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InDEx – Industrial Data Excellence

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FOREWORD

InDEx, the Industrial Data Excellence program, was created to investigate what industrial data can be collected, shared, and utilized for new intelligent services in high-performing, reliable and secure ways, and how to accomplish that in practice in the Finnish manufacturing industry.

InDEx produced several insights into data in an industrial environment, collecting data, sharing data in the value chain and in the factory environment, and utilizing and manipulating data with artificial intelligence. Data has an important role in the future in an industrial context, but data sources and utilization mechanisms are more diverse than in cases related to consumer data. Experiences in the InDEx cases showed that there is great potential in data utilization.

Currently, successful business cases built on data sharing are either company-internal or utilize an existing value chain. The data market has not yet matured, and third-party offerings based on public and private data sources are rare. In this program, we tried out a framework that aimed to securely and in a controlled manner share data between organizations. We also worked to improve the contractual framework needed to support new business based on shared data, and we conducted a study of applicable business models. Based on this, we searched for new data-based opportunities within the project consortium. The vision of data as a tradeable good or of sharing with external partners is still to come true, but we believe that we have taken steps in the right direction.

The program started in fall 2019 and ended in April 2022. The program faced restrictions caused by COVID-19, which had an effect on the intensity of the work during 2020 and 2021, and the program was extended by one year. Because of meeting restrictions, InDEx collaboration was realized through online meetings. We learned to work and collaborate using digital tools and environments. Despite the mentioned hindrances, and thanks to Business Finland's flexibility, the extension time made it possible for most of the planned goals to be achieved.

This report gives insights in the outcomes of the companies' work within the InDEx program. DIMECC InDEx is the first finalized program by the members of the Finnish Advanced Manufacturing Network (FAMN, www.famn.fi).

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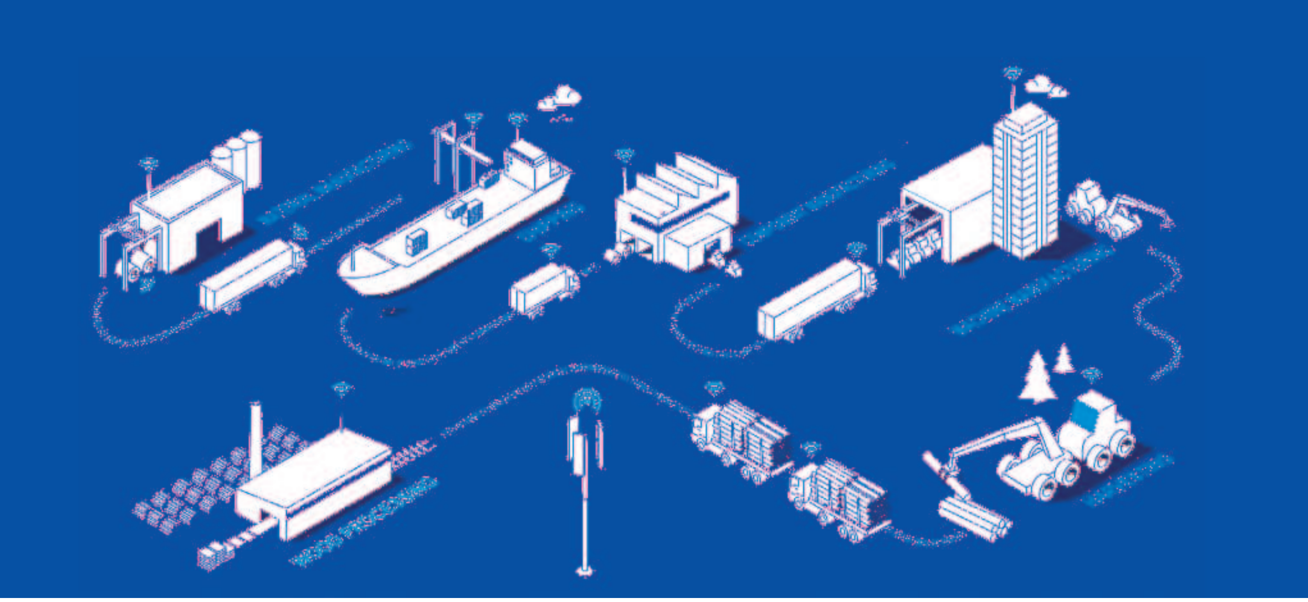
Software Advisor
Juha Kuusela
Danfoss

Program Manager
Dr. **Seppo Tikkanen** DIMECC



Danfoss

Fastems

KONECRANES
Lifting Businesses

Prima Power

HT LASER

elekmerk

RAUTE

UNIVERSITY OF TURKU

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Aalto University

Tampere University

UNIVERSITY OF JYVÄSKYLÄ

VTT

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DIMECC InDEx in a Nutshell

InDEx, Industrial Data Excellence, concentrated on data utilization in an industrial environment. In the program plan, the vision of the InDEx program was to unlock the value of data as an enabler for the next industrial revolution, centered around artificial intelligence in the Finnish manufacturing industry. The application domains and their topics are shown in the table below.

Application domains	
Smart Factory	**Smart Chain**
Smart Factory connectivity (Danfoss, Fastems, Konecranes)	Material information flow in the value chain (Elekmerk HT Laser, Prima Power)
Prescriptive maintenance (Danfoss, Konecranes, Raute)	AI-assisted demand-order-delivery process (Elekmerk HT Laser, Prima Power)
Manufacturing process excellence with AI (Fastems, Prima Power, Raute)	Manufacturing logistics (was not realized because of COVID-19 consequences)

Partners

Danfoss Drives, Fastems Oy, Elekmerk Oy, HT Laser Oy, Konecranes Oyj, Prima Power Oy, and Raute Oyj.

All the research work was subcontracted from universities and research institutes. The share of research work was about ten per cent of the total budget. Collaborating research partners were Aalto University, Tampere University, the University of Jyväskylä, the University of Helsinki, and VTT.

Facts

Duration: .... 9/2019 – 4/2022

Budget: .... about 6 M€

Funding: .... Business Finland and participating companies

DANFOSS DRIVES

Since introducing the world to AC drives back in 1968, Danfoss has continued to lead the charge when it comes to bringing variable speed control to electric motors. Drawing on decades of passion and experience within a wide range of industries, Danfoss can deliver drives that work with any motor or system.

Danfoss portfolio also includes servo drives, harmonics drives and medium-voltage drives, with the aim of delivering the kinds of technologies and digital solutions that will enable the company's customers to excel in an ever-changing world.

Drive as data source – what to expose?

Contributors

- Danfoss tools group and fieldbus group, and their subcontractors

Background

Drives can act as an efficient and interesting data source for various IoT set-ups. They have a number of internal and external sensors and can be programmed.

The goal is to enable customers to instrument their machines and factories so that they can collect the desired data from drives in the correct format with the required frequency. This data can then be used to monitor, analyze, and optimize the process.

The application scope is very wide. Drives can be used as data sources wherever they are used. Even when drives are not connected to a data network, data can be stored locally on a memory card and analyzed offline. The reasons for collecting data can be based on anomaly detection, monitoring behavior, finding out if motors and drives are correctly scaled, collecting data for preventive maintenance, and so on.

Drives are in a unique position to measure motor torque and supply grid quality. Measurements can also be conducted by adding specific sensors and connecting them to the control network. However, such a solution is much more expensive, and its deployment requires a production stop in a running factory or a redesign of the machine being instrumented.

Solution The need for data collection is rather generic, and the application area is wide. Hence, we have approached the solution in layers.

- Existing data collection points communicated through existing mechanisms is easy to apply. You can use a fieldbus to communicate existing read-out values. You can extend this by defining a specific fieldbus profile or point mapping, if needed. We have developed views in MyDrive Designer to define these interfaces.
- We have also implemented the OPC protocol and defined a drive profile with an E-class information model, containing an interface to capture data via data logger functionality. This is useful for those who already use OPC/UA architecture.
- If existing data points are not enough, the interface can be customized using the MyDrive Logic and Sequence Customizer. The implementation is still in an experimental phase. We have not been able to reach a performance level that would be suitable for all needs.
- Application SW modification with MyDrive Designer provides better performance and more flexibility. It also allows complete control over the data interface and supports data filtering and preliminary analysis. Drive CPU resources are the main limitation for analysis. We have been working to optimize the application runtime environment, and preliminary results are very promising.
- An alternative solution for customers that do not want to change the drive application SW is to use a programmable gateway. With the DDI protocol, it is possible to connect a Linux-based gateway to the drives and do the analysis in the gateway. The gateway also provides support to the IDS protocol.
- For data visualization, we have developed MyDrive Insight. This can show different signals and synchronize them to each other. It works both for real-time monitoring and for data logs.
- Data is formatted so that it can be analyzed in MATLAB. We have also developed drive models that can be used to define the semantics of different collected data points. These models also assist in analysis.

The problem scope is wide. Consequently, we have developed alternative solutions that can be deployed based on the customer's needs and capabilities.

Result, output, impact

There are already some commercial deployments. These are used to monitor system behavior and to detect anomalies. They also detect drives that are often overloaded and help in configuring the system so that lifetime expectations can be met.

In our own development, we use these mechanisms in our test systems. We have also deployed continuous data collection and streaming with early customers, to be able to follow drive performance and to understand the actual application requirements.

Most of these capabilities will be launched with the iC7 product series. We expect the development to continue.

Figure 1: **MyDrive Insight scope view (Danfoss)**

Using drive data for generic analytics

Contributors

- Tampere University, Danfoss research group

Background

Data collected by internal drive sensors can be used to analyze the health of the machine being controlled. Most of the anomalies and their detection are related to the machine being controlled. However, issues related to the supply grid, the AC drive and the motor being controlled are rather generic. The goal is to expand our product offering so that we could provide the analytics needed to detect these issues.

With the motor, common issues relate to leak currents, wiring and bearings. Together with Tampere University, we have been looking at more efficient ways of detecting bearing faults. Bearing faults have the highest frequency of occurrence and are one of the most challenging faults to detect and diagnose.

With supply grids, the common problems relate to phase shift and missing phases.

Solution

Several different techniques have been applied to detect bearing faults. Recently, data-driven deep learning models developed by machine learning researchers have been proposed as a solution. In earlier experiments, these achieved very high classification accuracy. Unfortunately, their application carries significant cost. A complicated learning phase requires large, labeled data sets. Deep models have high computational complexity and cannot be applied in real time. We aimed for early fault diagnosis with scarce data, and we minimized neural network complexity to support real-time fault classification.

A study was conducted to find the best alternative. Based on this study, we recommend using a one-dimensional self-organized operation neural network with the generative neuron model for bearing fault severity classification.

Result, output, impact

The detection of bearing faults works well. The comparison shows that this technique is especially good in differentiating medium and severe faults. Computational complexity is low enough for real-time application. With the GPU implementation used in this experiment, the total classification time was 9 μsec.

The target is to launch bearing fault detection, detection of loose wiring, and detection of supply-side issues in the iC7 product family after these functions have been commercialized. We are now looking at extending the detection function into the system being controlled. We will start by detecting issues with a pump being controlled. We can already detect an empty pump, and we aim to detect cavitation.

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  https://ieeexplore.ieee.org/abstract/document/9558835

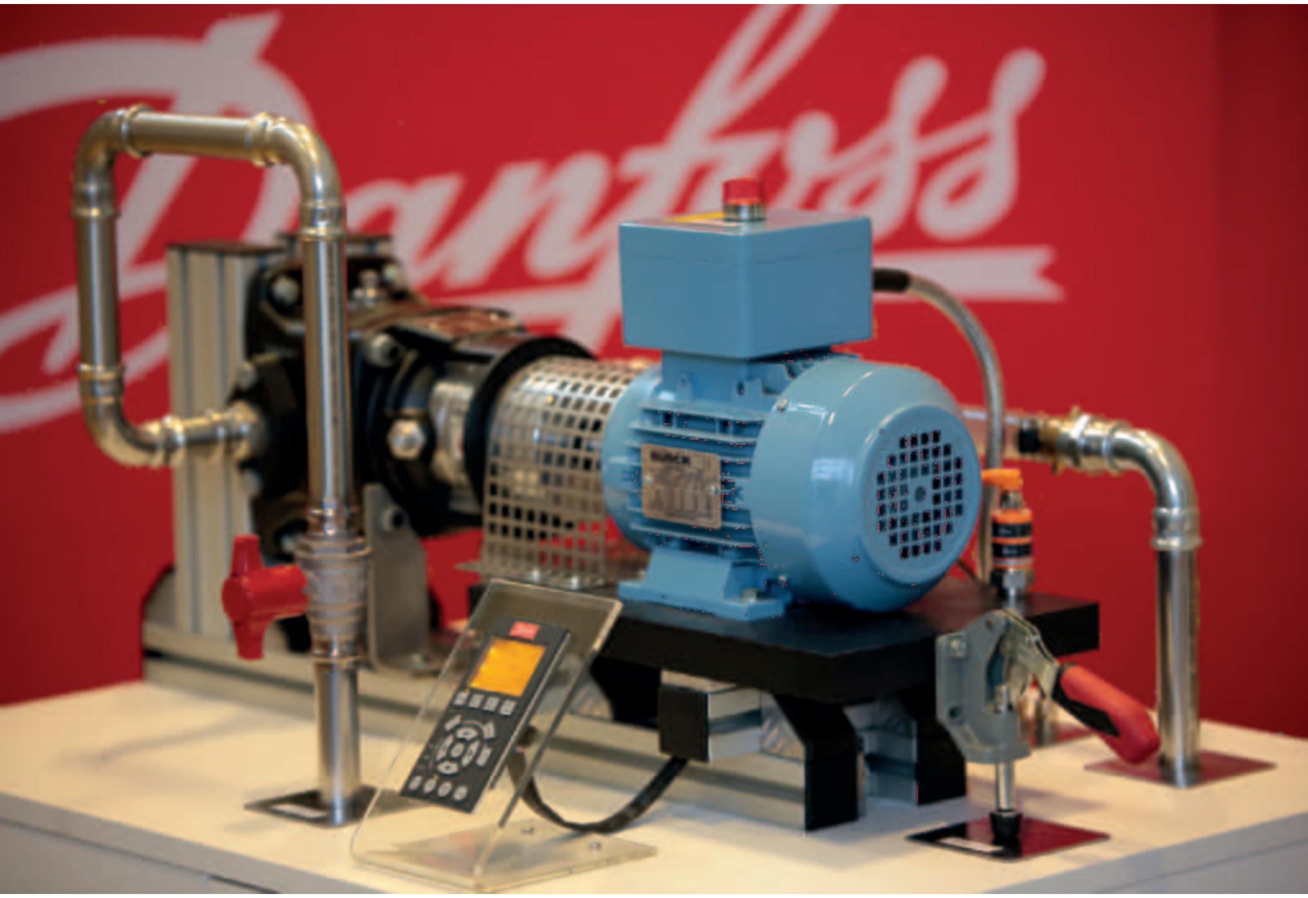


Figure 2: **Pump test setup (Danfoss)**

FASTEMS

Fastems is the leading supplier of flexible CNC automation solutions for high-mix, low-volume manufacturing. The company is a family-owned open integrator with over 40 years and 4000 installations of experience with 90+ machine tool brands. The majority of customers are industrial machine builders or subcontractors of various kinds, located in Europe, North America and Asia. The mission of Fastems is to help metalworking manufacturers improve their productivity and profitability. The main application fields of Fastems are pallet and robotic automation – always equipped with our industry-leading production planning and execution software, MMS. The company also has solutions for automating the production and resource planning of stand-alone machine tools and support systems with a wide range of services.

As a factory automation system provider, Fastems has a unique position in the core of manufacturing businesses. Fastems systems are uniquely positioned to interface between different isolated parts of a manufacturing company's operational and information processes. By default, Fastems' automation solutions connect different machines within an organization's workshop, but this is only a fraction of the process elements on the workfloor. Additionally, Fastems' control software has the capacity to connect with other software applications (such as ERP, MES, CAD/CAM, etc.) at a business level.

In overview, the unique position of Fastems and recent technological advances toward networked systems have enabled Fastems' business expansion from a system provider toward a data-driven service provider. In the future, Fastems could act as a manufacturing information HUB for critical manufacturing information and also provide end-to-end overall solutions for its customers. In this scenario, Fastems can provide value for multiple customers as an ecosystem driver. This will mean a strong transformation from product-centric business toward platform economy and service-centric business models.

In this vision, customers, partners, developers, and other stakeholders can create systemic value for the end customers by tapping into the resources and capacity of the ecosystem's network. This is something that requires effective collaboration. This ecosystem business view requires data and platform thinking, which are positions that could enable new information-based service offerings and totally new business models. This would enable numerous applications and business creation for the manufacturing industry. Furthermore, it would enable totally new ways of managing manufacturing capacities and would have dramatic effects on the overall supply chains, including factory-external logistics.

The goal of the InDEx project for Fastems is primarily to support the company in achieving some of the core elements of its current strategy and vision for the future, and specifically, the desire to transform itself to be a relevant ecosystem player in the emerging digital age.

