant in international logistics projects.

Prof. Dr. Holger Schuett combines academics, research and professional services in the field of port and terminal processes and IT. He grew up in Germany and received his Diploma in Applied Mathematics at the University of Hamburg. After he obtained his PhD in Automations Technology in the Technical University in Hamburg-Harburg he joined HHLA, the biggest terminal operator in Germany. The major project was the sim- and emulation based support for the fully automated terminal in Hamburg-Altenwerder (CTA). The emulation technology implemented in 1999-2002 is still used for software releases as well as optimising terminal's strategies. After CTA's going live he joined 2003 the worldwide recognized Institute of Shipping Economics and Logistics (ISL). In 2010 he founded the commercial subsidiary akquinet port consulting GmbH. Also in 2010 he joined the University of Applied Science Bremerhaven as a professor for the mastercourse "Integrated Safety and Security Management". In 2022 he retired from the university and the institute but is still working for akquinet port consulting GmbH.

Paul Kokot as Chief Project Manager is responsible for the successful implementation of the TwinSim project. He received his diploma in electrical engineering and automation technology at the University of Bremen. After graduating, he first worked as a member of a working group of the International Electrotechnical Commission (IEC) on the standardistion of wind turbine interfaces. As a developer and later as head of the development department, he was responsible for the implementation of control-, SCADA- and real-time simulation systems in the context of offshore wind energy. He is therefore familiar with the collection, processing, simulation and visualisation of data as well as the importance of this data for the fault-free operation of technical equipment. He joined the EUROGATE Group in 2019, and in addition to automation projects, he is mainly responsible for the development of software solutions in the field of digitalisation.