PLATTFORM INDUSTRIE 4.0

RESULT PAPER

Collaborative data-driven business models

Collaborative Condition Monitoring – How cross-company collaboration can generate added value

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1. Introduction

With the digitalization, provision, storage and processing of data increasingly becoming part of value creation processes, the boundary between physical products and the virtual world is more and more blurred. Data is becoming a core element of value creation. It is generated in engineering, in production and in the operation of networked machines, plants and products.

However, this data is often neglected in the development of digital data-driven business models. There is a huge treasure of data from the production process as well as operating data from millions of manufactured machines, plants and products is of immense value and can form the basis of new data-driven business models.

Innovative collaboration across company and competiton boundaries is essential to enable this data to be gathered and allow companies to offer self-determined data-driven business models. Nowadays, data is exchanged between various market participants in the value creation chain mainly by means of the factory operator's market leverage. This paper examines how this exchange could take place on a self-determined basis, using the example of condition monitoring.

Collaborative condition monitoring (CCM) describes an innovative approach that allows various market participants in the network to increase the reliability and service life of production plants and thus create added value for all stakeholders in the value chain.

Using this approach, mutual benefits can be achieved in the ecosystem if all market participants share their data and make it available on independent digital platforms. The added value generated from the use of correlation and AI methods (data analysis) can result, for example, in the increased service life of machines or components. The CCM approach is a novelty because it is based on multilateral cooperation between companies and competitors and gives rise to new business models. In this context, it is essential that companies competing with each other at an operational level make available the data that is so urgently required for the instanciation of digital business models in the same way as their physical products and recognise this data as non-related to brand and product differentiation.

This paper addresses these key questions:

- What rules apply to such a collaborative approach?
- How can participants in a B2B value creation network be encouraged to share their data?
- How can data (including shared data) be monetised?
- Who receives what share of the benefits generated by collective data provision?
- How is secure use ensured only for the entitled?
- What are the requirements for legally compliant use of the data?

2. Collaborative condition monitoring (CCM) use case

The following section describes a use case that shows a sample application of collaborative data-driven business models and examines their added value in a specific case study.

Scenario

The collaborative condition monitoring use case (abbreviation: CCM) focuses on the collection and use of operating and other data to optimise the reliability and service life of machines and their components in operation. A three-layer value creation network comprising different market participants is taken as a sample, simplified process of a business ecosystem (Figure 1):

1. Various **component suppliers** produce components, e.g. a variety of drives, which are each equipped with the appropriate sensors.

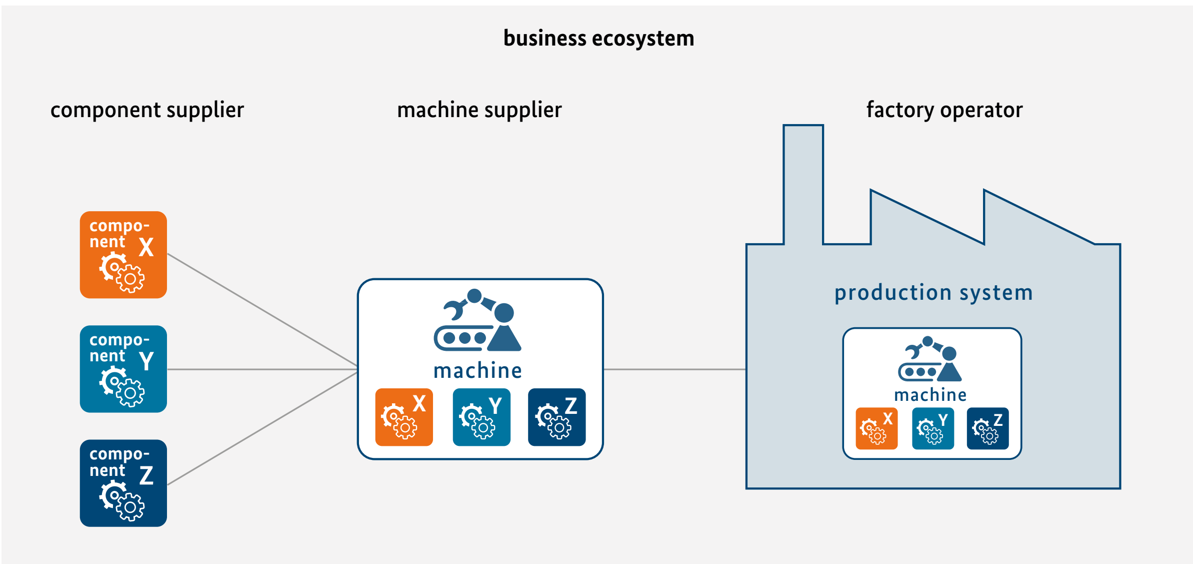
2. A **machine supplier** produces a machine in which the different components from the various manufacturers are installed.