Fastems' participation in InDEx was divided into three work packages:

- WP1: Trusted and integrated data flow for collecting and delivering data: Develop novel solutions enabling data sharing between value chain players.
- WP2: Advanced analytics for processing data: Building capabilities in order to create actionable information from data.
- WP3: Data-intensive business: How can data be turned into value and monetized?

Next, some of the results of the InDEx project will be introduced. Experiments 1 and 2 are related to work package 2 and Experiment 3 to work package number 3. Work package 1 results have been presented under their own section in this booklet, under the topic Smart Factory Experiment, which was done in cooperation with Konecranes, Danfoss and VTT.

Advanced analytics for processing data

Contributors

- Fastems: Harri Nieminen, Janne Kivinen, Juho Tasanko, Tomi Kankainen, Pasi Kauhanen
- Vaisto Solutions: Sami Dahlman, Juuso Pimiä, Jokke Ruokolainen

Background

MMS (Manufacturing Management Software) is at the heart of every delivered Fastems system. MMS is able to plan, run and monitor customers' manufacturing so that the customer is able to deliver the right parts at the right time – maintaining high productivity. When planning and executing production, in the background MMS also collects lots of data in its log files and database about past events in the manufacturing process.

As a part of InDEx work package 2, Fastems wanted to research how this collected manufacturing data could be further analyzed to create more customer value. Vaisto Solutions (later Vaisto) was selected as a partner for this study. Vaisto has long experience of developing different AI and ML-based data analytics solutions for its customers. The main goal of the study was to map the quality of the collected MMS manufacturing data from the AI/ML use point of view and to develop a working demonstrator for log file analysis, utilizing AI as a core element.

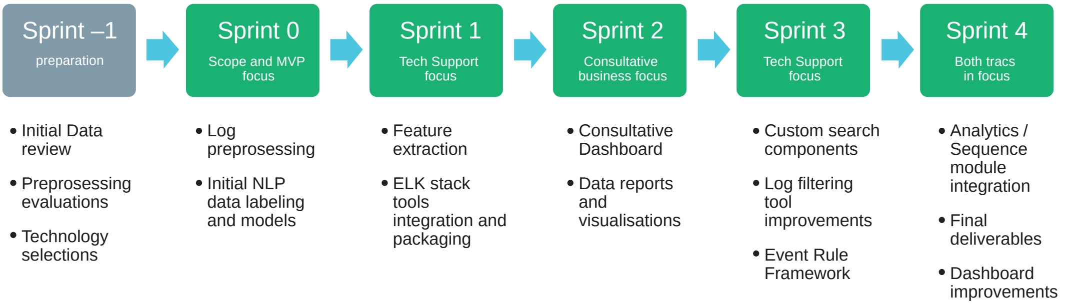
Solution

At the beginning of the study, two main tracks for developed solutions were defined:

Technical support track: There was a recognized need to develop better tools for Fastems technical support to streamline the troubleshooting process. Reading and analyzing system log files manually is resource intensive and takes time even from a senior-level support person.

Consultation track: Fastems has its own dedicated team for advisory services. This team helps Fastems customers to maximize their productivity. With AI, it would be possible to analyze the collected production data to see how the customer is using the system and what changes could improve productivity.

The development work was done in six two-week sprints:



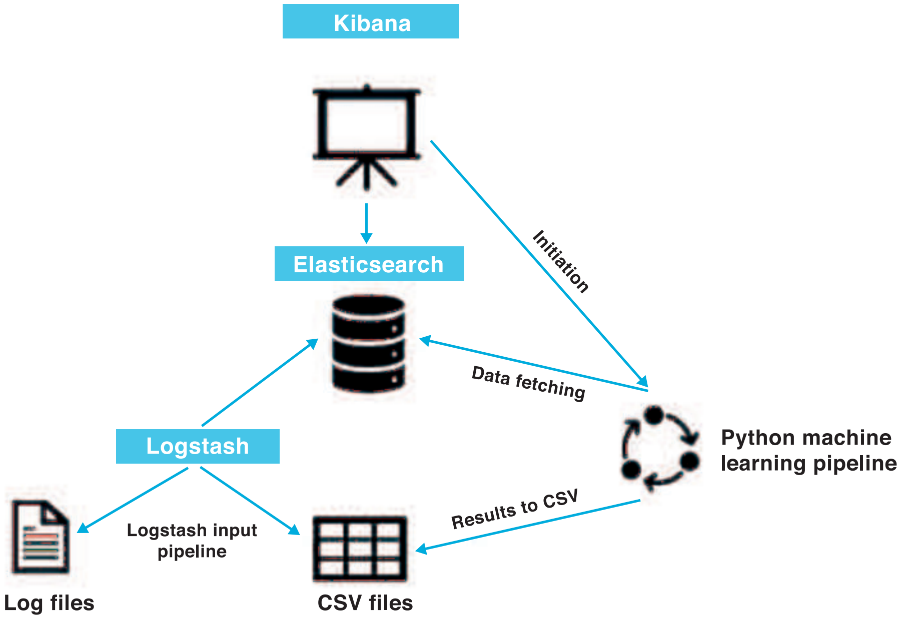
At the end of each sprint, there was a sprint review in which the results of the sprint were presented and the content of the next sprint defined.

In order to test the developed solutions, production data from real customers was needed. Luckily, Fastems got access to two customer systems that are in daily production and that thus provided a perfect data set for development and result validation. The used data consisted of system log files and system SQL main database data.

The project started with the technology selections. The following requirements were set for the used technologies:

- Flexible deployment scenarios
  - Local installation possible
  - Cloud installation possible
- Extensible environment
  - It was assumed that no out-of-the-box solution can meet the requirements, so the chosen solution should be extensible.
- Solution should scale to handle large amounts of data
  - Even though the proof of concept most likely won't contain very large data amounts, the possible productized environment will.
- Solution should be able to handle both batch log files and streaming (live) data
- Large user base
  - Helps to get support when needed
- No proprietary protocols
  - Open source when possible

After reviews, the so-called ELK (Elasticsearch, Logstash, Kibana) stack was selected for preprocessing the log events and storing the structured data. The analytics calculations and other machine learning-related computing was developed using ELK-integrated Python scripts.



Result, output, impact

The project provided Fastems with the first concrete touch points for experimenting with AI technologies within its business. The selected technical service and consultative development tracks both provided realistic and relevant use cases for the project. Next, the main findings of the project are listed.

Technology selections

The selected ELK technology stack proved to be valid for the use cases on hand from the development point of view. The development was quick, and Vaisto was able to develop the solution in the direction that had been agreed at the beginning of the project and that was later fine-tuned in the sprint review meetings. This was thanks to Vaisto's solid experience in the selected technologies. Later in the discussions with Fastems' own IT team, the maintainability and support of the selected technologies in the long run was questioned. This can, however, be seen as a common challenge when using open-source software.

Quality of data

The most important lesson learnt from the experiment was that the quality of the log files collected by MMS could be greatly improved from an AI point of view, with small adjustments to the structure of the log files. In the experiment, Vaisto used a lot of effort to pre-process the log files in a format that would be readable for a machine learning solution. Below is a simple example of the current status of the MMS log file and Vaisto's proposal on how to improve the structure:

- Current

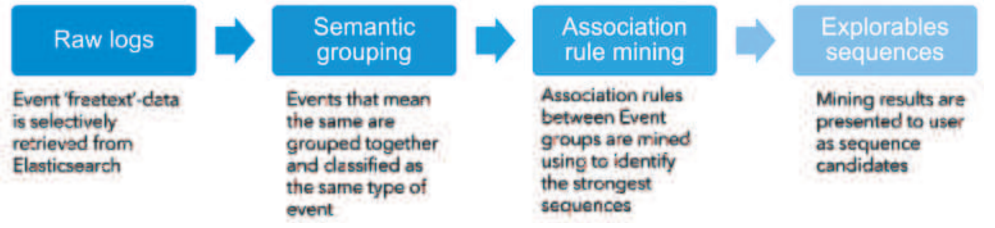
```
2019-08-16 00:14:27,117 INFO  [Machine 1 Service] - Updated pallet visit ID: dbf642ba
e849-42de-81cc-a08818bc3d0a, INDEX: 9, PALLET: [ID: 0297cb56-043a-483f-8bdb-
a8e90083fb3b, NUMBER: 8], TASKS: 1 with changes [Index, ExpectedStartTime]. (SOURCE:
ProcessingTaskManager.OnSynchronizePalletVisits)
```

- Structured

```
Time:       2019-08-16 00:14:27,117
Loglevel:   INFO
Service:    Machine 1
Action:     Pallet visit update
Changes:    Index, ExpectedStartTime]
Pallet_nbr: 8
Index:      9
Source:     ProcessingTaskManager.OnSynchronizePalletVisits
```

AI-assisted data analysis

One of the core ideas in the technical support track initially was to develop an AI-assisted log file analyzer in order to streamline the troubleshooting process. The development of the solution turned out to be even more challenging than expected. Fastems automation's flexible characteristics made it difficult to find clear repeating event patterns from the used data that could have been used to train the error detection machine learning model. Fastems systems' production routing and schedule are changed all the time by MMS intelligent scheduling. This means that every day's production plan can be different. The error sequences are new incarnations in many cases, and they are hard to spot within the millions of log lines. Based on this significant conclusion, that fault sequences do not repeat often, the team started to focus on developing an unsupervised learning-based sequence and an association rule mining-based pipeline for identifying potential sequences.



The found sequences were visualized using dashboards that were also created by Vaisto. The technical support track dashboards focused on error-level heatmaps and the consultative track on system status patterns.

Conclusions

Most of the effort in this experiment was spent on structuring the log files into a format that could be used with AI and machine learning. This was also the main key take-away for Fastems from this experiment. In future versions of MMS, the structure of the log files will be changed to increase AI compatibility. Another important benefit for Fastems was even more practical: this experiment provided valuable training and an introduction to the world of AI technology for the whole participating Fastems organization.

Fixture combination optimization using machine learning

Contributors

- Sandra Raitaniemi, Pasi Kauhanen

Background

In this project, the possibilities of using machine learning in Fastems products were explored, and finally a proof of concept using machine learning was developed. The project consists of two phases: idea gathering and selection, and solution implementation. The chosen idea for proof of concept was part fixture combination optimization. The goal of this work was to implement a possible solution for the optimization problem that would ultimately be implemented in Manufacturing Management Software (MMS).

The project began with collecting possible applications for machine learning in Fastems products and services. The aim was to find an application also fitting as a Master's thesis topic. Ideas were collected by organizing workshops within the company. Additionally, the workshops were a tool for gauging the need for applications using machine learning. Previous knowledge of machine learning and artificial intelligence was not a requirement for participating in the workshops. Therefore, the workshops were developed with the aim of giving a brief introduction to machine learning to enable attendees to discuss possible ideas. Three workshops were held, and attendees came from various roles, mostly technical and managerial positions in the company. Gathered ideas were analyzed, and finally a feasible idea was selected. A few criteria were set for the selection of the idea. The selected idea should use data collected with Manufacturing Management Software (MMS), and it should be relatively easy to implement.

After analyzing the collected ideas, a feasible idea was selected to be solved. A longstanding problem in flexible manufacturing system operations is allocating part fixture resources to production orders. Each part fixture occupies a fixture position on a machining pallet. Because the maximum number of machine pallets and their fixture positions are constant, filling the system fixture positions with one type of part fixture automatically decreases the available positions for other types of fixtures and, with it, reduces the resources of those orders using the other types of fixtures. This can possibly lead, for example, to orders being overdue and reduced machine utilization.

Fixture allocation must be done in an optimum way to ensure optimum production and high machine utilization. Typical trial-and-error type optimization becomes increasingly difficult as the manufacturing facility grows, since tracking the causal connection between fixture changes and changes in production quality becomes more complex as the number of parameters grows. Therefore, utilizing modern optimization techniques becomes essential, with machine learning being one emerging component of optimization methods. Additionally, the growing amount of available production data in MMS enables the use of machine learning in solving fixture allocation optimization problems.

From a customer's perspective, the solution answers a simple question: what is the number of each fixture type needed by the manufacturing system to ensure optimum production? The optimum combination of fixtures emphasizes the use of the right fixtures without taking up too many pallet resources from other fixtures. As a result, the production can be scheduled to better produce orders in time or to maximize the utilization of machines, or possibly both at the same time.

One motivation for solving the fixture allocation issue is the customer demand for an answer to the question of how many fixtures they should acquire. The market for this solution would be customers that have or are buying a Fastems pallet system.

Solution

The solution was reached by studying modern optimization methods that use machine learning. By following these methods and combining them with data production methods that fit our specific application area, we were able to define the specification for our solution. The reason for selecting this solution was its use of machine learning. Our ability to implement machine learning algorithms combined with a need for exploring the use of machine learning in our products made the solution compelling.

The solution is composed of three components: a fixture combination generator, a data simulator, and a machine learning model. The fixture combination generator samples different fixture combinations, and the simulation produces metrics of the combinations' effectiveness, more precisely machine utilization and order tardiness. In addition, data from the fixture combination and production orders are collected. The data is then passed on to the machine learning algorithm, which learns the model. The model is then able to predict utilization or tardiness based on production data and the fixture combination. The optimum fixture combination is the combination corresponding to the highest utilization or the lowest tardiness. The utilization metric and tardiness metrics offer a measure for how well the fixture combination will perform in the future when used to produce the current production orders.

In a real-world pallet system, the selected fixture combination typically doesn't fluctuate, and fixture changes are made conservatively. Therefore, the variance in fixture combinations needed for evaluating multiple different combinations could not be achieved by collecting real production data. Luckily, our existing simulation could replace real-world production data. In the solution, the simulation is an important tool in evaluating fixture combinations' effectiveness. However, real production data could be incorporated into the used data in the future to better account for production uncertainty when predicting a combination's performance.

Although fixture allocation is an important factor in production scheduling, it still remains a not widely researched issue. After an extensive search of academic studies, only two were found discussing fixture allocation [1][2]. The main principles of the studies' solutions were the same. The workflow of generating fixture combinations and measuring their performance to find the optimal combination was used, but the technical details and means of generating combinations were very different. Since parameter optimizing in general requires generating different parameter options, the uniqueness of this solution can be measured based on the technical choices alone. First, because the two studies did not use machine learning and second, because our solution is heavily reliant on the data produced by MMS, the solution can be deemed unique.

Result, output, impact

Development of data-driven optimization was new to Fastems, and therefore, the development work was anything but straight-forward. New iterations of the solutions will be needed before we can consider implementing it for a product. Regardless, Fastems has gained knowledge about developing machine learning algorithms that are a technical fit with MMS. In addition, the used optimization method's main principle could be applied to other areas of MMS. In general, this project has given confidence and depth to our discussions about machine learning-related development and has encouraged the use of machine learning in the future.

The solution was tested in two phases: first the machine learning model was tested for accuracy, and then the whole solution was tested by comparing the solution's fixture combination with a self-optimized fixture combination. The machine learning model itself is fairly accurate when predicting order tardiness and machine utilization. There are still some issues regarding the precision of the predictions. These issues can be combatted with data refining. Finally, the whole solution was tested against a simple simulated pallet system and a small set of orders and fixtures. A fixture combination was optimized and set by hand, and performance metrics were gathered from production estimates. Then the solution was used to produce an optimized fixture combination for the same system and orders.

The results are encouraging. When using a very simple part selection, the fixture combination produced by the solution is better than the self-optimized combination when optimizing to minimize order tardiness. On the other hand, when optimizing to maximize machine utilization, the self-optimized combination produces better results. Unfortunately, when optimizing for a more intricate part selection that needs a more specific fixture combination, the fixture combination produced by the optimization solution is worse than the self-optimized fixture combination.

The results show that research and development needs to be done to improve the solution before it can be implemented in MMS. Our future goal is to develop this solution to the point that it can be implemented.

Due to the iterative nature of machine learning problems, we will likely develop every phase of the solution. There are already possible development paths we could follow to improve the current solution. When the initial goal of producing the optimum fixture combination is achieved, the development can focus on improving the usability from the point of view of the operator making the fixture changes.

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Digital services

Contributors

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- **Futurice:** Salla Heinänen, Lauri Anttila, Joel Saarimäki, Aleksi Halttunen, Antti Järvinen

Background

In this work package, Fastems wanted to research the market potential and customer requirements related to novel digital services that could be offered directly to end customers. The aim of the research was to create initial concepts, validate potential new business models, and build the needed architecture, environment and technologies to support a minimum viable product that could be validated and tested with selected pilot customers. Several internal stakeholders from sales to life-cycle services were involved, and several customer interviews were held to understand the need and validate the draft solutions (POC), as well as MVP. Fastems worked with Futurice Oy to ensure that proven methods of service design and co-creation were used and adapted to Fastems' own toolkit for the future. Futurice offered knowledge in technologies that are not yet familiar to Fastems, such as the cloud environment and tools and especially architecture design related to cloud-based solutions. Fastems also participated in consortium workshops led by Aalto University to identify potential use cases, construct a customer journey, and define new services and potential business models around shared data.

