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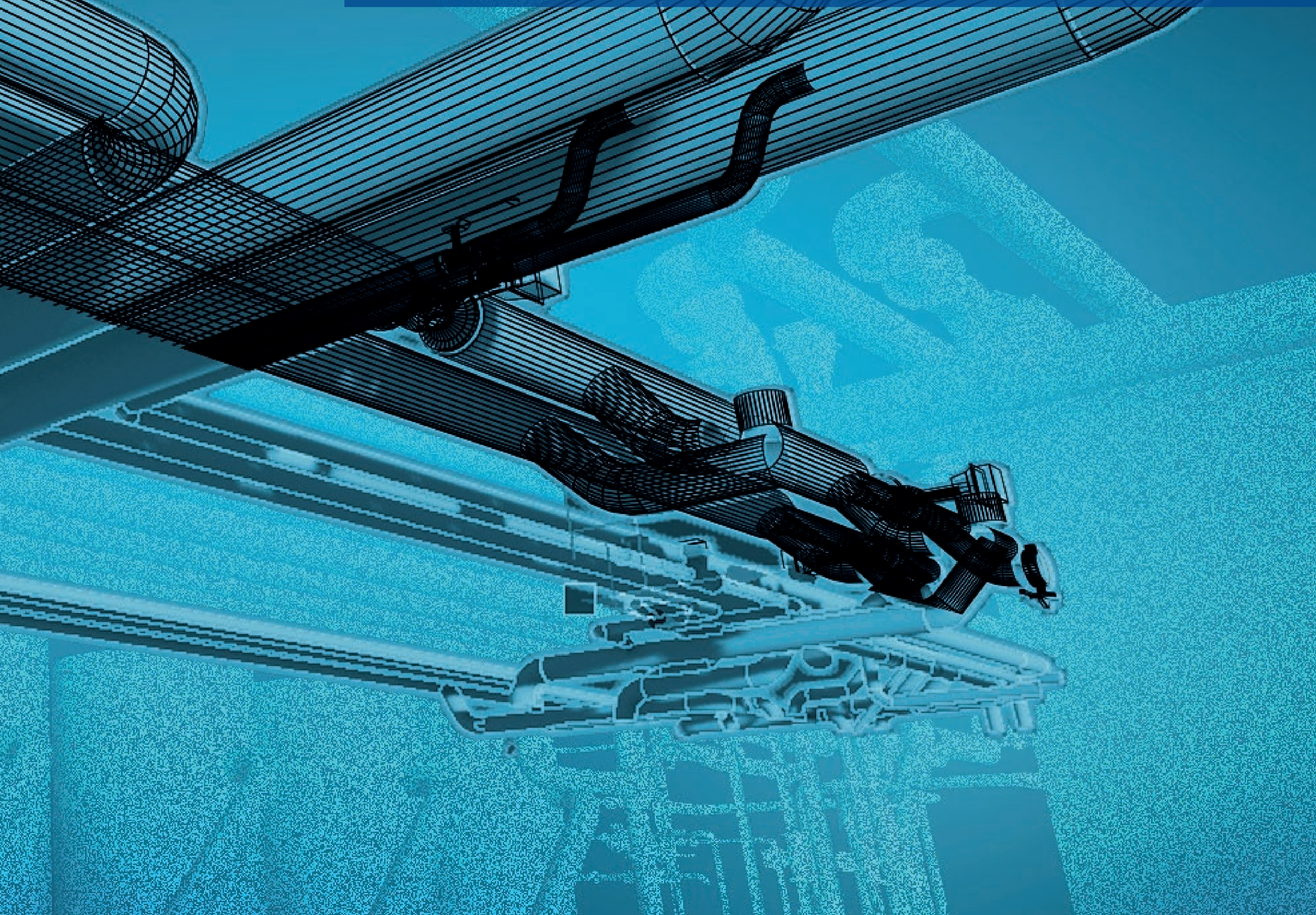
WHITEPAPER

FROM POINT CLOUD TO 3DIGITALTWIN:

DIGITIZING EXISTING PLANTS FASTER

Digital twins of existing plants facilitate the monitoring of operations, enable more efficient service and accelerate the planning of maintenance and modernization measures. However, setting them up manually is time-consuming and costly. This white paper by PROSTEP and Schuller & Company describes how this process can be automated through the AI-based evaluation of 3D scans and their linkage with P&ID information.