3. A **factory operator** uses this machine in his production system.

Conventional condition monitoring is defined as the presentation and analysis of operating data. The machine condition or status is recorded in this process by measuring physical values such as vibration and temperature. This data is traditionally shared bilaterally, for example, exclusively between the supplier and the operator.

The CCM vision adds a more collaborative dimension to conventional condition monitoring by collecting and sharing data not only bilaterally but multilaterally across the entire value creation network. This is in contrast to the usual cooperation between suppliers and customers which has existed to date and which is usually defined in agreements and contracts. Not only the opportunities but also the challenges associated with this vision are outlined below. The goal is to predict life cycles and failure probabilities within the overall system, based on a correlated analysis of operating data which is initially fragmented.

Figure 1: Conventional value creation network



Source: Plattform Industrie 4.0

Using the example of CCM, a typical scenario could appear as follows:

- The component supplier provides a component with an asset administration shell containing data fields for data relevant to service life or reliability.

- The machine supplier delivers a machine with its own asset administration shell, which also contains data fields for data relevant to service life or reliability. Essentially, the asset administration shell of the machine is made up of the asset administration shells of the components. Any relevant data generated during operation (e.g. installation position, acting forces) is saved in the asset administration shells of the components and of the machine. The machine's asset administration shell is assigned the function of forwarding the data that is accumulated from the machine and components during the period while the machine is in use to a neutral platform.

- The factory operator supplements the data with relevant application data from the machine (e.g. operating temperatures, maintenance intervals) based on the data fields in the asset administration shell.

All participants in the value chain are given access to the data, depending on their authorisations:

- For the component supplier, the added value consists of access to data on the service life/reliability of his component as well as other relevant associated machine data and environmental parameters of the production system. This enables the optimisation of components or new services, such as proactive spare parts management.

- Using historical data from many machines in a wide variety of environments, the machine supplier can use AI methods to recognise, for example, how availability and tolerances vary in production. With this knowledge, he can proactively contact the factory operator with a quote for maintenance and thus deliver increased customer satisfaction.

- The factory operator benefits among other things from increased availability and predictable time slots for maintenance. One possible result of this is improved delivery reliability, which is associated with a better customer experience among end customers.

Hypothesis

Collaborative condition monitoring can be used to generate an economic advantage ("digital business model") within the digital ecosystem by increasing the reliability and service life of components and machines. However, this can only be achieved through the continuous and consistent collection of operating data for components and machines across the entire value chain; that is, from many and various manufacturers, integrators and operators and their collaborative evaluation.