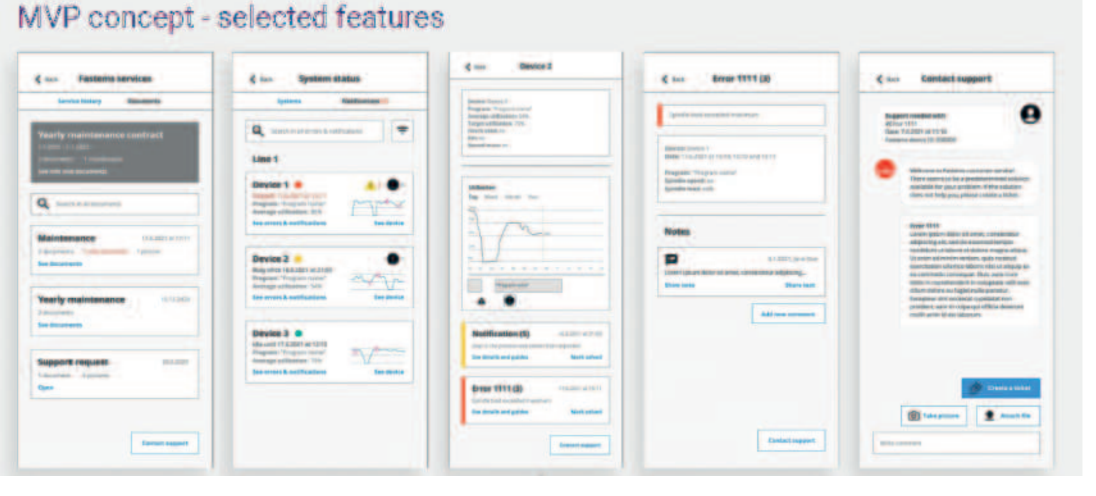
Solution The actions in WP3 were divided into nine sub-work packages:

SWP1 Service design, SWP2 Concept creation, SWP3 Concept validation, SWP4 Proof of Concept, SWP5 Initial data model and architecture, SWP6 Feasibility and desirability analyses, SWP7 Business model and design, SWP8 Environmental scanning, and SWP9 Development Roadmap.

SWP1: The work started with service design, identifying customers' problems that needed solutions in which digital, remote or data-based services could be utilized in the resolution. Customers for interviews were selected based on their willingness to utilize new technologies and our current relationship with them, which would enable open opinion sharing. Almost 10 customers in different roles globally were interviewed using a predefined agenda and leading questions. Interviews were then followed by workshops in which several experienced Fastems representatives from sales, services and product management around the world shared their thoughts and experiences and reflected on documented customer needs. These workshops enabled a clear, documented, well justified and common view of the necessary steps in further developing our service offering, especially related to value-adding and data-based services.

SWP2 & SWP3: Based on the customer interviews and internal workshops, where the customer needs were validated and different target groups identified, the initial concepts were put together. The initial concepts for the future digital service followed identified roles in the customer´s organization: a service hub concept for maintenance managers use, an efficiency tool for production managers/development managers' use, and an operational awareness tool aimed at supporting daily operations. Service hub concepts included an on-time view of system maintenance status, history and future, and upcoming tasks. It also enabled the maintenance manager to see potential risks related to end-of-life components, missed service intervals or neglected upgrades. Requests from the customers were also to provide features that are typically covered by separate maintenance system. The efficiency tool concept enabled a real-time view of the customer's production system, utilization, availability of each of the devices, and alarm status and diagnostics to react to potential issues. The intention was to find the means to utilize new technologies such as AI or machine learning to support fault finding or even proactive preventative actions. A longer-term comparison related to productivity and a peer comparison were requested. The operations transparency tool concept enables operators to have situational awareness of necessary actions to enable best performance. The service would signal an alarm if the actions are needed to support operations or maintain the system. It would also enable the operator to have more freedom in organizing their work schedule, giving transparency to when exactly the actions are needed and when there is time for a break by forecasting coming tasks.

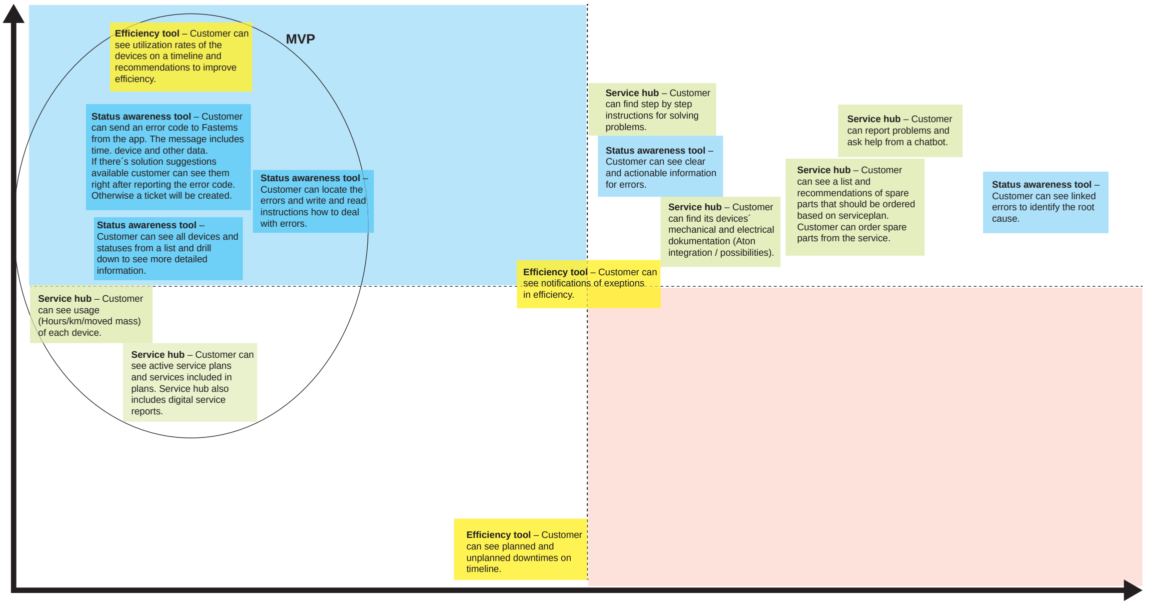
SWP4: The initial concepts were realized as dummy prototypes with "clickable" features that enabled quick prototyping and "like real" testing of the functions with customers. Customers were able to see the concepts come to life and to give their feedback and improvement ideas, as well as an evaluation of the importance of each feature. The comments and feedback were documented. Based on the feedback, the original ideas were revisited and fine-tuned.



SWP5: Based on the concepts and customer needs, the initial idea of a feasible cloud environment and architecture was drafted. The strategical business decisions guided this somewhat, and great effort was put into defining the sustainable base for all future Fastems cloud-based solutions and digital services. The IOT platform used initially was evaluated as not sustainable or scalable for solutions for the future, and Fastems decided to move to a new platform. Furthermore, the existing connectivity solutions and cyber security were investigated, which led to some further actions. This sub-WP enabled Fastems to critically review the existing solutions and evaluate their longer-term sustainability and feasibility, also leading to strategical decisions that will support development actions and business in the future. The data sources needed to produce the data were identified, data quality was reviewed, and main issues and gaps in the data were documented. The initial ideas of data modeling and current capabilities to visualize data in a value-adding way were defined. The actual solution was decided to be built as a PWA application (Progressive Web App) that could be used on a PC web browser or mobile device.

SWP6: Each of the main features requested by the customers was analyzed based on desirability and novelty. The full evaluation was also done from a technical feasibility point of view, as well as from a practical point of view in terms of ease of implementation in practice. The final evaluation results yielded a matrix representing feasibility and desirability, and the sweet spot where both met their maximum. Based on identification of the sweet spot, the starting point for the actual minimum viable product was agreed on, and the next steps were based on the assumption that the minimum viable product would deliver the mentioned functions and features. The aim of developing the MVP was to be able to release a first product to the customers that would be desirable enough for them to be interested in sharing their production/usage data with Fastems.

SWP7: New types of products and services enable Fastems to review the existing business models and renew the earning logic. Data in itself is valuable. So, from the beginning, the MVP-level product was planned to be free for our existing customers, and payment would be in the form of their data. Going further and expecting data to be available for different analytics and possible to aggregate in new ways, Fastems expects to be able to produce value-adding services. That value must be put into a meaningful business model, and in this sub-work package, different business models were investigated and considered as options. The specific customer segmentation from the perspective of the services business was done, and business potential, different go-to market models, and target segments were evaluated. The key target segment was selected, and the business model and go-to market model were tuned, especially to support reaching the selected segment in the first phase of commercialization of the novel digital services.



SWP8: The environmental scanning of Fastems' competitor environment was done the first time for digital and software-based services. The scanning aimed to understand where our concept product would be positioned in the competition, and if we could learn something from the current offerings of our competitors that would guide our research and development actions going forward. In environmental scanning, around 10 machine tool builders providing automation solutions and 4 integrators were compared, based on public information found on the internet but also utilizing information from Fastems based on contacts with different customers and their intentions for the future. Environmental scanning enabled a full view of what is available on the

market currently and where the focus areas lie for our competitors. In the end, we found that digital services utilizing real-time connections and data sharing are not commonly available yet, so Fastems' position to build that as a competitive advantage seems to be promising.

SWP9: The work package concentrated on creating a credible way forward to the next steps of developing a solution that could be launched for Fastems' customer base, first to selected pilot customers, then to the target customer segment, and eventually to make the benefits available to all customers. The roadmap was built on three separate streams supporting each other: the business and concept stream, the technical stream, and the productization stream. The business and concept stream was planned for concept creation and business model development and iterations; the technical stream for selecting the correct technologies and building technical solutions; and the testing and productization stream for offering development and combining new solutions with the existing product offering or productizing them as separate solutions for customers. It was realized that even though the high-level ideas and plans reached up to 2024, continuous detailed planning, iterations and re-prioritization would be needed to support the subsequent product development project. That is why the roadmap was planned only 12 months ahead in detail.

Result, output, impact

As a result of WP3, Fastems has developed a clear understanding of the overall market situation, the available offering, customer needs, and potential business models for developing novel digital services to support growth of the service business. In addition, there are several concepts, concept designs and working prototypes available, as well as main technological choices made and a technical approach defined for future development. The team, and Fastems as an organization, learned how to run service design and business design projects in co-operation with customers, and what kinds of routines to build for the development phase to ensure that utilizing customer feedback in a continuous way could be ensured and the services developed would be beneficial to customers. After this project, Fastems continued the development and has just released the minimum viable product to the first pilot customers, who have given very positive feedback om the solution: It helps them to be always aware of the current production situation, react to potential issues, and contact Fastems easily for support. Furthermore, they like the preventive maintenance focus taken and the tools that are available to check the maintenance history. The development continues according to the roadmap, and new features and functions are implemented in the roadmap according to customer feedback and ideas. The next big step for Fastems' data-driven digital services is to double the number of connected customers in order to speed up the development of data-based analytics and launch the service to all customers at the beginning of 2023.

KONECRANES®
Lifting Businesses™

KONECRANES

Konecranes is a world-leading group of Lifting Businesses™, serving a broad range of customers, including manufacturing and process industries, shipyards, ports and terminals. Konecranes provides productivity-enhancing lifting solutions, as well as services for lifting equipment of all makes.

The company's business is divided into three Business Areas – Service, Industrial Equipment, and Port Solutions – each contributing approximately one-third of Group sales. The Group's brand strategy is based on the corporate Konecranes master brand, which is complemented by the Demag and MHE-Demag brands and a portfolio of freestanding power brands, including R&M, SWF Krantechnik, Verlinde and Donati. On top of that, TBA Group is also part of the Konecranes Group's brand portfolio.

Konecranes Service offers specialized maintenance services and spare parts for all types and makes of industrial cranes and hoists. Konecranes Industrial Equipment provides an extensive range of industrial cranes, from components and light-duty applications to demanding process use and solutions. Konecranes Port Solutions provides equipment, software and service for the container-handling industry.

With their knowledge, products, services, and solutions Konecranes seeks to maximize the positive contributions to their different stakeholders and the surrounding society. Konecranes creates value for their stakeholders on multiple fronts: through a circular economy, digitalization, and their deeply rooted safety culture.

In 2021, Group sales totaled EUR 3.2 billion. The Group has around 16,600 employees in 50 countries. Konecranes shares are listed on the Nasdaq Helsinki (symbol: KCR).

Synthetic rope (Konecranes)

Synthetic rope condition monitoring

Contributors Konecranes and Tampere University

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Background

Konecranes is investing in making our customers' operations safer and more productive. Therefore, the company provides our customers with different solutions that enable monitoring the use and condition of the equipment in use. Konecranes recently launched a new hoist series that utilizes synthetic rope. A traditional monitoring system made for steel ropes cannot be utilized in these hoists primarily due to the different rope material, but also because the synthetic rope shows wear and damage in a fundamentally different way. To enable condition monitoring in this product series, too, Konecranes needed to develop a new method.

Solution

The utilization of non-steel ropes is not common in industry, and so research publications around the subject are not widely available. Therefore, the company needed to conduct research on how condition monitoring of synthetic ropes can be performed. According to the research, visual monitoring of synthetic rope is one possible method. Konecranes has developed a data collection unit that is able to collect images of the rope throughout its lifetime, but efficient, repeatable, and accurate analysis of the data is challenging. To solve the problem, Konecranes worked together with Tampere University to design a suitable neural network that can infer the condition of the rope.

Result, output, impact

As a result of the performed research, Konecranes has guidelines on how data analytics for synthetic rope condition monitoring can be implemented. The result enables Konecranes to build a service product for synthetic ropes. Both a technicians' tool and continuous monitoring products are possible, similarly to the current offering for steel wire ropes. The new offering is expected to directly increase sales of our service products. The research result will also have the indirect effect of boosting sales of the new product series by raising confidence in its reliability in use.

References

The research and its results are also published at https://www.dimecc.com/in-industry-data-sharing-means-increasing-productivity/

Synthetic rope (Konecranes)

Arkki Architecture Evaluation

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Background

Konecranes is building a next-generation TruConnect infrastructure called Arkki, to be able to run and update software running on equipment and to collect data from the equipment. The infrastructure consists of cloud backend and management components, mobile communication, edge computing hardware, and microservice software running on an edge device. Arkki will enable Konecranes to constantly improve and update equipment intelligence and functionality based on customer needs. Arkki will enable Konecranes to provide customers with edge intelligence that the competition cannot provide at the moment.

All cloud providers nowadays have edge device solutions to be able to deploy software with an edge device, communicating with the cloud. However, current capabilities do not meet all the requirements set by Konecranes for an edge computing solution. Therefore, Konecranes started its own Arkki infrastructure development.

Arkki infrastructure will replace the current TruConnect data collection system for all existing equipment and use cases, and will enable data collection and intelligence in equipment previously without TruConnect. Due to the flexibility of Arkki, the solution can be deployed to low-cost edge devices or to more capable edge devices, depending on the needs and desired price point.

Arkki has been developed for some time already, and the first use cases have been installed for customers. The goal of this work is to survey the current Arkki implementation and to determine how easy it is to build new use cases, reuse Arkki components, and give direction for future Arkki development.

Solution

The study of Arkki was performed with researchers from the University of Helsinki. A general introduction to Arkki was given, and it was decided to focus on evaluating the implementation of new edge device use cases.

Several workshops were held, and several points regarding current implementation were noted. Alternative improvement recommendations were described, to improve Arkki reusability in edge devices. Some evaluation criteria for evaluating Arkki reusability from different stakeholder points of view were discussed and defined.

The observations from the workshops were passed on to the Arkki development team, and notes will be considered in further Arkki development and improvement, based on current development needs.

Result, output, impact

The main results of this work were to spot issues hindering the reusability of Arkki components and slowing down the development of new use cases.

Direct results from the work are: development of a code library for common Arkki edge device functions, a template for creating a new Arkki microservice, and several Arkki infrastructure improvement proposals.

Arkki will, in the near future, be implemented more extensively, benefitting Konecranes with a better edge device and data collection infrastructure, and benefitting customers with more advanced equipment intelligence and equipment operation reporting. The solution is global and, in the lifting business, exceptional, as similarly advanced edge computing infrastructure is rare.

Arkki will be developed further to accommodate new use cases and capabilities. Arkki will, in the future, be used in all Konecranes equipment requiring edge computing and data collection.

Cyber security

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Background

The current situation of the world has increased the need to protect devices from all kinds of threats. Cyber-attacks against critical environments and machines are more possible, and stalling their operations can cause serious harm to their owners. Process and port cranes can be counted as critical infrastructure. If their operation stalls, then operations in the port or factory would also be stalled, or at least the performance would be much lower. By detecting attacks early, we can limit the damage, which enables faster recovery.

Solution

The increasing number of connected IoT devices in recent years has led to significant increase in the volume of cyber-attack instances, as the lack of security in IoT poses a risk to the sustainability of machines and smart factories. Traditional intrusion detection approaches are unsuitable for IoT networks due to the limited computational capacity of smart devices and diversity in their technology.

In this project, we focus on the problem of attack detection and mitigation, with the help of recently emerging reinforcement learning, which has already demonstrated excellent suitability for several cyber-security applications. We implemented an AI agent that continuously evaluates the risks of potential attacks and takes the most optimal action in order to mitigate them. In particular, it manipulates network security policies, depending on the current state of the environment. These manipulations include pushing software-defined networking flows to the network controller, as well as adjusting the detection sensitivity of IoT devices used for intrusion and anomaly detection.