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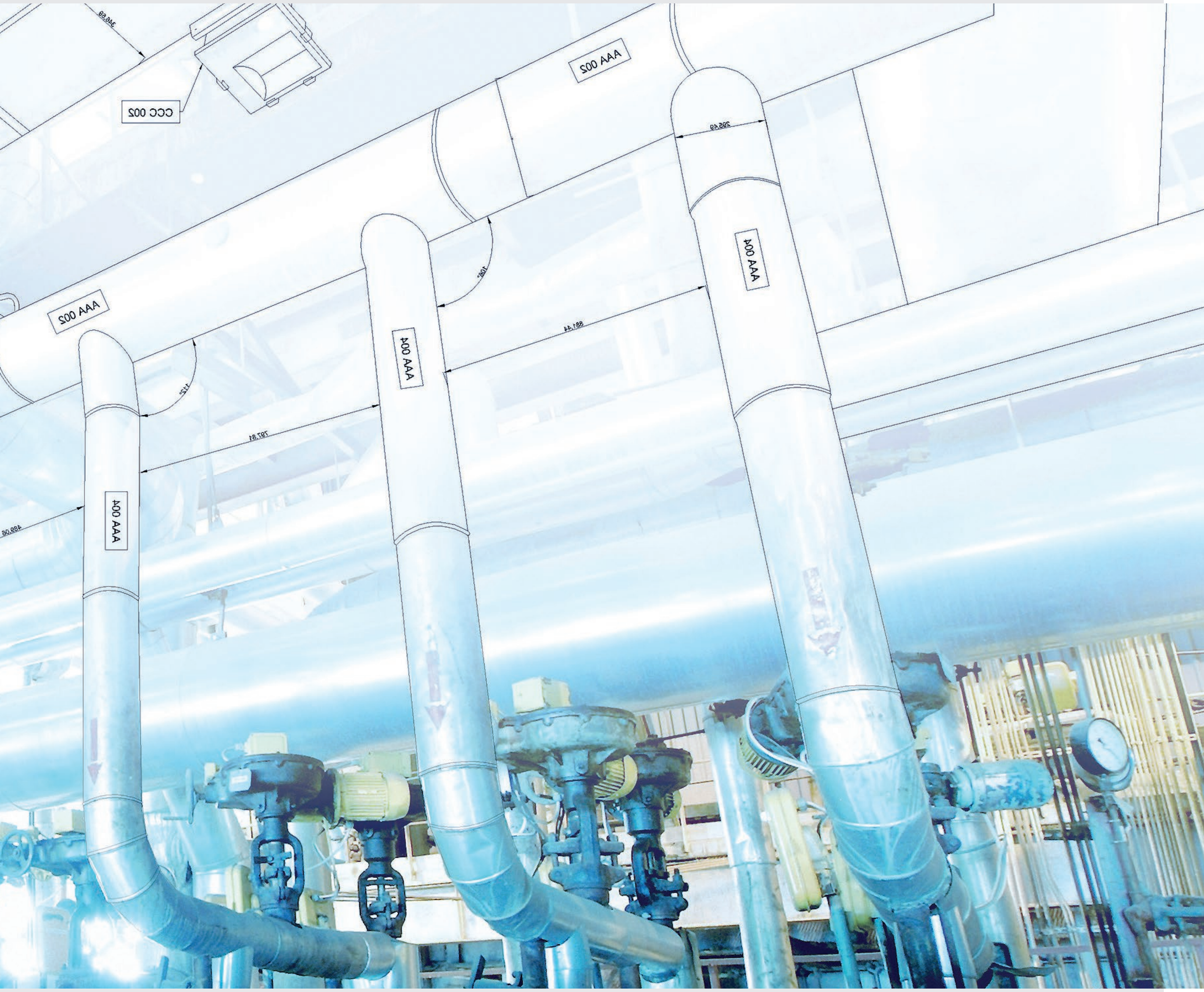
Abstract

Complete and up-to-date digital representations of plants are required for planning modernization measures. They also make it easier to virtually monitor plant operation and allow maintenance to be performed more efficiently. However, creating digital twins of existing plants retrospectively is time-consuming and costly. This is why plant operators are looking for ways to automate this largely manual process. Together with partner Schuller & Company, PROSTEP has developed a solution for this purpose that guarantees significant time savings and a rapid return of investment. The 3D scan data is evaluated using artificial intelligence (AI) methods and automatically linked to the plant's piping and instrumentation diagram (P&ID).

PROSTEP laid the foundation for this innovative solution concept together with partners from industry and the research community within the framework of the DigiTwin joint industry project funded by the German Federal Ministry of Education and Research. Key insights gained from this project were then adapted to meet the specific requirements of plant engineering with the help of the experts at Schuller & Company and incorporated into a new solution called 3DigitalTwin. This white paper outlines the approach to the creation of digital twins of plants from scanned data that the partners are taking and what potential this offers the stakeholders in plant engineering.



A number of good reasons for the digital twin

Plant operators need to document the as-built and as-maintained state of their plants for a variety of reasons. It begins with the legal burden of proof. Up-to-date plant documentation is a prerequisite for reconstructing the causes of malfunctions and minimizing the risks for operating personnel. In principle, plant operators could continue to do this on paper if it did not make auditing more difficult. While it is relatively easy to reconstruct a plant’s as-maintained state via the process control system, the as-built state is generally poorly documented. Deviations from the as-planned state occur as early as during the construction phase and are typically not inadequately incorporated in the documentation. Plants are for example often not planned all the way down to the last water pipe or are built before planning has been completed due to time constraints.