Collaborative dimension

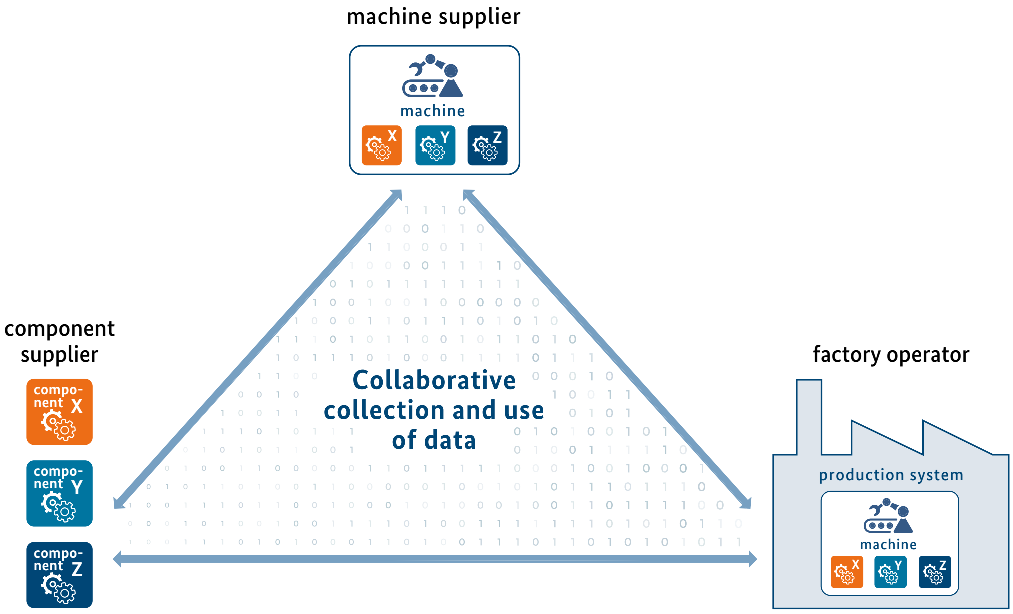
The smallest possible fractal (Figure 2) of a multilateral structure is a three-point structure, shown here as a component supplier, machine supplier and factory operator. Scaling up across value chains, networks and ecosystems is then simply possible by combining the three-point fractal as a building block of chains and networks, in which the knowledge and principles described in the following still apply.

A comprehensive database is an essential prerequisite for increasing the service life of components and machines. This means that data on the status or condition of all relevant components and the machine must be available and the semantics of the other manufacturer-specific data must be known. Only by processing sufficiently large amounts of data of sufficient quality it is possible, for example, to recognize recurring patterns in the operating behaviour of individual components and the machine or to analyse long-term wear under company-specific conditions. This is because the service life of components or machines cannot be determined by individual or measured variables. In practice this depends on a combination of different data, which can differ depending on the application and typically cannot be provided by one market participant alone. Context data, for example about the location of the factory and the area around the machine, can also play a role in this regard.

In short: The more comprehensive semantically standardised data from various actors is available, the more meaningful is the knowledge gained from the data. This knowledge thus gathered is beneficial for all market participants in the value creation network.

However, these advantages can only be achieved through extensive collaboration. Such collaboration requires component suppliers, machine suppliers and factory operators

Figure 2: Three-point fractal with a database



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to work together across company and competitive boundaries. Only in this way, namely through **collaborative condition monitoring**, is it possible to create a suitably extensive database that will potentially benefit all market participants.

Key question

The knowledge gained from the data provided can be used, for example, to optimise or redesign components or to explore the framework conditions for the most efficient operation of a machine. Both examples bring an economic advantage for the supplier or the operator. However, this can only be achieved if multiple market participants provide and share their data on one platform.

The key question in this scenario is how can these benefits be realised within the entire ecosystem? Many other questions also arise, such as how incentive systems need to be designed for the various market participants in order for them to provide their data, or which business models are associated with this collaborative approach. The technical implementation also raises a fundamental question. Which legal aspects must be taken into account if, for example, added value is generated from jointly provided data? The question arises which changes in competence requirements CCM places on employees.

Conceptual starting point of a solution

The operating data of components and machines is collected across multiple technologies in a manufacturer-neutral and, if possible, component-independent format. The data is processed and provided centrally, for example, on a digital platform. In this way, it is available bidirectionally to calculate the probability of failure, carry out predictive maintenance and generally improve the reliability of components and machines. The conceptual logic behind this approach is that the data accumulated by each of the individual market participants is too unspecific and therefore does not allow service life to be predicted. Correlations and contexts only become apparent (and forecasts possible) when data from a wide variety of operating conditions is merged. Integrating the operating data and corresponding correlations in this way the operating data receive a value and leads to improved reliability and service life of components and machines. An essential prerequisite in this case is the application of a comprehensive data model, implemented in the form of an asset administration shell.

This white paper outlines the challenges associated with such an approach, the requirements of the underlying digital ecosystem and concludes with some possible solutions.