In order to evaluate the reinforcement learning (RL) approach proposed, we have developed an environment as a network of several virtual machines (VMs) running in a hypervisor, which allows an RL agent to push software-defined network (SDN) flows and reconfigure IoT devices, as shown in Figure 1. The main purpose of the SDN controller in the resulting framework is to transform the security intent of the RL agent into SDN flows and push these to the switches. In our implementation, we use OpenDayLight, which is one of the most featured controllers able to run on different platforms. These SDN flows allow us to manipulate network security policy by redirecting certain traffic or blocking suspicious connections.

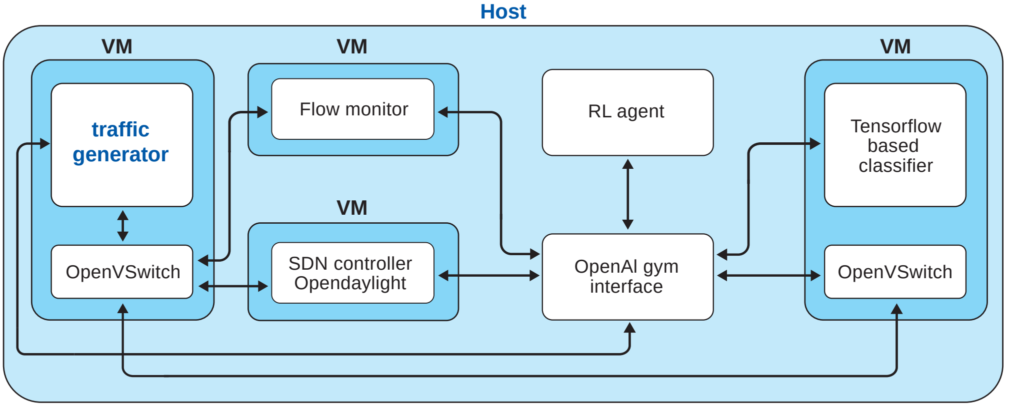

Figure 1: **Implementation of the AI-based defense system**

The resulting AI-based defense system has several advantages compared to standard detection methods. First, the system not only learns behavioral patterns of benign devices in the network, but also how those patterns change if of one or several of them are infected with certain malware. Moreover, the model is trained with real traffic patterns, but the training is carried out in a fully virtualized environment and does not affect real devices and network elements. Finally, the discovered methods of detecting and isolating compromised devices can be immediately applied to real infrastructure to protect it from new attacks in the future.

Result, output, impact

We implemented the first prototype for AI-based attack detection, and tests prove that it can detect attacks. However, the detection system is not currently implemented in the Konecranes digital environment, which prevents direct commercial utilization. After a business decision to commercialize the detection system is made, the next steps would be containerization of the solution and building interfaces to the Konecranes digital environment. The system should also be developed further, as currently the system only detects attacks but does not stop them. Before full commercial utilization, the system should be able to stop attacks.

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Prima Power

PRIMA POWER

Finn-Power Oy was established in Finland in 1969, and after merging with the Italy-based Prima Industrie Group, it now belongs to the Prima Power brand name. Prima Power is a leading specialist in the field of industrial machines for sheet metal working. The company offering is one of the widest in this field and covers many applications: laser cutting, shearing, punching, bending, and automation, as well as software for machine programming, production planning and reporting. Prima Power manufacturing facilities are located in Italy, Finland, the USA and China. The Prima Power sales and service network is active in over 80 countries with a direct presence or through a network of specialized dealers. At present, the company's installed base numbers more than 13,000 systems.

AI-assisted order-to-delivery – Step 1: Cloud Manufacturing

Contributors

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Background

Finn-Power Oy (Prima Power)[1] is an industrial machine tool manufacturing company that offers a variety of solutions for sheet metal processing: laser cutting, shearing, punching, bending, automation and software. While digitalization is transforming the sheet metal working industry at an accelerated pace, Prima Power also has to keep up with the evolving customer expectations and adapt the business model to smart connected production solutions and digital services.

One of the key Prima Power customer groups is sheet metal (sub)-contracting companies that purchase Prima Power production systems to manufacture sheet metal components and fully assembled products

[1] Finn-Power Oy is a part of the Machinery Division of Prima Industrie Group and belongs to the Prima Power brand. For this reason, the Prima Power brand name is used in the rest of the document.

according to custom technical specifications. Usually, these (sub)-contractor companies possess such metalwork capabilities as laser cutting, punching, and bending, in addition to welding, painting, silk coating, engraving, and assembly.

As a rule, the production cycle of sheet metal parts starts with the quotation phase, when the buyer contacts the sales manager in the (sub)contractor company by email and requests a price quote. However, heavy workload and labor shortage are common challenges for (sub)contracting companies, and it can take a long time for them to give accurate price quotes to potential customers. In comparison to loyal customers with standard high-volume production orders, custom products (e.g. prototypes) require more attention and time in the quote calculation process to tailor them to customer needs. As a consequence, customers get frustrated about the long waiting times, and (sub)contractors lose their leads to a competitor.

Another problem with the quotation process in the sheet metal working industry is that occasionally sales managers receive the handwritten scanned drawings of sheet metal parts by email. This means that managers need to spend extra time transforming these drawings into CAD models in DXF or STEP formats to be suitable for production.

In today's competitive environment and rapid business, speed plays a crucial role for sheet metal working companies, and Prima Power was able to find a solution to these common customer challenges and speed up the quotation process from days to hours with a cloud manufacturing tool. While participating in the InDEx project, Prima Power utilized the latest technological advancements in cloud manufacturing to automate the quotation calculation process, reduce the amount of manual work, and help (sub)contractors offer quick responses to quotation requests.

A further challenge from the perspective of Prima Power customers is receiving sheet metal orders by email. This inconvenient, time-consuming and error-prone task requires sales managers to manually enter order data into the inventory system before sending the order into production. The cloud manufacturing solution addresses this problem and makes order placement easier through online ordering and order status tracking via a secure web application.

To sum up, the key target market that highly benefits from the Prima Power cloud manufacturing result in the InDEx project is (sub)contracting companies in the sheet metal processing business that deal with an abundance of price quote requests and orders on daily basis.

AI-assisted order-to-delivery process

While cloud manufacturing represents one of the key results in the InDEx project, this web application is a part of a larger strategy that aims to utilize AI and transform the conventional order-to-delivery process in the sheet metal processing industry (Figure 1). Cloud manufacturing provides a starting point for the AI-assisted order-to-delivery process, which is then followed by the development of AI-assisted automated programming (CAM) (Step 2) and production line optimization in the manufacturing phase (Step 3).

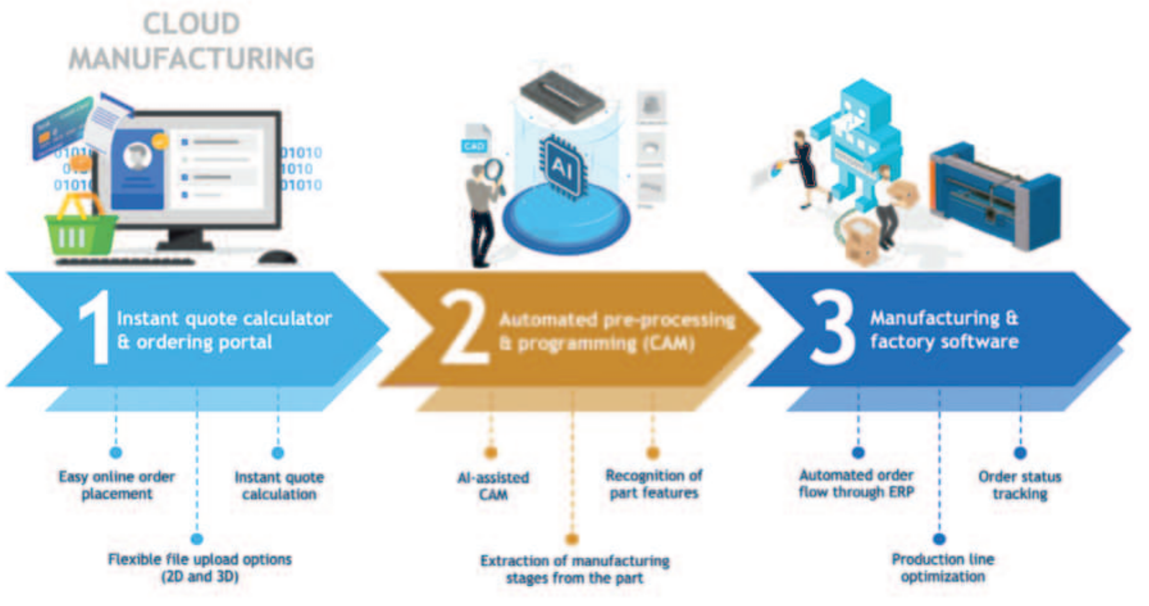

Figure 1. **The AI-assisted order-to-delivery process experiment in the InDEx project (Prima Power).**

Solution implementation

One of the main InDEx project outcomes for Prima Power is the 'Cloud Manufacturing' web application, which Prima Power is planning to offer to its customers as a software-as-a-service (SaaS) product. The key users of Cloud Manufacturing would be Prima Power customers (metal industry contracting companies) and their own customers that order sheet metal products from them.

Cloud Manufacturing is a result of joint efforts between Finn-Power Oy, Elekmerk Oy and Jubic Oy. Elekmerk is a contract manufacturer, and as a pilot customer it played a central role in helping Prima Power to collect user requirements and specifications, and undertake testing, validation and evaluation of Cloud Manufacturing before it enters the market. Jubic, as a software technology provider, took an essential part in the project by developing the frontend and backend of the Cloud Manufacturing software solution.

To ensure that the Cloud Manufacturing application is safe and secure to use, Prima Power has been cooperating during the project with the Faculty of Information Technology at University of Jyväskylä to gain more knowledge and skills in the area of cyber security. There is a lot of data (e.g. personal information, product designs, commercial offers, etc.) passing between Cloud Manufacturing, Prima Power customers, and their buyers, and therefore cyber-security risk management is a crucial task to avoid data loss or theft. The Cloud Manufacturing architecture is built in a such way that user permissions and rights are granted to authorized persons and can be easily revoked.

Taking into account that Cloud Manufacturing is a product to be used by Prima Power customers and their own buyers, it is important to ensure that there is a formal legally binding agreement for all parties to sign. Therefore, together with the Business Law department at University of Vaasa, Prima Power was able to draw up a detailed legal contract outlining the key rights, conditions, and responsibilities for all parties that use Cloud Manufacturing.

Current market situation

The increasing attention toward digitalization and digitization in the sheet metal working industry has led to an emerging interest among companies in cloud manufacturing solutions over the past few years. For example, Protolabs offers the eRapid free add-on for SolidWorks for instant sheet metal part quoting and ordering. You can also find the HUBS platform and online CNC machining service for rapid prototyping that utilize machine learning algorithms for instant quoting and order placement to the closest manufacturer in the area with suitable machinery and materials. The Ponoko online quote calculator, 247TailorSteel Sophia online assistant, Geomiq platform, Xometry solution, AlmaQuote software, and Oroox OX Quote are among other digital manufacturing products that revolutionize sheet metal manufacturing industry through quoting and ordering sheet metal parts online.

However, from the more in-depth market analysis, it can be seen that the majority of technologies available on the market are either limited to a specific sheet metal fabrication technology, restricted to a quote calculation function, or order quantities or manufacturing operations in specific geographical areas. In comparison with the existing competing products, in Cloud Manufacturing, Prima Power attempted to address the pros and cons of solutions available on the market to build a unique product with a user-friendly interface and integration with Prima Power machine control software.

Result Cloud Manufacturing is a software-as-a-service (SaaS) product that combines built-in CAD for processing design files in DXF or STEP format, calculating instant price quotes, and placing orders online. Cloud Manufacturing is based on the latest AI and machine learning algorithms, which automatically pre-process the uploaded CAD models, recognize the sheet metal part features, and extract the key work steps in order to calculate the production time, operating costs, and total price per part.

The simplified flowchart below demonstrates the role of Cloud Manufacturing in the industrial ecosystem and the key operations carried out by the (sub)contracting companies (manufacturers) and sheet metal buyers (end customers) (Figure 2).

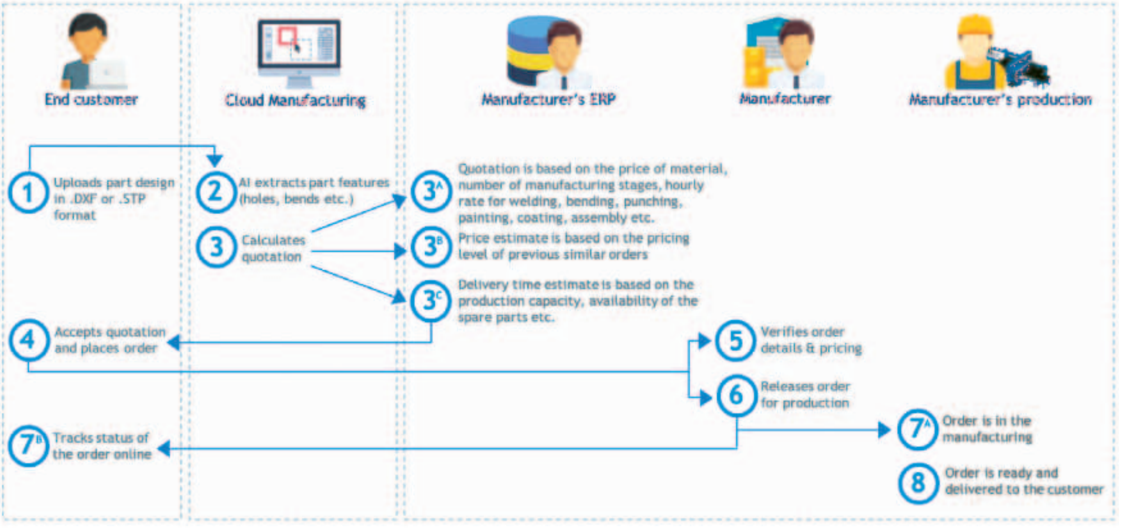

Figure 2. The role of Cloud Manufacturing in the sheet metal industrial ecosystem (Prima Power).

The functionality of Cloud Manufacturing offers some degree of flexibility for the convenience of both end customers (buyers of sheet metal parts) and manufacturers ((sub)contractors) (Figure 3). In other words, users can upload their product designs directly to the Cloud Manufacturing platform and get an instant price quotation right from the web. Another option is for the end users to send CAD models to the manufacturer, who will then manually upload the files into Cloud Manufacturing, generate a price estimate in a PDF document, and send it back to the potential customer for verification by email or through an ERP/PDM.

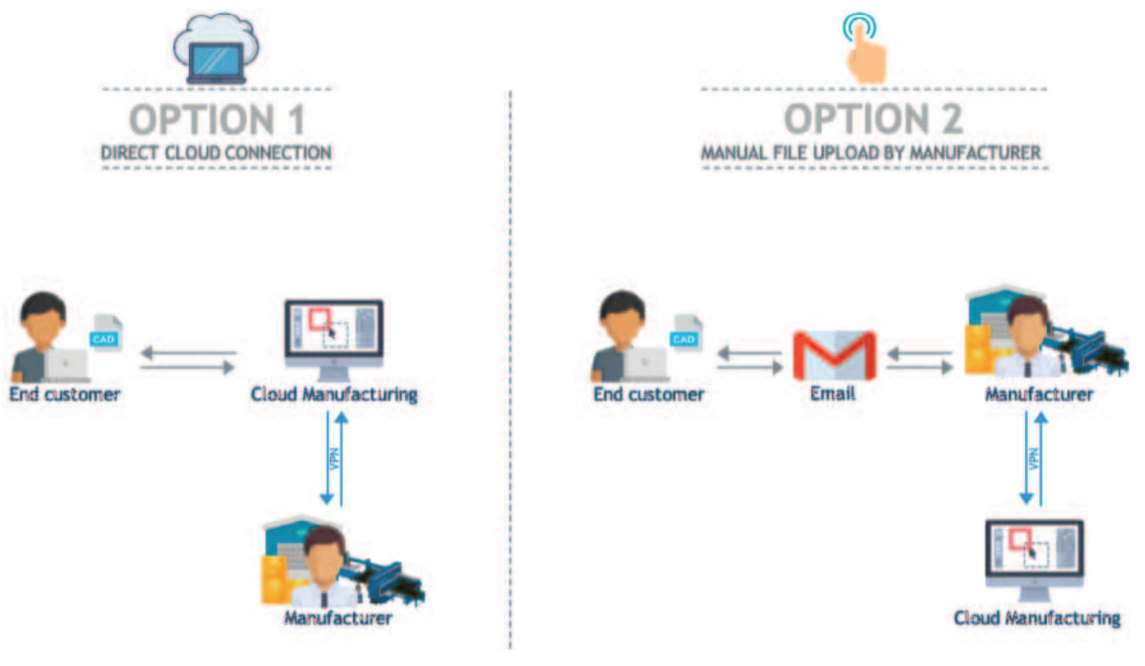

Figure 3. **Different usage scenarios of Cloud Manufacturing (Prima Power).**

In order for Cloud Manufacturing to automatically calculate the price quotation, there should be a library of machine properties and costs defined by the (sub)contractor (manufacturer) in the setup stage (Figure 4). In particular, the manufacturer has to either manually define or export material properties (e.g., material type, density, thickness, sheet height and width, clearance min. and max.) and cost per material thickness. In addition, the manufacturer should define the machinery type, sheet metal fabrication technologies (e.g., laser cutting, punching, shearing, forming, bending) available at premises, and tool information (e.g., tool type, size, die clearance min. and max.). Furthermore, the data on time parameter behavior should be filled in for each process (e.g., bending setup time, bending size and weight multiplier, bending time per bend and per part), as well as part/scrap sorting parameters. Finally, the manufacturer needs to define the price margins for the material and for each process (e.g., blanking, bending, laser marking, packaging, assembly), as well as pricing configurations to be applied to different customer groups. The base cost and hourly cost could also be separately defined for custom processes (e.g., painting, welding).