Incomplete documentation of the as-built state also makes it more difficult to plan and carry out maintenance work in the plant later on. Maintenance engineers often have to use the P&ID to get their bearings. It describes the structure of the plant from a process engineering perspective but does not contain spatial information and does not always include all the components. Piping is only represented in a simplified way as connecting lines. Information about length and how it has been assembled are not included. This means that maintenance engineers cannot use the P&ID to determine where which pump is located and where the pipelines run. Two pipelines which, according to the diagram, branch from a pump to the left and to the right can, in fact, run parallel in the actual plant. In practice, this can result in scaffolding being erected for a maintenance step and then being taken down again even though it is required at the same position for the next step.

In the case of smaller plants, their design might require relatively little time and effort to compare the P&ID with spatial conditions. The situation is however different in the case of e. g. a large chemical plant, which can measure hundreds of meters and be spread over multiple buildings and floors. The maintenance engineers, who are often employed by external service providers, then have to spend hours walking through the plant to find the fittings that need servicing. This wastes time and leads to additional costs. Apart from this, plant operators would for safety reasons like to exclude humans as a “disruptive element” where possible – especially when it comes to external personnel.

In addition, process engineering plants have very long lifecycles and can also change hands during their lifetime without all the know-how being transferred to the new owner. In many cases, this know-how involves the expert knowledge in the heads of the operating and maintenance staff. This is lost when employees retire or are replaced by employees from external companies who are unfamiliar with how the plant operates. Plant operators must therefore provide their operating engineers with better visual orientation in the plant so that in the event of a malfunction they immediately know, for example, which stop valve they have to close by hand.

The increasing complexity of plants means that it is becoming more difficult for even experienced employees to keep tabs on everything. This makes it all the more important that information about the plant be made available in a visual form that maintenance engineers, who as service providers are not sufficiently familiar with the plant, can understand or to overcome language barriers. Today, young engineers in particular expect information to be provided in digital form and be available everywhere.

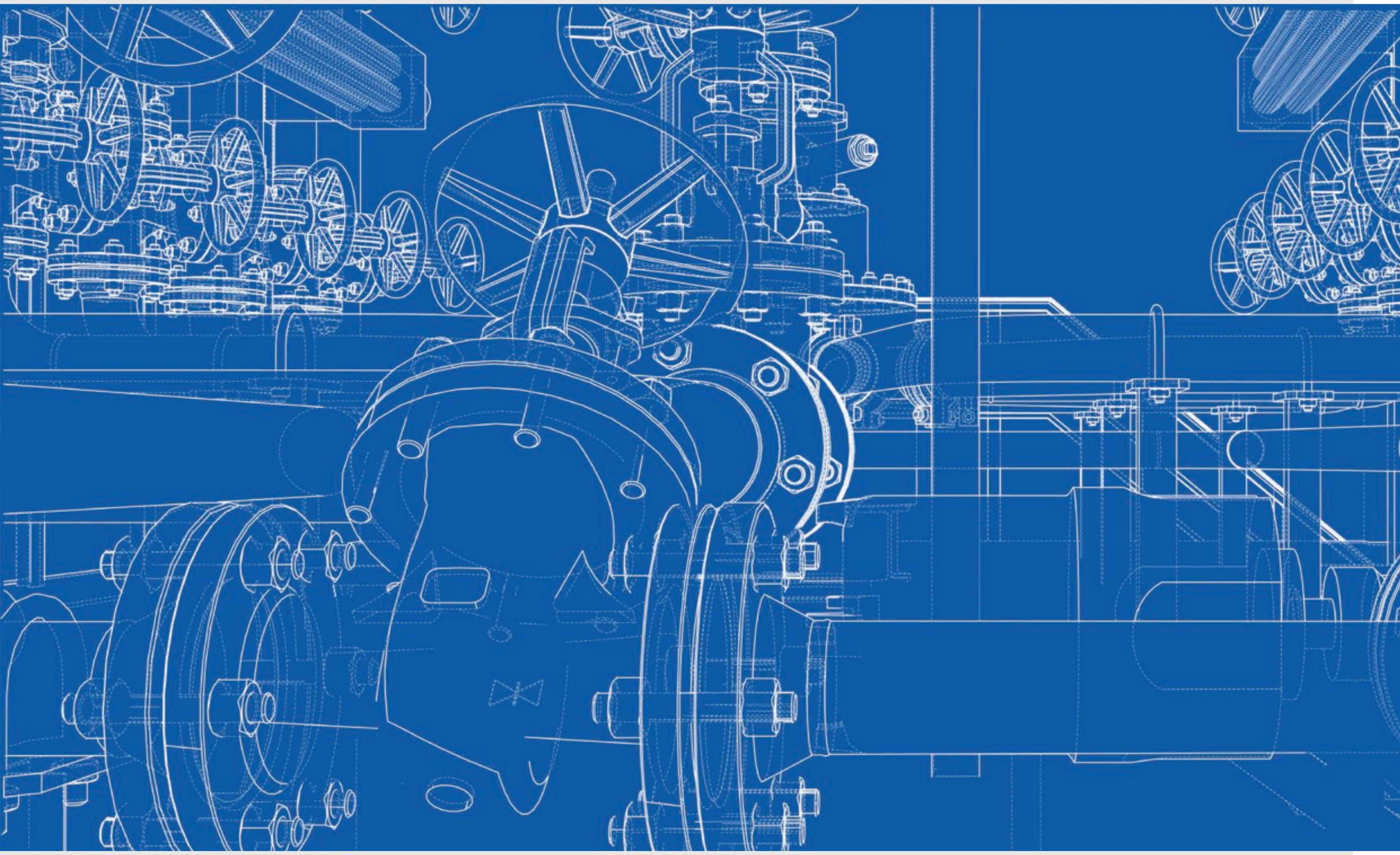
Plants are often redesigned or their layout changed during their lifetime in order to increase productivity or making it possible to manufacture other products. When optimizing existing plants, planners start with a status that may be consistent with P&ID from a process engineering perspective but does not reflect the current spatial conditions and fixtures and fittings. Today’s plant engineering firms spend a considerable amount of time and effort comparing the P&ID with the given space before they can actually begin designing the new plant components. Accurate documentation of the current plant layout is also required to recommission the modernized plant and in many cases, clients and also regulatory authorities now expect 3D documentation. This gap needs to be closed by creating a digital twin.