3. Current barriers to implementing collaborative business models

The collaborative approach behind CCM has advantages for all market participants. Nevertheless, CCM is not yet being implemented in the today practice. There are many reasons for this lack of implementation.

Lack of cooperation

The cooperation that takes place nowadays is mainly bilateral, for example when the factory operator and the machine supplier exchange operating data. Under this cooperation, machine data generated during operation is used, for example, to analyse operational faults or organise maintenance work. Such cooperation usually takes place between two partners and is initiated and carried out via the customer/supplier relationship (including market leverage).

Lack of scalability

Only large amounts of data provide the meaningful basis that is necessary for more precise analysis of the service life and reliability of machines and components. However, due to the primarily bilateral nature of business cooperation, this data is only available to two partners. In addition, the data only comes from a single source. For any qualified data analysis and AI applications to be possible, scaling across multiple market participants is required.

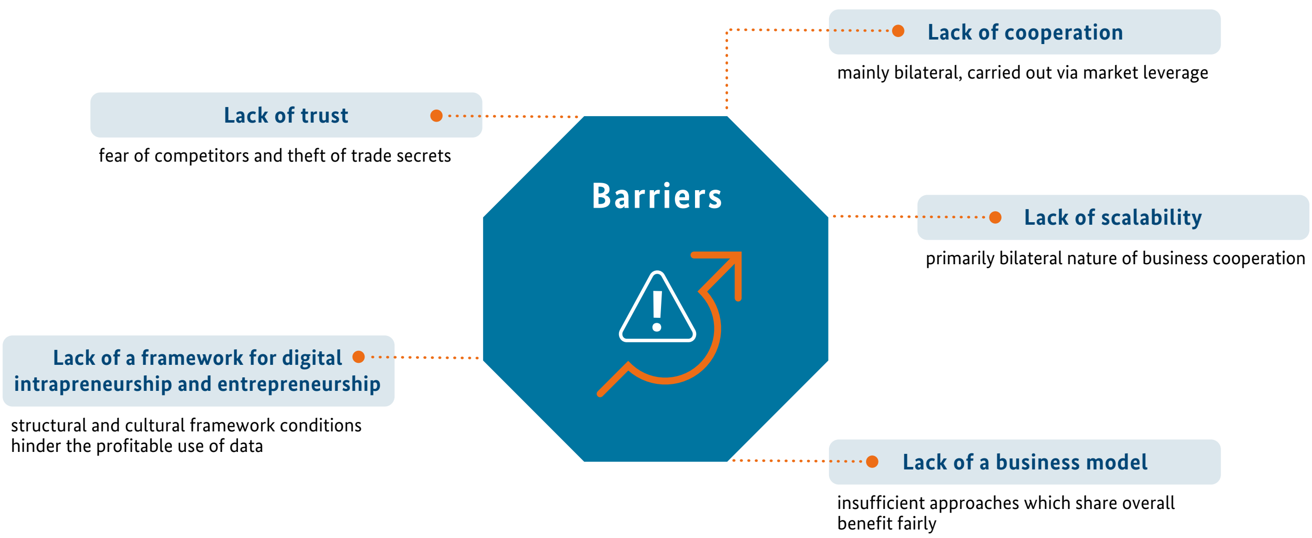
Lack of trust

Secure data transmission, storage and access rights are critical if market participants are to share their data and protect it from competitors or from theft of trade secrets (sensitive production data). All market participants want to control the use, application and accessibility (private, semi-public, public) of their own data (digital sovereignty). Digital platforms on which the data required for CCM is made available must therefore allow appropriate access rights and meet adequate security standards to win the trust of their users.

Lack of a business model

The provision and use of data from the various market participants in CCM can generate added value that can potentially result, for example, in a longer machine life, reduced spare parts and maintenance costs, fewer planned and unplanned downtimes and thus have a positive impact on total cost of ownership. However, the associated cost and benefit calculations will generally vary greatly with regard to profitability for the market participants involved. For each partner to be sufficiently engaged in the partnership, the overall benefit that can be achieved must be appropriately distributed within the framework of a defined "collaborative business model". The resulting win-win-win situation is critical for profitable collabora-

Figure 3: Barriers to collaborative business models



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tion. This is especially true because CCM enables new payment models, such as Equipment as a Service (EaaS) or Pay as Used (PaU), combined with availability guarantees at every level.