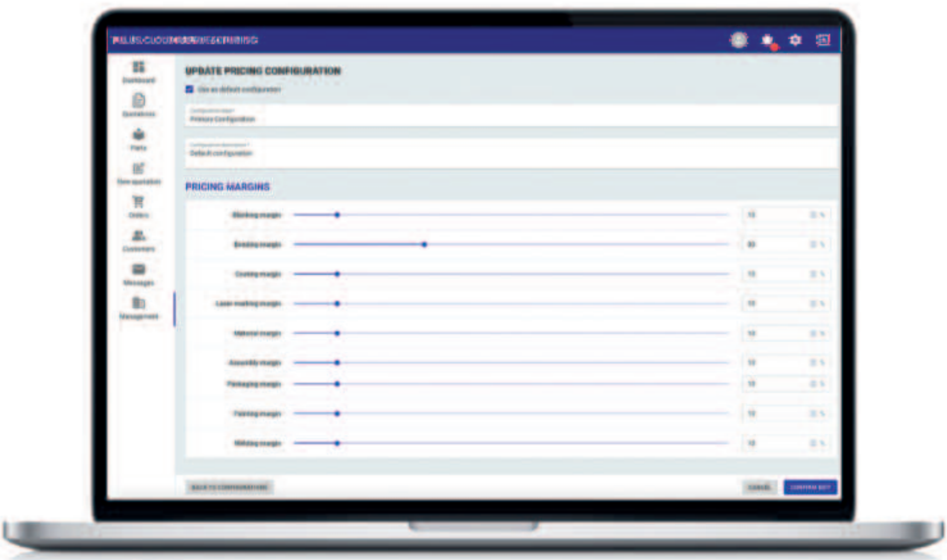

Figure 4. **Example of parameterization settings in Cloud Manufacturing (Prima Power).**

The key principles of pre-processing, machining time, and cost and price calculation operations are illustrated in a nutshell in Figure 5.

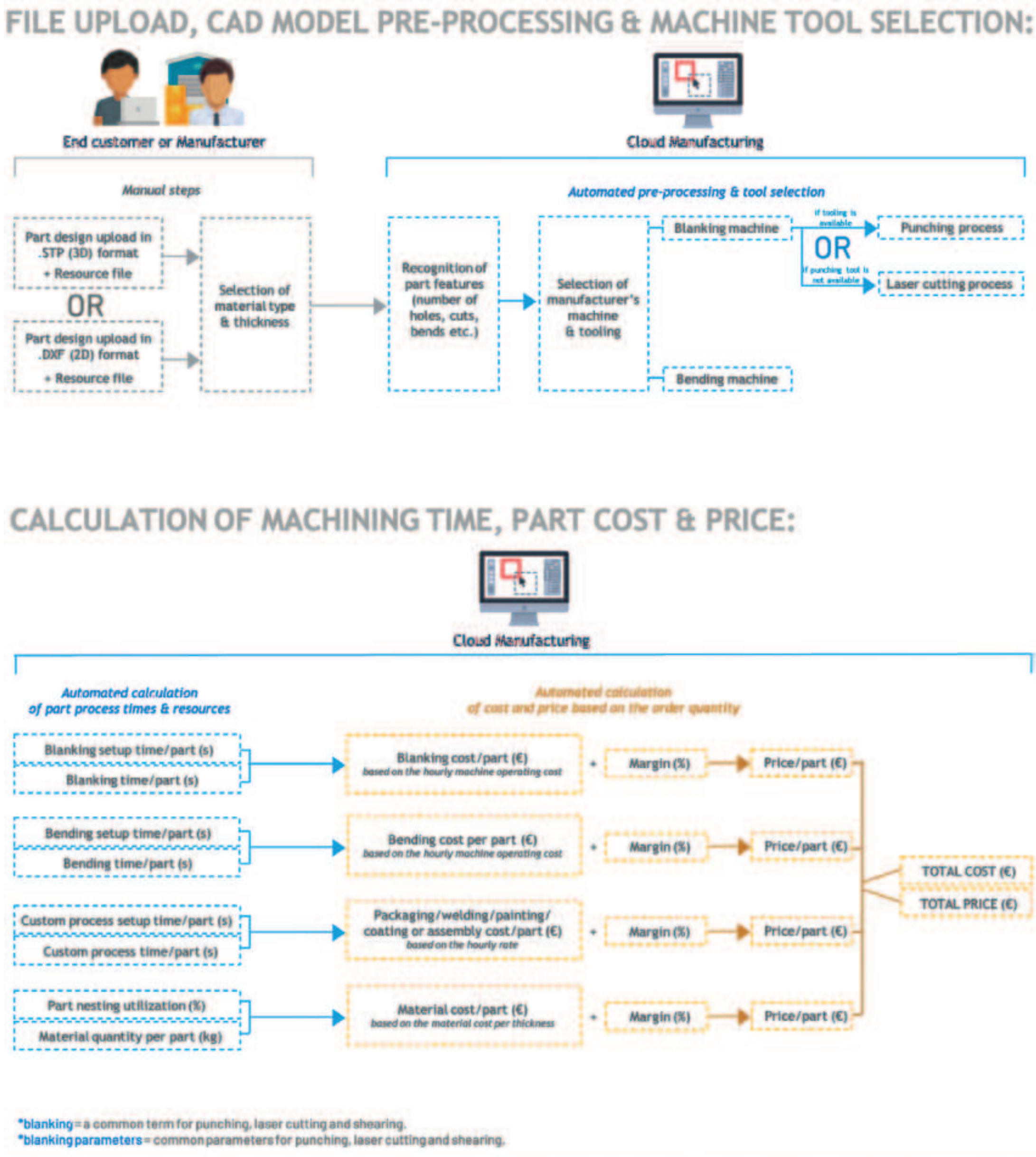

Figure 5. **Simplified principle of operation (Prima Power).**

How result works

The key users of Cloud Manufacturing, (sub)contractors and buyers of sheet metal parts, can log in online to Cloud Manufacturing with their username and password after registration (Figure 6).

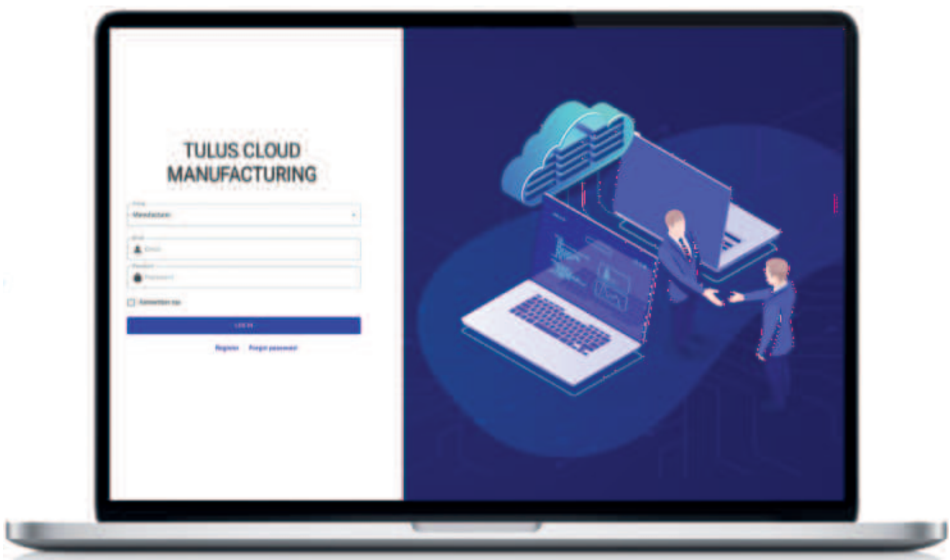

Figure 6. **Cloud Manufacturing landing page (Prima Power).**

Users can upload CAD files in DXF or STEP format by browsing them on the computer, by dragging and dropping files directly into Cloud Manufacturing, or by selecting from the library of saved files (Figure 7).

Figure 7. **Product design file upload in Cloud Manufacturing (Prima Power).**

After the sheet metal part design is uploaded and the part is unfolded, the automated pre-processing recognizes the part features (e.g., number of holes, bends) and extracts the work steps from the part in order to calculate the production time and estimated cost (Figure 8). In the case of a 2D model, the user needs to manually enter the material type and thickness. The built-in CAD enables design revisions in real time, modifications to quantity, and adding manual steps (e.g., welding, painting, special packaging, assembly) to see how the price estimate changes.

If the uploaded part design is simple and does not need, for example, additional welding, painting, laser marking, special packaging or assembly, then Cloud Manufacturing calculates an instant quotation. If the customer is satisfied with the price level, the order can be placed right away. An instant quotation is considered as a preliminary estimate, and a ±5–10% deviation from the price is possible after the manufacturer confirms the order.

The price quote is based not only on the raw material cost, machining time, hourly machining costs and manual steps, but also on the pricing level of the customer's profile and order history (e.g., new, loyal or high-volume customer).

In the case of a complex product design or many manual steps, Cloud Manufacturing might not be able to generate an instant price quote right away. In that case, the manufacturer needs to manually verify the CAD file and calculations before the quote can be sent to the customer.

Figure 8. **Automated part pre-processing in Cloud Manufacturing (Prima Power).**

After Cloud Manufacturing calculates the price estimate (Figure 9), a formal PDF document with a quote and cost breakdown is available for the user to download.

Figure 9. **Price quote calculation in Cloud Manufacturing (Prima Power).**

Both the manufacturer and the customer can see the latest information about orders and quote requests on their customized dashboards (Figure 10).

Figure 10. **Example of the Cloud Manufacturing dashboard (Prima Power).**

After an order is placed online via Cloud Manufacturing, order status tracking becomes available for the customer. Price quotes and orders are saved in the Cloud Manufacturing library and can be easily re-ordered at any time.

Impact To stay ahead of the competition, the Cloud Manufacturing solution is built in a way to benefit different actors in the sheet metal industrial ecosystem: Prima Power (machine tool builder), Prima Power customers (sheet metal (sub)contracting companies) (e.g. Elekmerk), and end buyers (that order sheet metal components or products).

First of all, Cloud Manufacturing satisfies the needs of sheet metal (sub)contractors by automating the price quote calculation, reducing the lead response time, and speeding up the sales process. With the help of Cloud Manufacturing, (sub)contracting companies do not need to manually calculate the quotes, since AI pre-processes the uploaded file and calculates the cost and price. In addition, Cloud Manufacturing can handle the most frequently used product design formats (DXF and STEP) in the sheet metal processing industry, which makes it convenient for both (sub)contractors and their customers to exchange 2D and 3D files. Furthermore, Cloud Manufacturing offers a quote as a PDF document, with a breakdown of material and labor costs, based on the product design, quantity, material type and thickness. This helps manufacturers to understand the operating costs and price per part and, at the same time, the item-by-item breakdown gives more transparency to customers and increases the trustworthiness of the (sub)contractor. Figure 11 summarizes the estimated benefits that sheet metal contracting companies get from using Cloud Manufacturing.

From the perspective of sheet metal product buyers, with Cloud Manufacturing, there is no longer a need to waste time on waiting for a quotation for weeks or days. The end customer can easily get an instant price quote and place an order online. Another advantage of Cloud Manufacturing is improved order traceability and, with the online order tracking function, users no longer need to send emails to the (sub)contractor to find out about the current status of their orders.

Finally, by offering the Cloud Manufacturing product to customers, Prima Power will strengthen its relationships with existing customers and will create a new revenue stream from launching this product on the market.

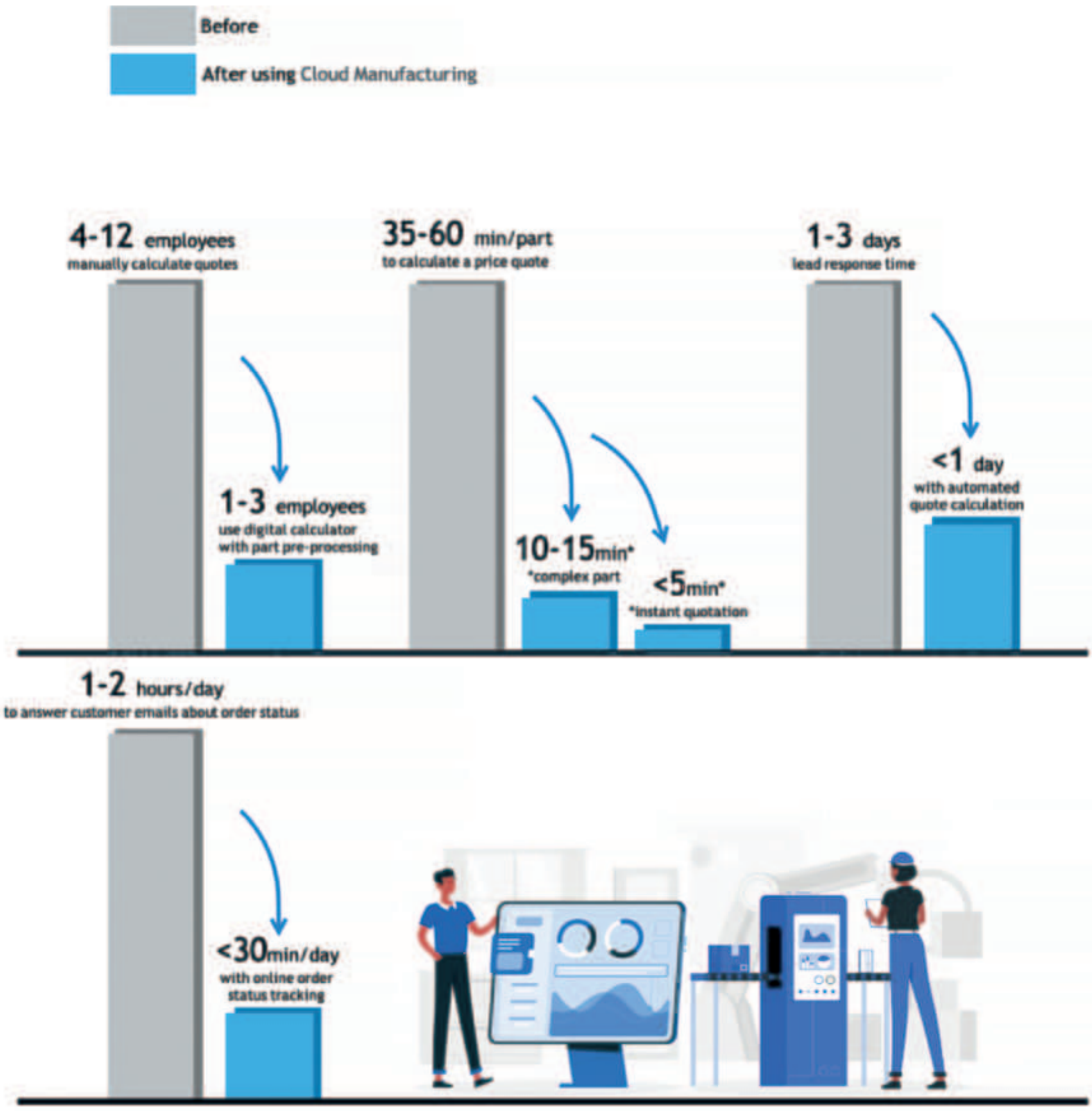

Figure 11. **Impact of Cloud Manufacturing on Prima Power customers (sheet metal (sub)contractors) (Prima Power).**

Commercialization

After completion of the InDEx project and additional testing and marketing activities, Cloud Manufacturing will be launched as a new product on the market and will be added to the Prima Power software portfolio. Cloud Manufacturing will help Prima Power to differentiate itself from competitors, and it will be a perfect fit into the existing Tulus® product family and Industry 4.0 solutions that Prima Power offers to customers. It is expected that the product pricing strategy will be based on the subscription business model that charges manufacturers (Prima Power customers) a recurring monthly or yearly fee for using Cloud Manufacturing software with their own customers. The use of Cloud Manufacturing will be free for the end users (buyers of sheet metal parts). In the meantime, Prima Power, as the provider of Cloud Manufacturing, will be responsible for managing the infrastructure and security, instances, user access and identity permissions, software updates, and new features.