The challenge of digitalization

There are many good reasons for plant operators and other stakeholders in plant engineering to map the current layout of their plants in a digital twin. This twin is a virtual representation of an existing plant. It can include a variety of information and be used by a variety of users depending on whether it is intended to support development, planning, assembly, production or service. The challenge for plant designers and operators is creating the digital twin without having to invest excessive amounts of time and money.

Incomplete 3D documentation makes creating digital twins in plant engineering more difficult than in other industries. The position of the plant equipment within the given space is usually first of all captured using laser scanners. Depending on the resolution of the scanners and the size of the plant, this may create point clouds with enormous amounts of data that are almost impossible for today's systems to handle. The point clouds provide plant designers with a kind of template that can be used as the basis for manually remodeling equipment (containers, pumps, etc.), pipelines and fittings using any of the leading plant design systems. This is an extremely time-consuming and cost-intensive task. It is the primary reason many companies do not create digital twins containing 3D information for their existing plants. In consequence the plant documentation, which is e.g. used for the planning of maintenance tasks, is incomplete . To compensate this lack plant operators have to invest more time and deploy additional staff.

Up until now, no technical solution was available that allowed the P&ID to be linked automatically to spatial data relating to the plant equipment currently installed and thus move the P&ID into the third dimension. This first of all requires automatic object recognition, which allows objects like pipelines and fittings to be recognized and their position in space to be determined using a fraction of the scanned points. Secondly, it must be possible to enrich the recognized objects with the corresponding information from the P&ID with as little effort as possible. If necessary, these "intelligent" objects can then be converted into an editable planning model to, for example, plan changes to the plant.