Lack of a framework for digital intrapreneurship and entrepreneurship

Tapping into the value creation potential of industrial data will be an important factor in determining the future competitiveness of Germany and Europe as business locations. Risks such as a loss of expertise or lack of data security are a key concern in relation to the sharing, handling and use of data. Nevertheless, collaborative data-driven business models offer sizeable opportunities and advantages for all market participants. However, for these to become a reality, structural and cultural framework conditions and rules are required that simultaneously recognise and support intrapreneurs and entrepreneurs, manage risks in a controlled manner and enable the profitable use of data.

4. Fundamental requirements for collaborative business models in Industry 4.0

What requirements would such a collaborative approach place on the digital ecosystem? It may be necessary to differentiate between the specific requirements of the various market participants in the value chain; that is, in the CCM scenario, the requirements of the component supplier, machine supplier and factory operator.

Sustainable business model

The potential of CCM can only be fully realised if as many market participants as possible participate and share their data. This also includes market participants who may not derive any direct added value from providing their data. A system of incentives that takes these market participants into account and encourages their participation is necessary. We need a business model that is focuses on these requirements and that distributes the benefit (which mainly goes to the factory operators by extending the service life of their assets) generated by CCM fairly among all market participants.

Trusted environment

A fundamental requirement for the implementation of CCM is an accepted environment that reliably meets the expectations of all market participants. Only if this collaborative environment is appropriately designed there will be an increased willingness to share data. The common goal of increasing the availability of valuable data in order to create economic value can then be realised.

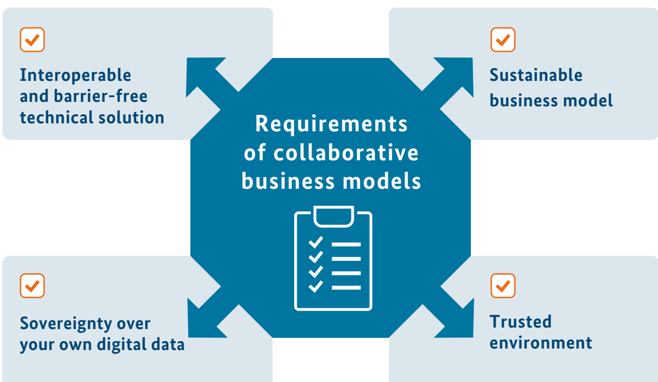
Sovereignty over your own digital data

All market participants in the CCM scenario share the desire to have full control over the use of their own data. This essentially means that full control over the data is retained by whoever creates the data. However, a closer look at the CCM scenario shows that this basic requirement needs to be considered differently. When, for example, a machine generates data during operation, the factory operator has control over this data. In a traditional bilateral cooperation scenario (Industry 3.0), the factory operator would only share this operating data with the machine supplier if required. In CCM, however, the component supplier would also need to be allowed to access the operating data of its components in order to optimise their service life. In this case, the component supplier also necessarily requires context data, including data related to production or location, for example. It must therefore be ensured in CCM that the component supplier can access this data and that the factory operator retains sovereignty over the data. Appropriate access and security concepts must be designed such that sensitive information such as recipes, production data are only shared to the extent and level of granularity allowed by the data producer (in this case, the factory operator).

Interoperable and barrier-free technical solution

In technological terms, there are two basic requirements for the CCM approach. The first of these is technical and semantic interoperability. A common standard is required so that all market participants not only provide their data, but most importantly, can also use it. This standard must be vendor- and domain-neutral. It must be able to map all forms of assets (components, machines etc.), including non-intelligent assets, and enable the storage and processing of their data. The second requirement is participation. This means in principle that all market participants can participate in CCM and that there are no technological or competitive barriers. It also means that data usage should ideally be based on neutral standards.

Figure 4: Requirements of collaborative business models



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5. Solution modules based on collaborative condition monitoring

Many different solution modules already exist for partial aspects of a digital collaborative B2B ecosystem. These include both technical and non-technical aspects. The following shows how these solution modules can be combined to form an overall approach based on the example of CCM.