Finally, as a result of continuous innovation, development, and improvement of Cloud Manufacturing, it is expected that, in the future, this web application will become a fully autonomous product that does not need human assistance for calculating quotes for complex products. At the moment, Cloud Manufacturing requires human intervention in some cases, but in the future, it is planned to take a step forward and equip Cloud Manufacturing with fully autonomous capabilities so that it can demonstrate adaptability and data-based decision-making. Furthermore, in the future, Cloud Manufacturing would also benefit from two-way ERP integration in order to reduce the manual work of doing parameterization and adding machining costs, raw material costs, and other data to the application in the setup stage. These steps in the future would make Cloud Manufacturing an even more intelligent and efficient product on the market.

In conclusion, besides the commercialization of Cloud Manufacturing, Prima Power is also planning to bring to the market other solutions developed during the InDEx project. For example, AI-assisted automated programming (CAM) and production line balancing will undergo additional testing, piloting and marketing activities before they are added as products to the existing Prima Power software portfolio and introduced to customers. As a result, all new solutions developed within the three steps of the AI-assisted order-to-delivery experiment in the InDEx project will be further converted into viable products and will generate a financial return on the investment in innovation.

HT LASER

HT LASER OY

HT Laser is an industrial system supplier and a flexible service partner for the global metal industry. The company's special expertise is sheet metal assemblies and component manufacturing. HT Laser offers comprehensive cutting, bending, welding, laser welding, CNC machining, 3D metal printing, surface treatment, assembly and product development services. HT Laser has seven production units in Finland and one in Poznan, Poland. It also serves in Sweden. In 2021, company net revenue was 70 M€. HT Laser is part of the Teiskonen Group.

In cooperation Aalto ARTS, Aidia, Arrow Engineering, Elekmerk, Eqvitia, Green Carbon Finland, HitScan, Hubik, Insinööritoimisto Savolainen, MLT Machine & Laser Technology, Palvelupisara, Ponsse, Prima Power, SSAB, TAU, Tehos, THO Consulting, Varusteleka, Visma, Zyfra

In this project, the major goal of HT Laser was to find and implement new business opportunities enabled by better data utilization and digital solutions.

An additional goal was to develop and pilot practical solutions enabling better supply-demand match, data and information sharing between value network players, online production and deliveries, quality data views, and logistics.

Some of the most relevant pilots and results are described below.

Trusted and integrated data flow

Here, HT Laser's focus was on finding new technical solutions to develop supply-demand match and to enable data sharing between value network members. Many development practices have been implemented concerning data flow.

First, digitalizing the New Product Introduction (NPI) process was piloted at HT Laser Vieremä to accelerate the process, managing design and material parameters, as well as interaction and quality assurance between several actors in the value network. In this pilot, a 3D laser measurement scanner was acquired. In addition, a 3D measurement room was designed and built at the HT Laser Vieremä site. This enabled 3D measurement and modeling of products, fast operation, and information exchange (e.g. feedback on production and measurement parameters and design information) between the parties in the NPI process. 3D laser scanning has been found to significantly accelerate the NPI process utilizing 3D models. With the help of measurement data, it has been possible to communicate quickly in the delivery network. The necessary changes in demanding steel structures (where, for example, material deformations and bending compensation happen) have been quickly modified and implemented with the help of 3D models.

Another sub-project was done to develop technical solutions enabling data sharing in the value network. The HT Laser Keuruu, Vieremä and Tampere sites developed their internal logistics processes. This is, the delivery control process, work queues, and pick-pack processes were visualized, dynamized, and digitized. The needs for ERP-based portal tools were defined, the necessary and visually optimized portal displays were created, and the number of required display devices in production facilities was increased. In addition, the whole storage location system was digitized. In the same context, HT Laser Vieremä created a novel digital tool to ensure that requirements and instructions offered by value network partners can be digitally reached and utilized in the workshop. The sub-project significantly increased opportunities to collect real-time information about production and to share it in the value network. The results can be seen in improved lead times, efficiency, and quality in the services. The work has brought direct benefits to end customers, such as improved security of supply and reduced errors in the pick-pack process.

Advanced analytics for processing data

Related to the agile and AI-assisted order-delivery process, HT Laser surveyed the exact needs, suitable digital solutions, and necessary integrations related to the quotation-order process, as well as managing customer and other value network partner data and communication. With the help of digital solution specialists, a suitable pilot product integrated with the company ERP system was selected. A customized solution was created, which enables advanced and more efficient quotations and offers management, as well as stakeholder-specific data collecting and handling. Development of information flow in the value network is needed when building a digital purchasing path, sharing data, and working toward AI-assisted pricing and marketing. The new quotation-order management system is now introduced in most HT Laser units, and the results in increased efficiency (better hit rates) and advanced customer service (shorter lead times in quotation handling) are expected.

Transparency and traceability to material usage and properties throughout the lifecycle were also worked with. In a pilot conducted with two customer companies and CO2 emissions management specialists, HT Laser and its sister company Elekmerk studied the possibilities to measure company-level emissions data, as well as to collect and share product-level emissions data in the value network. This real-life pilot generated valuable knowledge about essential CO2 emission sources in the value network, as well as real-life experience in collecting and sharing emissions data, and in shortages of such data available in the value network. The pilot resulted in valuable insights in emissions data production, ownership, and relevancy for value network partners.

Ecosystem business and governance models

The third major focus area was recognizing and evaluating the most promising ecosystem business models and opportunities for HT Laser and its sister company Elekmerk.

Related to this goal, HT Laser and Elekmerk cooperated with TAU to update the companies' digital vision and roadmap. A survey of the organizations' digital maturity was carried out, and the ICT architecture was mapped and described from the perspective of data sharing. The possibilities for developing more data-driven services and ecosystem business models were outlined.

HT Laser and Elekmerk also worked with Aalto ARTS to enhance the organizations' competencies in digital business and service models, digital customer experience management, and related digital solutions. Different customer types, customer experience goals, and customer journeys were examined. The process resulted in better understanding of the needs, value-adding potential, and digital solutions for data sharing in the value network.

elekmerk

ELEKMERK OY

Elekmerk offers comprehensive sheet metal mechanics, machining, surface treatment and assembly services. The company serves as a contract manufacturer for international technology companies and meets the needs of their customers, from product design to testing of finished products. In 2021, the company net revenue was 6 M€. All Elekmerk operations are guided by certified quality and environmental systems, in accordance with the ISO:9001 and ISO:14001 standards. Elekmerk is located in Keuruu and is a part of the Teiskonen group.

In cooperation Aalto ARTS, Aidia, Bronto Skylift, Devoca, Genelec, Green Carbon Finland, HT Laser, Hubik, Japo, Jubic, Palvelupisara, Prima Power, TAU, Tehos, Teleste, THO Consulting, Visma

In this project, the major goal of Elekmerk was to find and implement new business opportunities enabled by better data utilization and digital solutions.

An additional goal was to develop and pilot practical solutions enabling better supply-demand match, data and information sharing between value network players, online production and deliveries, quality data views, and logistics.

Some of the most relevant pilots and results are described below.

Trusted and integrated data flow

Here, Elekmerk's focus was on finding new technical solutions to develop supply-demand match and to enable data sharing between value network members.

The main results were achieved in a pilot conducted with some key customers. Here, the goal was to pilot a new way of making the order-supply chain more efficient, improving its quality and lead time by automating order processing without the actual integration of information systems.

In practice, ICT specialists planned and created a new digital tool for Elekmerk. The program customized for this purpose can now automatically read order information into Elekmerk's ERP system from order documents. As a result of the development work, the manual work of order processing is reduced, and the quality of the process is improved when human errors are reduced. The automation system, without really integrating information systems, is faster, cheaper and simpler to establish. The solution prepared for Elekmerk has been introduced in its sister company, HT Laser, as well.

Advanced analytics for processing data

Related to the agile and AI-assisted order-delivery process, Elekmerk has acted as a pilot partner for Prima Power. Prima Power has developed a cloud manufacturing solution that digitalizes sheet metal orders. This AI-based solution automates the manual workflow and reduces the time to create a quotation and production plan from days into seconds.

Elekmerk has tested the cloud manufacturing solution in a sheet metal manufacturing environment and provided feedback on the usability of the cloud manufacturing portal. To ensure the privacy and security of data shared through the cloud manufacturing platform, the University of Vaasa and the University of Jyväskylä have provided knowledge and expertise in the areas of contractual law and cybersecurity.

Through this cooperation, Elekmerk has gained real-life experience in an advanced way to organize a digital order-delivery process, and it has discovered new benefits from it, such as the automation of manual operations, as well as time and cost savings in order processing. The project and its results are covered in more detail by Prima Power in this report.

Transparency and traceability of material usage and properties throughout the lifecycle were also worked with. In a pilot conducted with two customer companies and CO_2 emissions management specialists, Elekmerk and its sister company, HT Laser, studied the possibilities to measure company-level emissions data, as well as to collect and share product-level emissions data in the value network. This real-life pilot generated valuable knowledge about the essential CO_2 emission sources in the value network, as well as real-life experience in collecting and sharing emissions data, and in shortages of such data available in the value network. The pilot resulted in valuable insights in emissions data production, ownership, and relevancy for value network partners.

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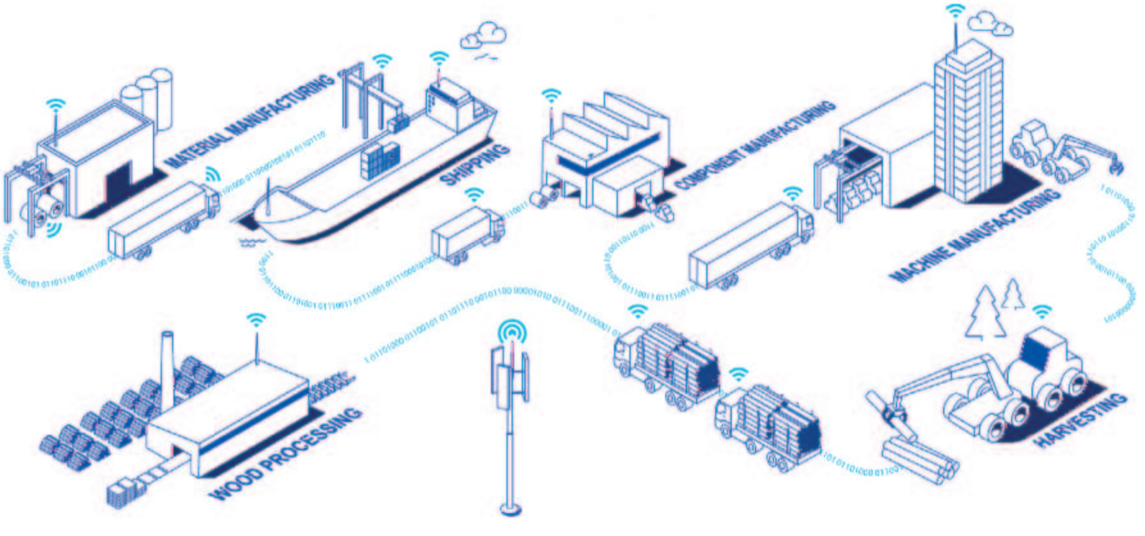

(DIMECC)

RAUTE

RAUTE

Raute is a technology and service company that operates worldwide. Raute's customers are companies operating in the wood products industry that manufacture veneer, plywood, LVL (laminated veneer lumber) and sawn timber. Its technology offering covers the entire production process for veneer, plywood and LVL, and special measurement equipment for sawn timber.

As a supplier of mill-scale projects, Raute is a global market leader in both the plywood and LVL industries. Additionally, Raute's full-service concept includes technology services ranging from spare parts deliveries to regular maintenance and equipment modernizations.

Raute's head office is located in Lahti, Finland. The company's other production plants are located in Kajaani, Finland, the Vancouver area of Canada, the Shanghai/Changzhou area of China, and Pullman, Washington, USA.

More information about the company can be found at www.raute.com.

Contributors

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- Dreija Oy: Ilmari Junttila, Oleg Shadrunov, Dmitrii Shustrov, Anton Hokkanen
- Tampere University: Tuomas Jalonen, Firas Laakom, Moncef Gabbouj

Background

The Intelligent Industry vision of the world is one where people, machines, services, and other assets operate seamlessly together. The growing volume of data and connectivity enabling real-time access to data forms the basis for the change. Smart products are producing and processing vast amounts of data at a pace that was simply unimaginable until a few years ago. Paired with powerful analytics tools, companies can do collaborative demand and supply planning, increase traceability across supply chains, gain a deeper understanding of customer needs and interactions among input variables, and make automated decisions and take actions in real time.

The industry level of intelligence, however, is achieved only if data is shared and utilized across organizations. Therefore, the way companies and other economic actors are able to use and exchange data is a common factor driving the emergence of Intelligent Industry. At the moment, however, only a fraction of the value of data has been captured in the manufacturing sector. The manufacturing sector is one of the sectors that is generating more data than many other sectors. Still, the utilization of data is one of the lowest in the manufacturing industry. As a result, 99 percent of manufacturing data value is lost.

Unlocking the value of data and driving the emergence of Intelligent Industry requires much more than one enterprise making better use of their existing data. It requires that the entire industry operates through the intelligent use and sharing of data. To make an entire industry operate through the intelligent use of data, data should be made available for all value chain partners, and companies should have the capabilities to form such information-intensive insights and services that significantly increase the value add in the overall value chain.

Raute wants to maintain and develop a leading position as a technology and optimizing system provider for its customers by developing new data and digital tools-based technologies that help Raute's customers to improve their position in global competition. This way, Raute is able to differentiate itself from the global competition.

Raute's aim is to provide a comprehensive mill-scale solution that helps Raute's customers to control and optimize the entire panel manufacturing process and material flows.

Raute's Smart Mill concept connects Raute-made production lines and other production lines with added Raute measurement and optimizing technologies, and offers possibilities to improve the profitability of the whole production process over the sub-processes. Now, when the technology already exists to maximize the performance of the individual sub-processes, the natural step further is to develop optimizing technologies for mill management. Raute´s future vision is to grow in multiple business areas. Growth areas are mill-scale projects in emerging areas and new service business concepts. In addition to traditional services, there is room to grow in the area of mill-scale manufacturing control and advanced automation. This "production as a service" is a potential new business concept, especially in developing markets, and it would need proper technology and tools to control and measure it.

Current opportunity

Mill process tuning in veneer-based production is based on statistical averages and deviation monitoring. It is accepted that raw materials will have variations due to nature, and this will lead to certain deviations or "errors" in the output.

Health index – Preventative maintenance via machine learning

Background

Raute did a research project with Dreija Oy to prove that we could use data-driven methods to improve machine performance and availability. The project concentrated on detecting anomalies from existing lathe production and process data. This package concentrated on researching methods and machine learning algorithms for the lathe equipment "health index" calculation. The second objective was to use the data to predict downtime.

Dreija tested and compared 17 different machine learning algorithms. According to performance testing, the most promising algorithms were extreme boosting outlier detection and a feed-forward neural network. Those algorithms were used for the final calculations in the project.

Results

Dreija developed the multi-level calculation and visualization of the equipment health index based on metrics produced by a machine learning algorithm from historical data.

The downtime prediction algorithm was able to predict downtime in the next two hours. The accuracy of the downtime prediction final precision/recall score was 0.8-0.9, and the anomaly detection final precision/recall score was 0.8-0.9.

Prediction seems to work in the short term, which is not very useful in real life.

We learned how data quality and synchronization need to be improved. Linking data from different sources is too complex, and data preprocessing took more time than expected.

Simulation from digital twin to raw material tracking

(Raute Oyj)

The program started with simulation system development utilizing the existing Matlab tool by Smartelligence Oy/Jyrki Savolainen. The target was to find out what is needed to identify the relationship between process stages. This provided us with the following requirements:

- efficient and machine-made image pairing
- dryer data collection
- data sync is must

Based on this exercise, the simulation complexity was also found to be too great, but some of this could be cleared out by tracking an individual piece of raw material and all the operations done on it.

While doing this, some other observations or findings were made, such as the lathe knife running life simulation/estimation based on raw material type. One thing typical of all these findings was that there is no platform that could collect multidomain data efficiently in the current industrial environment, not to mention any tools to further process this data.

This forced us to narrow the scope, and the peeling-drying section of the process was selected as a target case. It was estimated that if this part of the process could be done fully, the fundamentals would be easy to copy for the rest of the stages.

To be able to fine-tune the process in the veneer mill, accurate raw material tracking is fundamental. Due to the nature of the raw material, it is on one hand not predictable, and on the other hand difficult to handle as a constant flow or in stream tracking. Having said that, it easily becomes unpredictable from the machinery side, too. Most of the existing real-life veneer industry processes still involve lots of manual interventions (e.g., a forklift-managed warehouse) that cause data to be invalid, as there is no reasonable way of tracking the material outside the machinery. To avoid this, we decided to identify an actual piece of raw material, whenever and wherever it resides in the mill process, and then connect this sheet to known measurements.