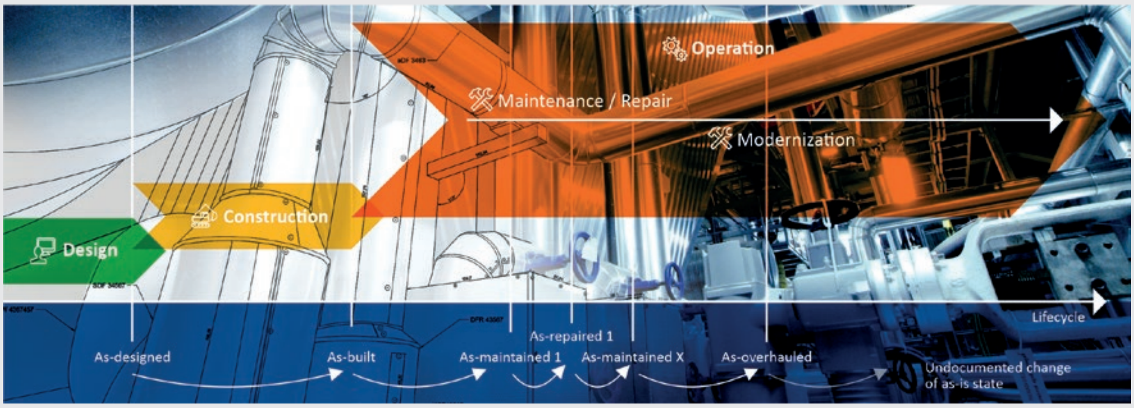


Use cases for the digital twin

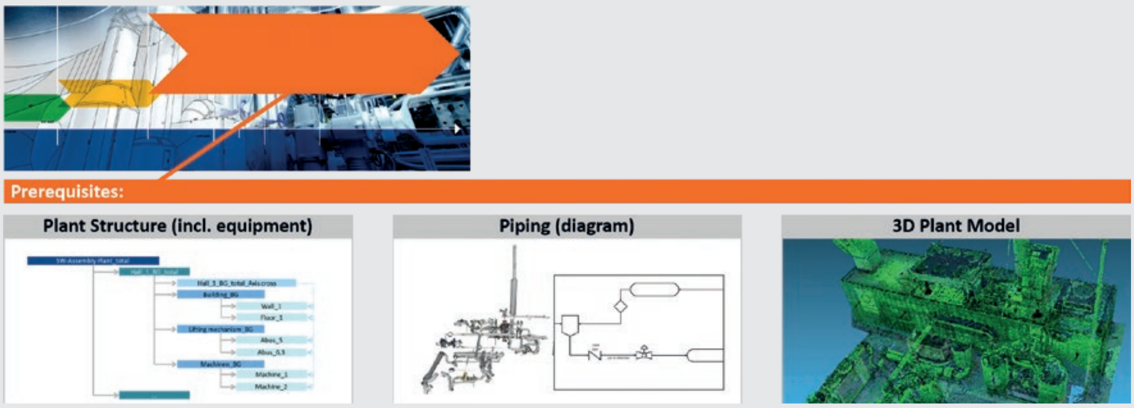
The 3DigitalTwin solution, which PROSTEP developed together with the experts from Schuller & Company, masters both challenges, thus making the economic creation of digital twins for different plant engineering use cases possible for the first time. This includes modernizing existing plants, failure studies, maintenance planning, the virtual monitoring of plant operations and training the employees responsible for operation and maintenance. The use cases promise significant potential benefits but also place different demands on the preparation and provision of digital information.

A key requirement for the digital twin in the context of the legal burden of proof is that it reflects the current layout of the plant in question. Over the course of their lifecycle, however, plants undergo numerous changes, which are entered in the P&ID if they are relevant from a process engineering perspective but not usually in the geometric information in the installation plans. This also has something to do with the fact that many plant engineering companies do not provide this documentation in electronic form, let alone as

As-is documentation



Modernization



3D models. So it is not enough to simply create the digital twin once and leave it at that. The digital twin has to be maintained over the entire lifecycle of a plant so that it can be used during operation for planning maintenance measures or for preventive failure analysis.

A digital twin containing 3D information makes it possible to move virtually through a plant and, for example, simulate the evacuation of employees in the event of a failure. Operating engineers can be trained to deal with failures so they immediately know where the valves that need to be closed are located. Digital twins also facilitate maintenance planning by making it possible to prepare maintenance tasks virtually on the 3D model. The position of inspection areas within the given space is identified in advance so that the use of auxiliary equipment such as scaffolding can be taken into account. Digital twins make it possible to map the expert knowledge stored in the heads of operating and maintenance staff who are gradually retiring. This makes it the central source of knowledge for training the next generation.

Virtual Reality

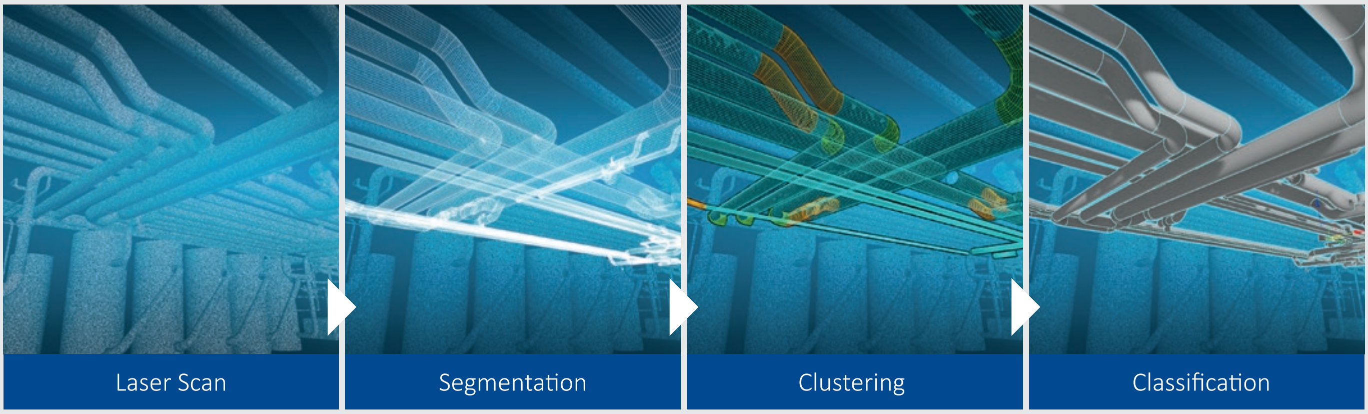
Augmented Reality

One of the most important use cases for the digital twin is the modernization of plants. Complete and up-to-date plant documentation is required for both planning changes to the plant layout and for re-approval of the modernized plant. Plant designers need not only the logical structure of the plants including equipment, fittings and the current pipework but also a 3D model for incorporating the new components into the existing plant. This currently means that the plants have to be painstakingly measured and remodeled, which can cost millions. A key requirement for plant operators is therefore that the digital twin can be created and maintained faster and more cost-effectively.