Cooperative integration platform

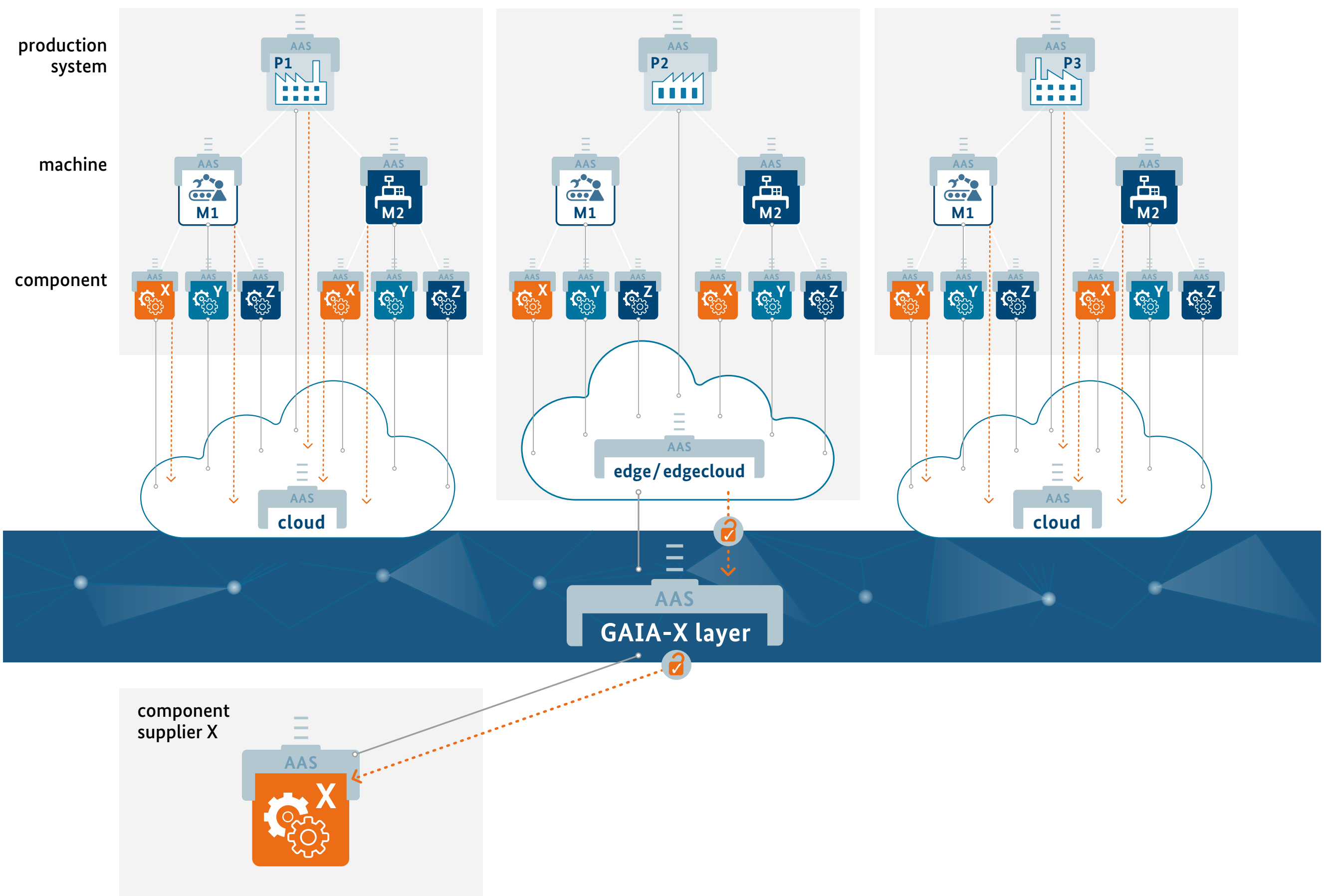
Neutral platforms form the technological basis of CCM. These are platforms that are based on the use of international standards and on rules accepted by all market participants. The operating data of component suppliers, machine suppliers and factory operators is collected and processed on these platforms. They can be implemented as a stand-alone system or as a federated cloud that brings together existing cloud and edge/edge cloud solutions. Conceptual approaches for this second variant are currently being developed in the GAIA-X project, which creates a networked data infrastructure by combining multiple individual cloud and edge/edge cloud platforms. GAIA-X creates a networked and provider-neutral data infrastructure designed to enable secure storage (data at rest), sovereign exchange and collaborative use of data and services. The classification ("privacy") and use of the data desired by the data producer must be guaranteed. Possible classification levels can be: public, private and semi-public.