From the original target of mill-wide simulation, control and AI-learning, this particular area of the research became the new target.

We tried to use some machine-learning based methods to solve the issue, but they all ran into the fact that whatever material was learned, it never repeated, and learned similarity was not accurate enough to be used to detect the similarity.

Instead, we concentrated on further finding the methods (methods, algorithms, and image processing) that identify the similarity the most. Without going into too much detail, nature brings a wide variety of material as images, and this was and still is somewhat challenging.

During the program, it has been a journey of hunting for a solution, and the things we tried had to be tried in order to understand how the next step could be done. Sometimes in research, this is the path: the need to poke around to find a clear path out.

Currently, we have a prototype of a software-based system that is capable of detecting a single sheet of veneer in a mass of veneer sheets, based on the similarity of the grain pattern and other visual features of the sheet. This works fairly well for softwood species, and the latest improvements should make it usable for hardwood, too. The accuracy has to be over 99% to be practical. While doing this, we have also created a capability to reconstruct original peeled logs and further connect the analysis to the forest. This was not planned, but it most likely will open up new possibilities for more detailed process tuning.

CASE: Identify a peeled and clipped sheet after drying.

As soon as algorithm performance is fully tested, we will start implementing this in our research platform software, which will provide this pairing function as a feature.

This is something that has never previously been done in the world.

(Raute Oyj)

Result, output, impact

The pairing method works (POC level), and it now provides a foundation for further data refinement.

During the research, we found a new method for detecting similarities in hardwood species, and this can be used for softwood species, too.

Data collection has developed a lot during this program, and automatic measurement data processing methods have also been created.

The project plan and specs for dryer data collection have been made and are waiting for resources.

Further research on models will eventually be part of our digital product line. This will add a new area to the Raute business, with "production as a service" as planned.

An agile, cost-efficient, and multidomain data collection platform needs to be created.

Lessons learned

Looking back, we should have hired more people dedicated to work on these program themes, so we could have done more regarding the top layers of the actual goal. Due to the chain of events, this never became reality. For example, we thought that COVID would pass and, similarity, that algorithm challenges could be solved within a few months instead of years. More material from real production would have helped the research work, but entering the mills became impossible.

Data collection has also been more difficult than expected, as people are becoming more and more aware of the possibilities of machine learning. Companies, in particular, protect their assets, and more specifically, immaterial things that may become assets should something new arise. Traditionally, this has been avoided by signing NDA-style contracts, but having said that, creating such contracts has become really difficult too.

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(Raute Oyj)

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Smart Factory Experiment

Konecranes, Fastems, Danfoss, VTT, Aalto University,
University of Helsinki and University of Turku

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- **Juho Latvio**, Fastems

Background

Industry in general is trying to reach the fourth industrial revolution, or Industry 4.0 for short. Industry 4.0 is not possible without implementing the latest communication standards and agreeing on standard interfaces. Konecranes participates in the definition of a new machine-to-machine communication interface standard, based on OPC UA for industrial cranes, in accordance with the European Material Handling Federation (FEM) and German Machine Manufacturer Association (VDMA). Danfoss has demonstrated compatibility with the newly defined (VDMA, ZVEI) drive profile with an E-class information model.

The standardization activity supporting Industry 4.0 will guide product design and enable us to benefit from the application ecosystem that is likely to develop once the standardized data models and interfaces are put into effect. At the same time, IDSA is developing an international data spaces (IDS) solution that aims for a standardized solution for secure and trusted data exchange across organizations and sectors.

Traditional companies like Konecranes, Danfoss and Fastems are interested in utilizing and providing their existing data sets as part of the ongoing Industry 4.0 movement. The motivation is to enable new business around data-intensive products, which is something that has not been a traditional source of revenue for traditional manufacturing industry companies. Thus, Konecranes wanted to conduct basic research on how the company could create new data products for its customers and become part of Industry 4.0.

The initial starting point for the research was a recent customer insight that there is an increasing number of different smart factory production solutions among the large industrial players. These require more sophisticated data integrations from machines directly into their own systems, easier connectivity solutions, and machine adaptability for the entire data ecosystem. To make the study more realistic, Fastems and Danfoss were invited to integrate their operations into the Konecranes Smart Factory.

Solution

Together, the standardized interfaces and IDS make it possible to build industrial ecosystems that enable flexible, secure, and profitable production in all surroundings. In this research, we have built a prototype of this kind of smart factory. First, we built a prototype of a smart factory in which controls were distributed around the factory. Different IoT devices were set to deliver information to the crane control logic. The control logic was built to react to the collected information and to serve the factory automatically by commanding cranes to perform material movements when needed. When we had a functioning ecosystem of our own, we invited our research partners to join the industrial ecosystem. The research partners made it possible to start research on the pain points, when several independent actors start to operate as an ecosystem. The technical approach was one research question, and we decided to utilize International Data Spaces (IDS) provided by IDSA and supported by VTT.

Konecranes' smart factory environment was utilized to study new data-intensive business opportunities by first mapping the ongoing situation regarding its data capabilities. This included comprehensive internal interviews with various experts to get a proper understanding of what the starting point is for developing the new data services. The results of the interviews indicated that Konecranes has a good starting point for upcoming development, but that there are certain identified gaps to fill before entering the implementation phase.

As another part of the research, we conducted an extensive series of workshops and discussion events with the help of the University of Turku and Aalto University, to progress the research on new data services. These activities included study of the required legal framework around data services, to clarify the fundamental requirements for how a company can operate as part of future data ecosystems with other players and stakeholders. Understanding the legal framework and data governance in such an environment has brought lots of new insights during the research, which can be applied in any possible upcoming development work.

Service concepts and the customer value perspective were also researched during the project. The chosen activity here was to co-create draft versions of different service concepts depicting how multiple companies can offer their data services to customers when operating in the same ecosystem. The results from this part gave the industry participants an initial understanding about the bottlenecks and opportunities that are related to data services and ecosystems alike.

Result, output, impact

As a result of this research, we were able to verify the abilities of IDS. By implementing the smart factory prototype, we tested IDS in practice. Implementing the system at this large scale had not been done previously in Finland, and on the wider European scale, our implementation was also unique. The implementation proved that we have readiness to act as a member of an industrial ecosystem. We were also able to demonstrate flexible, distributed control based on data shared by each active workstation in the factory. As the transition to Industry 4.0 moves forward, we expect a move away from hierarchical control models to more distributed models, with cloud-based analytics and optimization playing a larger role.

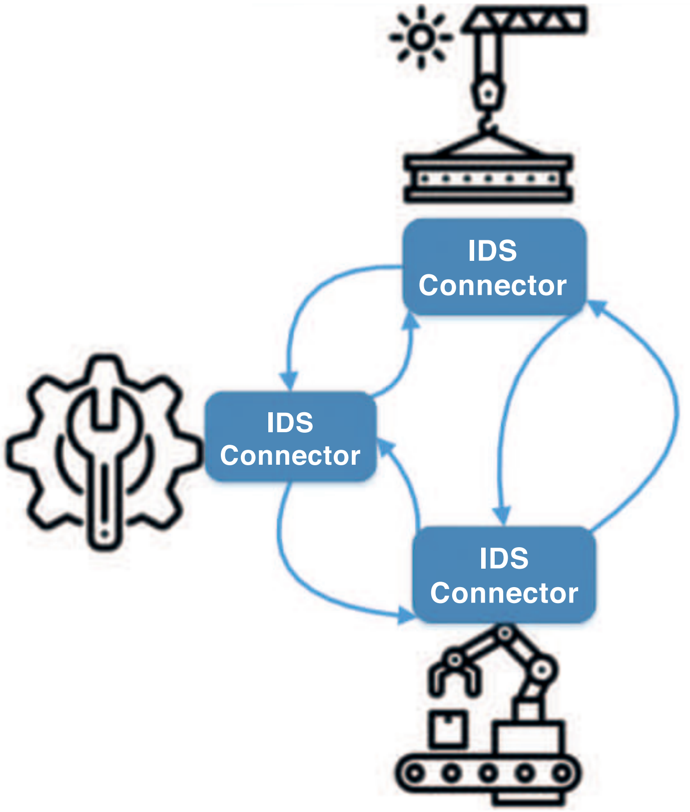

Figure 1: **Private factory network (VTT, Ilkka Niskanen)**

A customer request to buy the whole smart factory at one time is not realistic, but we estimate that soon customers will begin to request smart factory work cells containing smart crane operations. The implementations trials so far have made it possible for us to offer smart components developed in this project. As an example, Konecranes has already provided a customer with a crane solution based on the standardized crane interface.

The results from the data-intensive services part of the research will be the foundation of future decision-making when the industrial participants outline their approach to data service. Thus, it can be considered as a collection of best practices for top-level decision-makers. Insights into customer needs, a depiction of service concepts, legal framework scenarios, and mapping of customer experiences of new services were all produced during the research and are available material when new services are to be formulated. The results will help us to execute much more customer-focused and efficient data services, and they also enable us to recognize the possible pitfalls and dangers to avoid when implementing new services.

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VTT

IDS (International Data Spaces) in a Smart Factory Experiment

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Background

In the Smart Factory experiment, together with Konecranes, Danfoss and Fastems, VTT explored solutions to securely exchange data among manufacturing machines that deploy heterogeneous interfaces and communication protocols. The data ecosystem that was aimed to be established between the companies presented new challenges to data sharing. How can we support data sharing within such a data ecosystem? What are the technical and non-technical barriers to data sharing within the ecosystem?

To address the specific requirements set by the experiment, a dedicated dataspace was created. In general, the term dataspace refers to a type of data relationship between trusted partners, each of whom apply the same high standards and rules to the storage and sharing of their data [1]. In addition, dataspaces can be characterised by certain requirements that partly distinguish them from classical centralised data platforms. For example:

- Decentralisation – data is not stored centrally but at source and is therefore only shared (via semantic interoperability) when necessary
- Data sovereignty – the data owner can control the use of its data and create value-add out of it
- Neutrality – different actors and stakeholders are treated equally within a dataspace
- Identity management – identification, authentication and authorisation of organisations or persons
- Traceability – transactions made within the distributed system are recorded and logged

- Data interoperability – the ability to establish mutual understanding of the structure and semantic meaning of data
- Data findability – the ability to discover available data services through, for example, service catalogues

During recent years, approaches that aim to address the above-mentioned dataspace requirements have been introduced both by the research community and by industry. In the Smart Factory experiment, the design principles of the developed dataspace solution were based on the IDS (International Data Spaces) reference architecture model. IDS is one of the most promising dataspace initiatives, and it aims for a standardised solution for secure and trusted data exchange across organisations and sectors [2]. IDS originates from the European Data Strategy, which attempts to create a single market for data with common policies and shared rules, while ensuring data sovereignty [3].

IDS is coordinated by the IDS Association (IDSA), which currently has more than 130 member organisations representing a variety of different industry sectors and countries. The IDS Association has nominated VTT as the national IDS hub of Finland, which means that VTT aims to promote dataspaces, data sovereignty and IDS technology adoption in Finland. In addition, VTT hosts an IDS testbed that is available for different use cases as an experimentation platform, and it offers customised IDS component development, as well as compatibility tests for IDS components.

The IDS reference architecture defines the needed components and the relationships between components that form the basis of dataspaces. The central piece of the architecture is the IDS connector, which provides the required communication interfaces to enable the exchange of data between different devices, machines, systems and organisations. IDS connectors can be deployed in various types of data infrastructures and environments, and they can be connected to existing back-end systems. In addition, the IDS connector enables definition of the rules of communication and data exchange. This means that the data owner can explicitly configure who can access the data and how it can be used by data consumers. The IDS reference architecture also specifies other modules necessary for establishing dataspaces. For example, the DAPS (Dynamic Attribute Provisioning Service) component provides required identity and access management services, whereas the IDS Broker component allows searching for data resources that are offered by different actors within a dataspace. Figure 1 represents a basic IDS connector-based data exchange scenario.

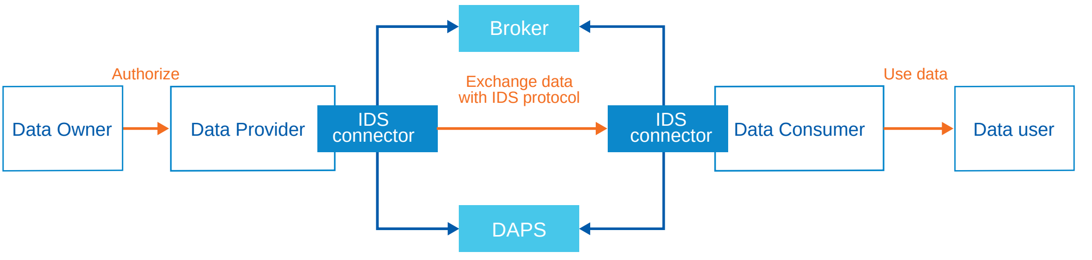

Figure 1: Basic data exchange scenario with IDS connectors

The main technical challenge addressed in the Smart Factory experiment was developing an IDS-based solution to enable the secure exchange of data among heterogeneous production machines. The experiment required that the machines are able to communicate with each other and collaboratively perform tasks in a pre-defined workflow. Besides improving the interaction capabilities and interoperability of existing production machines, the project aimed to develop a reusable approach, introducing new machines into the factory without the need to develop case-specific interfaces. Additionally, the project focused on supporting companies in selectively disclosing data from their production machines to external stakeholders in a trusted and secure way. An example of such an external stakeholder is an organisation that aims to create digital twins of factories. A high-level architectural view of the experiment is shown in Figure 2.

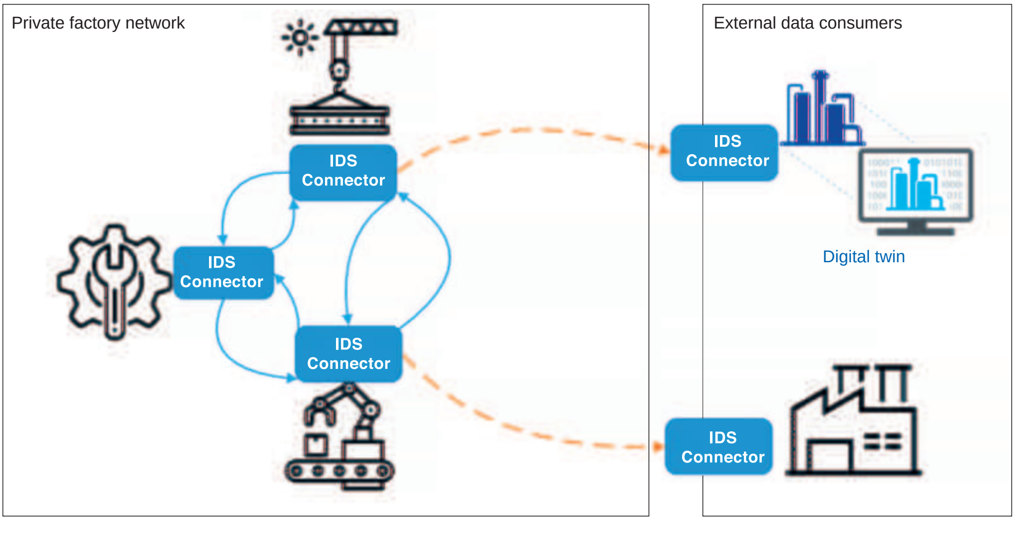

Figure 2: High-level architectural view

As described above, the experiment involved machines supporting different types of communication protocols. In more detail, some of the machines were equipped with communication capabilities based on OPC UA (OPC Unified Architecture), whereas other machines supported only HTTP (Hypertext Transfer Protocol) communication. To solve this interoperability challenge, a so-called OPC UA-compatible IDS connector was developed. OPC UA is a machine-to-machine communication protocol for industrial automation, and it is widely used across diverse industry fields for integrating hardware devices and interconnecting systems [4]. An IDS reference implementation called "Trusted Connector"[1] was used as a baseline for the development work. The IDS connector instances developed in the experiment implement specific OPC UA listeners that utilise Apache Camel[2] technology and are able to automatically detect changes in specified OPC UA node values. Through IDS connectors, these value updates can be transmitted to other machines or systems that either support or do not support the OPC UA protocol. In this way, the developed solution enables communication across heterogeneous communication interfaces and protocols, and facilitates the interaction and collaboration between different types of production machines.

In the Smart Factory experiment, the created IDS connectors enabled machines to easily and accurately communicate their state transitions to other machines deployed in the factory. A more detailed view of the developed approach is presented in Figure 3. The picture depicts how two OPC UA servers can communicate through IDS connectors using Apache Camel-based OPC UA listeners and the IDS communication protocol. It is important to note that with this approach, the other OPC UA server could be replaced with, for example, an HTTP server without losing the established communication capabilities.