Up until now, plant operators have rarely had digital twins of entire plants created. When carrying out modifications and modernization measures, only certain areas are normally remodeled in order to provide points of connection to the new areas to ensure that the modifications mesh with those parts of the plant equipment that are to be retained. If the time and effort required to create digital twins is dramatically reduced, they can in the future be used to compare the as-planned and as-built state of new plants. Plant operators can track the progress of the construction work and, if necessary, demand that corrections be made if serious deviations occur. This of course assumes that they ask the plant engineering companies for the 3D models from the plant engineering process so that they can compare them with the scanned 3D models.

Automatic identification of piping systems

Creating digital twins of existing plants gives rise to two major challenges that can be mastered with the help of machine learning methods and object recognition algorithms. The prerequisite for this is that AI has been trained accordingly beforehand. This not only involves recording the current layout of the plant, which can deviate substantially from the planned layout, including all equipment, fittings and piping systems in 3D. In addition, the point cloud of the plant – or if appropriate the 3D models derived from it – has to be linked to additional information from the P&IDs to ensure unambiguous identification of the plant components and their function.



A 3D scan performed using a high-performance scanner, which generates a point cloud of the surfaces, provides the basis for the digital twin of an existing plant. Instead of using a 3D CAD system to manually remodel the plant based on this 3D scan – a process that can cost hundreds, sometimes thousands, of hours depending on the size of the plant – the point cloud is converted, to a great extent automatically, into an intelligent 3D point model that is linked to the plant logic in a multi-stage process using the method developed by Schuller & Company and PROSTEP.

- The starting point is a 3D scan of the existing plant. 3D scanners are used to capture the surface of the plant, creating a point cloud that represents the current layout of the plant.
- The first step involves reducing the number of points to the level required for object recognition. This significantly reduces the amount of data, thus making it manageable.
- In the next step, the point cloud is segmented according to functional aspects using object recognition, i.e. it is broken down into equipment, fittings, pipe sections and elbows. AI has to be trained accordingly beforehand. Each point “knows” that it is part of a pump or pipe, but objects are not yet defined with their position in space.
- Clustering is used to group together all the points associated with a component and derive geometric properties such as radius, center line, dimensions and their position in space. The result is a 3D model that is described using points.
- The final step is establishing a link to the P&ID. The previously recognized components are mapped to the according objects in the P&ID. This makes it possible to extend the geometric and position information previously recognized to include logical information from the P&ID. The experts at Schuller & Company have developed a method for this purpose that compares the constellation of fittings and pipes in the 3D model with the P&ID and searches for similar patterns. Once a piece of equipment has been correctly identified, the information from the P&ID can be automatically assigned to all the other components in the pipe run.

The components recognized and linked to the information from the P&ID with the help of AI makes it very easy to generate CAD models of existing plants. These can be used in their native format in leading plant engineering CAD systems such as AVEVA Plant or CADMATIC. Apart from that, plant designers already work with simplified CAD geometries. The nominal diameter and wall thickness of pipes are defined by their pipe class rather than geometrically. Numerous fittings are also represented in simplified form to reduce the volume of data, as they can occur thousands of times in a large plant. This is what makes the use of CAD in plant engineering very different to its use in mechanical engineering.