Figure 5 shows an abstract representation of a three-point fractal in a data ecosystem with participants in three security domains, whose data is stored in a cloud or edge/edge cloud. The figure also shows a component manufacturer X that can access the data from its delivered components in the operating phase via the GAIA-X layer.

Digital standards

To restrict access and use of the data to the authorised group, the semantically interoperable attributes to be assigned to the data must be defined. International and cross-domain standards are required for this purpose. This is particularly necessary because CCM is sector-independent and therefore includes a wide variety of components and machines. In addition, uniform semantically interoper-

Figure 5: Three-point fractal embedded in a data ecosystem based on the example of operating data acquisition of a component X



Source: Plattform Industrie 4.0

able data standards make it easier to implement AI applications on the platform. The asset administration shell (AAS) offers a cross-sector and cross-technology approach for this purpose. It is used to digitally map assets in the form of a digital twin. The asset administration shell thus provides the interface for Industry 4.0 communication. In addition, by ensuring that digital images of the assets are consistently available, the asset administration shell opens up new business opportunities and offers new value propositions relating to product purchases.

Digital identities

The various market participants in CCM need digital identities that can be used and authenticated across different companies on the neutral platform. A digital identity ensures that access and use of the data is restricted to the authorised group.

Digital sovereignty

Data owners want to decide themselves which data to share with which users, with which access rights and for what purpose the data is to be processed. Digital sovereignty is specified as the foundation of the ecosystem. In particular, it should be possible to select and control the location of (particularly) confidential data, for example with reference to people, expertise or production secrets. Another requirement is that it must be possible to individually select which data should be shared at every level of the value chain for each participant, from the data producer through the data processor to the data consumer. Depending on the decision of the data owner, data should in every individual case be optionally private at each level, assigned to certain dedicated consumers for processing ("share" with a designated group of users) or public, i.e. visible and/or usable for everyone. The use of data and services should be easy to understand, for example, by virtue of a logging mechanism that can be used by the data owner at all times to view access operations through to individual data records.

The standardised and secure communication interface of the asset administration shell, with its attribute-based access control (ABAC), enables the definition of fine-grained access and use of data in an Industry 4.0 network. With regard to a neutral platform, it should be clarified where the ABAC policy instances are to be located. The concepts of the IDSA (International Data Spaces Association) are relevant to the technical implementation, especially in relation to enforcing data usage. The IDS initiative offers a reference architecture (IDS-RAM) for this purpose, which enables data providers to share data while protecting digital sovereignty. This architecture specifies a distributed network of data endpoints (IDS connectors) and represents an essential component of the networked, open data infrastructure sought by GAIA-X. The asset administration shell and the IDS connector complement each other and have common requirements for a digital infrastructure. Integrating both concepts allows the definition and implementation of access control and data usage control.

Asset-specific data on reliability and service life

The concept of the asset administration shell allows application-specific submodels to be generated. For the CCM use case, such a submodel would contain data relevant to the reliability and service life of an asset. This data could then only be interpreted with appropriate access rights. For example, the operating data of the factory operator can be made fully available over the entire life cycle of a machine together with its components. Data analysis methods and access to the relevant data could improve the reliability and service life of the machine.

Governance

Each market participant in the ecosystem requires a digital identity. This allows them to identify themselves (in particular to other market participants) and also allows for authentication of each identity (Federated Identity Management). The rights of data producers and consumers, platform operators and possibly other market participants such as brokers or AI service providers must be clearly defined with a data management policy. This is especially important, not only with CCM, for trustworthy collaboration between all market participants.

Legal aspects

In addition to technical interoperability, interoperability is also a requirement of the relevant legal framework (e.g. intellectual property, contract law, etc.) with respect to automated contracts (smart contracts) and data usage.