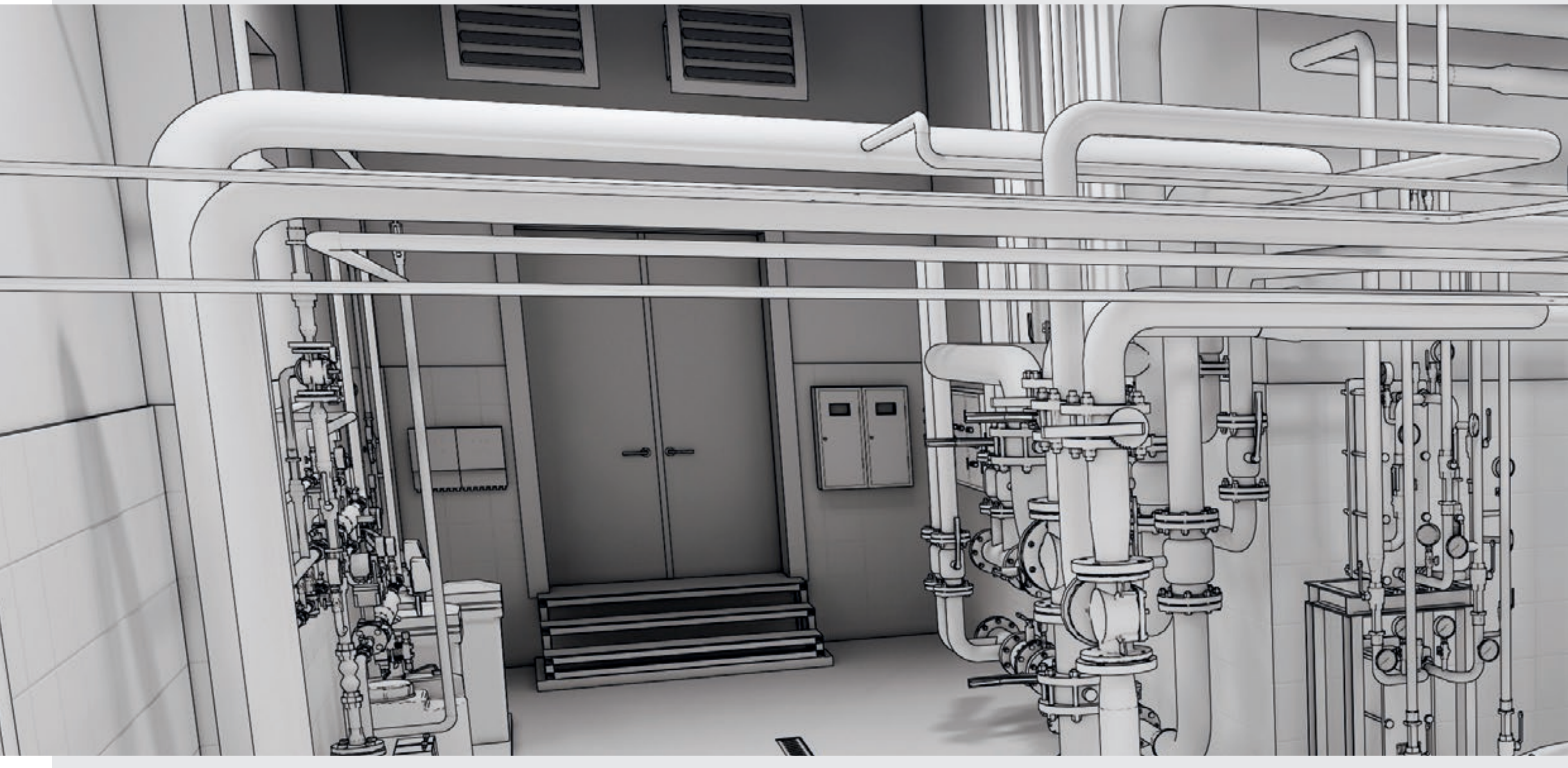
Potential benefits in plant engineering

There are a variety of use cases for the digital twin in the context of plant engineering. The potential benefits of automating the creation of plant twins using the solution developed by PROSTEP and Schuller & Company are therefore no less diverse. The solution can be used regardless of the respective plant planner's or plant operator's IT landscape. The 3DigitalTwin solution is able to link P&IDs from different systems to the recognized 3D objects and then convert these objects into CAD models using any planning tool. This means that users are not forced to use certain tools if they want to exploit the potential benefits that the solution offers.

In the case of modernization projects and changes to plant layouts, the automated creation of the digital twin reduces the time required for the manual remodeling of existing plants by up to 80 percent. This makes it possible for plant engineering firms to start designing the new plant components much faster. At the same time, the cost of capturing the required data, which can easily exceed one million euros even for a medium-sized plant with 300 to 400 pipelines and 800 fittings, can be cut in half. This makes creating a digital twin economically viable for a larger number of plant operators for the first time.

Plant operators perform failure studies as part of the approval process to ensure that they are prepared to deal with possible failures. These studies are intended to reduce the risk of failures and assess their impact. If a failure nevertheless occurs, the plant operator bears the burden of proving that they have not violated their duty of care and that the failure is not the fault of the operator. 3D scans and 3D models of the current layout of the existing plant make this process more reliable. This is of particular interest to those responsible, as they quickly also have to bear the legal and personal consequences in the event of a failure. Generally speaking, digital twins support evaluation, examination and/or traceability by making all the information relevant to a plant available, for example when analyzing a failure.

However, 3DigitalTwin offers the greatest benefit during operation. Linking 3D models and P&IDs makes it possible to plan and prepare maintenance measures more efficiently and avoid having to hire additional staff to compensate for the imprecision of the planning process. First and foremost, improved planning reliability reduces downtime, the cost of which can quickly run into the millions. In addition, the 3D models can be processed and used for the (further) training of maintenance engineers with AR applications.