Services, data marketplace and business model

The data collected on the neutral platform can be used in the form of CCM-specific services. These services can include applications for condition monitoring or the performance of components, for example. Monetisation of the data is another consideration. The neutral platform can also act as a data marketplace where data can be offered and traded, with corresponding business models.

Grasping the opportunities of data entrepreneurship: Action area for industry

In the area of digital business models, German industry needs to exhibit more of the courage that is typical of entrepreneurs. Concerns and excessive caution can be overcome by taking the first steps towards data entrepreneurship. At present, vast amounts of data are lying idle, waiting for a suitable use. The opportunities for new business models have been described. All market participants are encouraged to grasp these opportunities by striking a balance between the benefits and risks involved.

Digital expertise in business

The CCM vision is made technically possible by AI, which is capable of processing large amounts of data. However, CCM's potential can only be fully exploited if there is a fundamental shift in mindset as regards the way business is transacted. Technical optimisation of the overall system is not enough. Comprehensive optimisation can only be achieved through a sufficient number of market participants, fair conditions and interoperable standards. Networked thinking and action that incorporates technical, digital and entrepreneurial expertise is the key to success for the dissemination of CCM on a broad scale. Good business decisions can only be made if all levels within the company have the appropriate expertise and can thus weigh up opportunities and risks. For this reason, extensive further training is required for the current workforce. The content of this training must be integrated into future training courses.

Laboratory testing

Under the direction of the Fraunhofer Institute for Industrial Automation (IOSB-INA), regional companies and network partners are working together to research innovative AI technologies under various Industry 4.0 conditions. For this AI RealLab, real data from a complex process chain is used, on the basis of which the technical aspects of CCM are then scientifically examined. The goal is to evaluate and further develop AI methods in a realistic industrial environment. Data from different sources are brought together in this process in a semantically interoperable way. The knowledge thus gained under laboratory conditions is an important prerequisite for the reliable use of AI in real production plants.

6. Summary and outlook

The digital transformation offers an abundance of economic opportunities for industry through data-driven value creation networks.

New collaboration models, flexible and resilient structures and the cooperative use of data allow for innovative operating and business models, while also promising significant added value for all market participants within the network. This potential can be significantly enhanced through an open exchange of data based on common rules within a multilateral cooperative framework that spans companies and competitors.

The present model of collaborative condition monitoring is an example of such a collaborative, cross-cutting approach and describes its potential benefits for market participants within the ecosystem. A central element here is the open exchange of data within a three-tier network, which therefore goes beyond conventional bilateral partnerships.

The three-tier network forms the structural basis for the development of multilateral networks. In principle, every use case can be mapped using the three-stage model, not just the CCM use case shown here.

The CCM approach is novel because it gives rise to new business models. In this context, it is essential that companies competing with each other at an operational level make available the data that is so urgently required for the generation of digital business models in the same way as their physical products and recognise this data as non-related to brand and product differentiation.

The implementation of such a model poses numerous technical, regulatory, economic and socio-economic challenges and cannot currently be embodied (in an economically viable way) within conventional approaches. The key requirements for successful implementation are an open and interoperable infrastructure which allows for sovereign, self-determined data exchange in the CCM ecosystem, as well as a regulatory and cultural framework which efficiently promotes and supports cross-industry cooperation.

These basic requirements are currently being developed in various initiatives and projects and form the basis of future “smart, digital services” in industry: GAIA-X and the International Data Space provide a basic data infrastructure for the sovereign handling and exchange of data in various application domains, while the asset administration shell offers a uniform communication standard for interoperable networking of all market participants and assets in Industry 4.0. In addition, further projects, such as the Industry 4.0 Legal Testbed, describe the legal requirements for technically reliable and legally compliant cooperation in digital ecosystems.

For successful implementation of smart digital services in Industry 4.0, these results must be brought together and integrated within a common digital basic infrastructure. In conjunction with targeted programmes for training and further education, this infrastructure will furnish the necessary environment for the development of digital business models for industry in Germany and Europe.

The present model of collaborative condition monitoring offers a practical experimental field for bringing together existing approaches and perspectives in a defined ecosystem and testing their interaction with each other.

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