Partnership

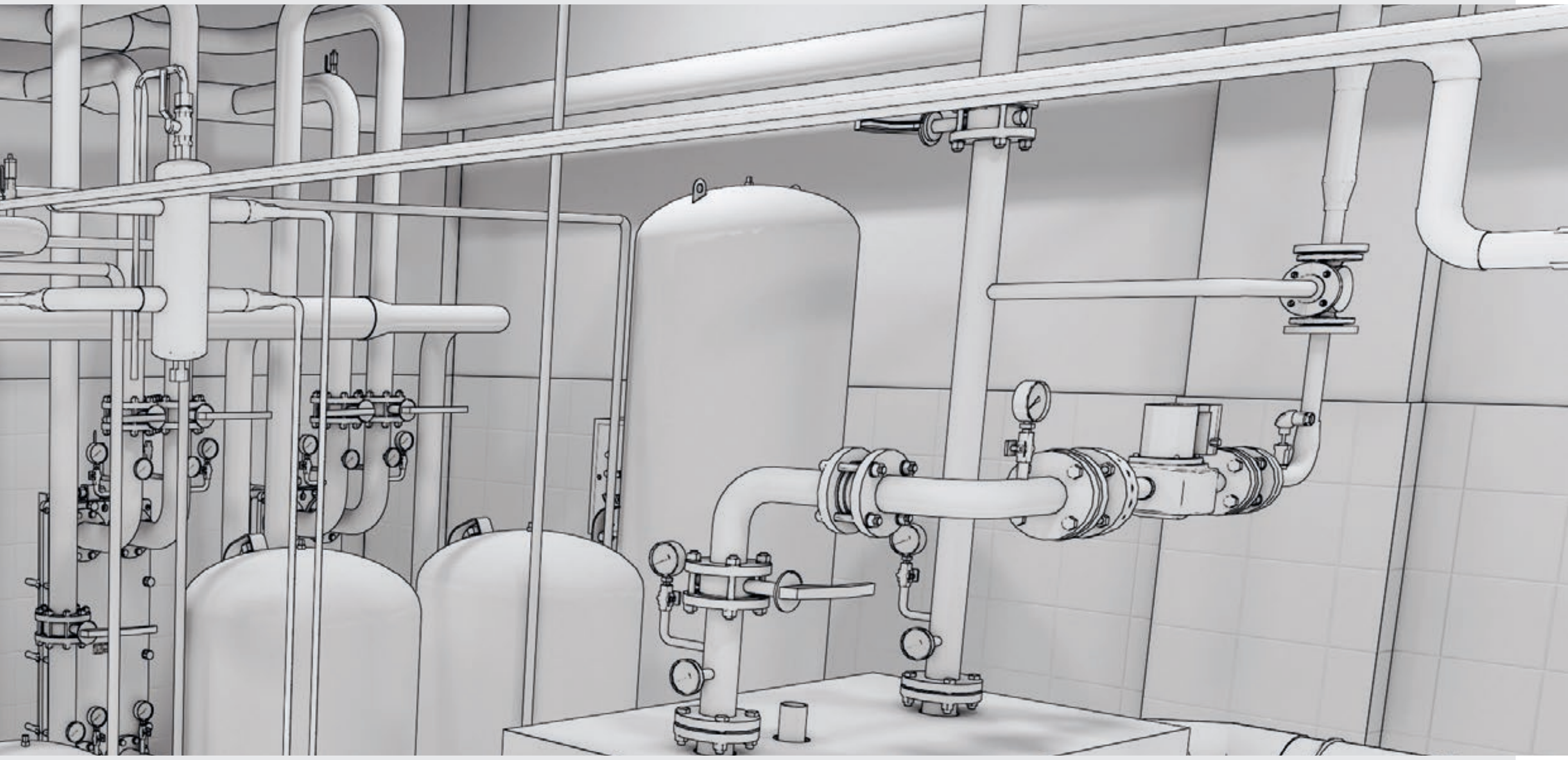
A great deal of know-how is required to make available a digital twin that has been scaled according to your wishes. Processing very large point clouds and getting to grips with AI play a significant role in this context. An in-depth understanding of engineering processes is also crucial for plant engineering. Combining all these competencies makes it possible to create a digital twin that meets the demanding requirements of plant engineering and operation.

The digital asset experts from Schuller & Company provide companies from a wide variety of industries with support on their path towards digitalization. Focus in this context is placed on data and document management and the visualization of this information. Schuller & Company thus offers solutions for creating customized digital twins.

PROSTEP is the leading PLM consulting and software company, with over 25 years of experience in the field of PLM integration and end-to-end digitalization in a wide range of industries. Integrating data from a wide variety of source systems in order to create digital twins and implement other use cases is a core competency. The team of experts at PROSTEP's OpenDESC.com data logistics service have developed an AI-based object recognition process for 3D scan data and optimized it for plant engineering.

By bundling our competences, we have developed 3DigitalTwin with the aim of using artificial intelligence to create a digital twin of your existing plant from a point cloud generated by a scan as requested. You benefit from our partners' outstanding know-how covering every aspect of plant engineering, their many years of experience in handling and converting model data, and their vendor independence as a service provider.

SCHULLER & Company + PROSTEP integrate the future



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