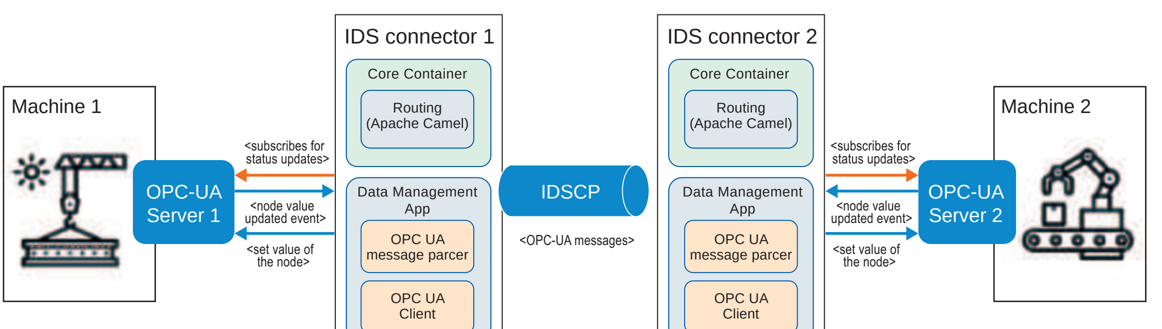

Figure 3: Communication between OPC UA servers through IDS connectors

[1] https://industrial-data-space.github.io/trusted-connector-documentation/
[2] https://camel.apache.org/components/3.11.x/milo-client-component.html

Over the course of the experiment, the above-described technology setup was tested and demonstrated in the Konecranes factory premises in Hyvinkää. The development work included implementing dedicated IDS connectors for each of the production machines and, subsequently, integrating the connectors with the back-end systems controlling the machines. Additionally, in order to facilitate identity and access management, company-specific certificates were created for the connectors and configured to the centralised identity management system (i.e. the DAPS component).

Although the installation, initialisation and deployment of the connectors was relatively straight-forward, we also encountered some challenges during the experiment. For example, the configuration of data routes (i.e., determining which data can be accessed by whom) needed to be performed manually by editing XML-based configuration files. However, this text-based route configuration turned out to be complex, laborious, error-prone and time-consuming. More easy-to-use graphical user interfaces would have greatly facilitated the configuration of the connectors and their data routes. In addition, especially in the early phases of the development work, we had some problems with the reliability and stability of the connectors. The final challenge that we faced was related to network security policies. IDS communication requires opening a network port through which data traffic between connectors can be directed. This initially caused some concerns about the potential cyber-security risks involved. However, as the work proceeded, we were able to solve these issues and successfully execute the planned demonstration. Based on our findings and experiences in the Smart Factory experiment, it can be concluded that IDS is a highly promising approach with several advantages, but some development work is still needed to increase the maturity level of the technology.

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Testing of the Rulebook for Fair Data Economy developed by SITRA

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Introduction

This report presents the findings on the testing of the Rulebook for Fair Data Economy [1] developed by SITRA as part of the IHAN programme. The testing focused on the ecosystem governance framework, including evaluations of suitability of the governance model framework. To enable the evaluation of the applicability, the testing also included scrutiny of the checklist questions in the rulebook. This report also includes suggestions for improvements to the rulebook and the way it can be applied.

The Rulebook for Fair Data Economy was tested in this project because it is a pioneering framework for emerging industrial data networks. Industrial data-sharing networks are a relatively novel phenomenon, and many stakeholders have elevated expectations of the potential benefits. Therefore, it is important to develop better understanding of how companies can engage with a data network, and how service providers can come together to offer added value for their customers. In the context of Finland, these factors are expected to contribute significantly to the future competitiveness of industrial companies.

1. Theoretical background

1.1 Industrial data economy

Industry 4.0 refers to a recent phase in the Industrial Revolution that builds on the availability of digital technologies and focuses heavily on interconnectivity and real-time data [2]. Industry 4.0, sometimes referred to as smart manufacturing, combines physical production with smart technology to create a better connected ecosystem for companies in manufacturing and supply chain operations. While every company is different, they all strive for improved connectedness and access to real-time insights across products, processes, partners and customers. Data paired with powerful analytics tools can improve collaborative demand and supply planning, increase traceability across supply chains, and gain a deeper understanding of customer needs.

Although the manufacturing industry is investing in analytics tools and expertise, it still has difficulty gaining value from data effectively. One of the biggest reasons behind this is that many of the use cases offering manufacturers the most value would require data involving multiples partners [3].

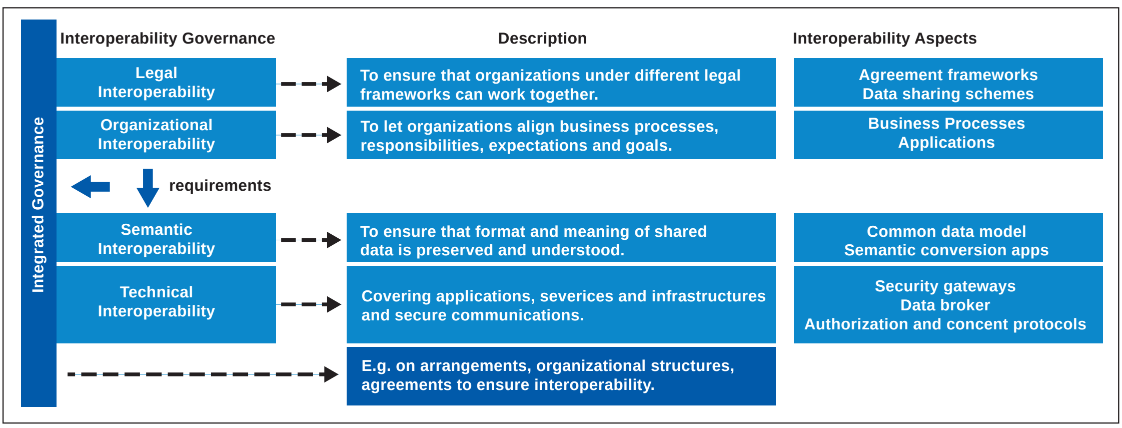

Figure 1: The new European interoperability framework [4]

The European Interoperability Framework (Fig. 1), developed by the European Commission, provides guidance for meeting interoperability challenges. The framework identifies four levels at which interoperability must be implemented in accordance with a comprehensive integrated management approach: legal, organisational, semantic, and technical interoperability. While International Data Spaces seeks to develop a technical reference architecture that enables the secure sharing of information between organisations, special attention still needs to be paid to legal agreements between participating organisations.

This requires an approach that allows for the negotiation of information-sharing agreements between organisations. This aspect is mentioned in the reference architecture of the International Data Spaces initiative without currently providing concrete details on how it could be designed [5]. Data sovereignty – the assignment of binding legal and technical restrictions on the use of information – is becoming more and more important and is increasingly a condition before parties are willing to share their (potentially sensitive) data.

1.2 SITRA IHAN rulebook

In 2019, the Finnish Innovation Fund SITRA set out to lay the foundation for a fair data economy in which successful digital services are based on trust and create value for everyone. As part of this work, the IHAN Rulebook for Fair Data Economy was developed as a guide for organisations, to enable establishing fair data networks that build on transparency and trust.

The rulebook offers a template for a governance structure and contracts. It defines the legal, business, technical, and administrative rules that organisations need to comply with when sharing data in a data network. The guidelines devote particular attention to ethical principles, in addition to privacy and data protection requirements. The rulebook is recommended by International Data Spaces [6].

The guide contains model agreement templates, including:

- the **General Terms and Conditions**;
- a template for the **Constitutive Agreemen**t;
- a template for the **Accession Agreement**;
- a template for the **Dataset Terms of Use**;
- a template for the **Governance Model**.
- a description of the Data Network consisting of a Business Part and a Technology Part

However, the agreements need to be adjusted for each ecosystem/network. For this purpose, the framework suggests using checklists. These are lists of key questions that help to modify and amend the contractual framework.

1.3 Underlying focal assumptions of the rulebook

It is critical that, in addition to the current regulatory and legal requirements, the data ecosystem developers understand the assumptions on which the rulebook builds. These are listed in Table 1.

Table 1: The focal assumptions of the rulebook

1	The Parties to the Constitutive Agreement are (1) the Data Provider (makes data available within the Network), (2) the Service Provider (processes data to provide related services and redistributes the data, such as anonymisation, pseudonymisation or combination of data), (3) the End User (uses the data in its business), and (4) the Operator (provides services to facilitate the operation of the network, such as provision of APIs, management of identities, connections and/or contracts). In addition, the rulebook refers to (5) the Third-Party End User (any Third Parties who receive data from Service Providers where the respective Data Provider has permitted such transmission of the data). A Party may simultaneously occupy multiple roles. Data Networks may not necessarily require all roles.
2	The Data Provider may decide, separately for each dataset, the Parties who are granted access to the data.
3	The provision of data within the Data Network does not constitute a transfer of intellectual property rights.
4	Unless otherwise defined by the Data Provider in the Dataset Terms of Use or agreed by the Members, the Data Provider grants the right to use the data free of charge.
5	The data can be redistributed only to the Members of the Network, but Data Providers may allow redistribution of the data to Third-Party End Users under the applicable Dataset Terms of Use.
6	The Parties are entitled to redistribute derived materials to third parties, subject to additional requirements related to intellectual property rights, confidential information and personal data.
7	Where the data involves personal data, the default approach assumes that the data recipient becomes a data controller.
8	The Data Provider indemnifies other Parties against claims that its data, which is subject to any fees, infringes intellectual property rights or confidential information in the country of the Data Provider.
9	The Members are entitled to use the data after the termination of the Constitutive Agreement, in which case the Constitutive Agreement survives the termination, except for cases in which the Constitutive Agreement is terminated as a result of a Party's material breach.
10	The Data Provider is entitled to carry out audits related to its data.

2. Research methodology – How rulebook usability was tested

The rulebook was empirically tested with three member organisations of the InDEx consortium. The use case was to provide a joint data-intensive service that would allow the customer to create machine-to-machine integrations with their in-house knowledge (no specific expertise needed). Integrations are quick to make (plug-n-play) and scalable (integrations are possible to reproduce to other similar setups).

All three organisations participated in all phases to enable identifying potential problems with the contracts. First, each company familiarised themselves with the outline of the rulebook. The checklists of the rulebook were handled in two workshops with the companies. The first 4-hour workshop focused on the questions on data and technology. Before going into the actual questions, the participants went through the current understanding of the InDEx use case and each participating organisation's role in the use case. In addition, there was an introduction to the rulebook by one 1001 Lakes, which has been involved in developing the rulebook. The second 4-hour workshop focused on business and ethics questions. The workshops were facilitated by researchers external to the participating organisations but involved in InDEx research. After each workshop, the facilitators shared notes from the discussion on the checklist questions. The workshops lasted three hours each.

After the workshops, the contractual framework was examined by legal experts from each company. They provided comments on the legal text.

The study was carried out in spring – autumn 2021. We always used the most recent version of the rulebook. Therefore, during the workshops it was version 1.2 and for legal commenting it was version 1.3.

3. Findings from the rulebook testing

In this chapter, we present the findings of the rulebook testing. We first provide more general comments on the contractual framework and its applicability, followed by specific comments on different contracts included in the framework. Then we continue with findings related to the checklists.

3.1 Findings on the contractual framework

A lawyer of one of the participating companies gave credit to the framework as a whole: According to her, it is a *"relatively good and well-prepared* *contract on a difficult topic with suitable level of complexity".* Hence, it is a good starting point for a network of actors preparing to organise around shared data.

However, before going into the details of the contractual framework, the parties need to make sure they fully understand how their existing contracts relate to the issues defined in this contract. One focal factor is the contracts with existing customers that outline the ownership and rights to use data. For example, when an equipment manufacturer has agreed that the customer owns the data created using the equipment, and that the equipment manufacturer has the right to access and analyse the raw data, the processed data from the analyses is the equipment manufacturer's data. Moreover, data ownership influences the roles defined in the contract, such as which actors are defined as the founding parties in the contract. It also has an impact on the role of the customer in this contract.

Importantly, a company needs to understand in which roles it operates under this contract and what requirements the contract imposes on it. Thus, it can make sure that there are no conflicting requirements for its roles. A picture or some other means of visualising the different roles in the data network would be helpful.

3.1.1 General terms and conditions

The definitions in the "General terms and conditions" template are important, but there are some details that may call for more specification. In addition, there is some ambiguity in the use and definition of the term data (it is not clear how 'data' and 'Data' are used in the templates).

Allocation of costs is an issue that calls for attention. Section 6.3 in the General terms and conditions states that *"joint costs incurred for the maintenance and administration of the Network will be allocated in equal shares between the Parties"*. It might be preferable to divide the costs on a case-by-case basis like IPRs (see section 8.2 in General terms and conditions)

In the section on data protection, there are multiple sections on personal data. Some of these sections need further specification. For instance, a Party disclosing data to the network must warrant that it has a legal basis for doing so (section 9.3 in General terms and conditions). In addition, the same section does not include any reference to a potential situation of joint data controllership. Overall, in relation to personal data, it must be taken into consideration that even though individual datasets do not contain personal data, combining different data may create personal data.

Other comments:

- Notification of “any changes introduced by the Data Provider to the applicable Dataset Terms of Use” thirty days in advance may be challenging in practice.
- General terms and conditions section 3.4 refers only to the Data Provider, whereas in practice it may be an external operator that provides the access to the data in machine-readable form.
- Liabilities: 11.1 – It must be defined whether the data is provided “as is”.

3.1.2 Constitutive agreement

Specific attention needs to be given to the governance of the network section. The template is similar to many R&D project governance agreements defining that the network is governed by a joint steering committee. However, it is noted in the template footnote that the wording on the governance model is very generic, and each network needs to consider what amendments are needed in their case in the current situation, but also throughout the network life cycle.

- Limitation of liability refers to GDPR Article 82, which states only damages relating to data subject claims, not inter parties' liabilities under this agreement. Therefore, it would be good to clarify this part by, for example, adding that this relates to damages to data subjects only.

3.1.3 Dataset terms of use

Defining the dataset is the most important document in the whole contractual framework due to its multiple implications for all parts of the contract. Here, each data set and its restrictions on the processing of the data needs to be described, and its location and method of distribution are defined.

It remains unclear if the term recipient in the contract refers to members of the network or to the users or some other actors.

To make the rulebook easier to apply, we suggest including an exemplar of a well-defined dataset. Currently, it does not provide much help in what should be included in the description of the data set.

3.2 Findings on the rulebook checklists

As a general notion in all the themes discussed below, the scope of the data-driven service in relation to which questions are discussed is a focal point to be defined: whether the questions are discussed in relation to the first/initial version of the service (e.g., the pilot) or a later, commercial version. This greatly affects the content of the discussions. In the case examined in this project, the pilot phase is relatively straight-forward. However, after the pilot phase, there are multiple significant questions that remain unanswered, and thus looking into these questions in relation to the commercial version of the data-intensive service bundle is necessary.

The testing workshops reported here were carried out during the pilot phase of the services. Therefore, the aforementioned phases were mixed in the discussion. Some comments referred to the pilot phase, whereas some comments referred to the time after the pilot. Therefore, this report does not go into the details of the participants' views but tries to abstract the big picture of how well the checklists advanced the process.

In the discussion on the different themes, it was evident that the business questions were not highlighted in the pilot phase. Instead, many more details were clear in terms of the technology and data-related question. In addition, it must be noted that the participants from each company looked at the questions from the perspective of their own expertise. The testing workshops in this project included people from different functions, yet the picture remains limited. It must be emphasised that each organisation needs to go through the templates with a diverse internal team.

The most suitable order of handling the themes may vary from case to case. The authors of the rulebook recommend that it is advisable to start with the business questions. However, the companies involved in this experiment saw it more fruitful to start with the data-related questions. This may be due to the development phase of the service and the companies' approach to developing data-based services. The data questions were the clearest ones in this use case. The development began from the realisation of technical possibilities, and the commercial possibilities or the customer needs were crystallised during the pilot phase. If the customer needs are the starting point, the order recommended in the rulebook most probably works well.

The notions are presented here in the order in which the themes appear in the rulebook.

3.2.1 Business

Outlining the business case was not straight-forward in this case. The starting point was quite much technology driven. There was a general understanding of the customer needs, but outlining specifically the customers' job-to-be-done that the service solves was difficult in the early phases. Challenges relate to the added value of combinations of different actors' data-intensive services.

Based on the discussions on pricing, as well as additional interview material collected during the project, assigning monetary value to data tends to be perceived as problematic. On the other hand, identifying the costs involved in developing and operating the service is also very challenging. The firms could not define, for example, potential costs from having third-party service providers or data brokers involved in the process.

Moreover, the firms also had difficulties in figuring out the roles of different players in the ecosystem. This is also tightly linked to the customer needs. Due to all these uncertainties or questions that remained unanswered at the time of the workshop, it was also difficult to shortlist potential key performance indicators.

Because of the incompleteness of the business case, it was still unclear which data is the most important in meeting the customers' job-to-be-done. In addition, it was still too early to discuss data lifecycle management, and thus the data rights questions under the business theme did not offer much insight. Naturally, however, they showed areas where further work is needed.

Nevertheless, parallel to the work on the rulebook checklists, the companies also worked on the business case by focusing on the service process description, and they defined the roles involved in service production/consumption, as well as the customers' jobs-to-be-done that the service targets. The findings on this process are in the report for InDEx WP3.3.

In addition to the checklist questions on business aspects, six alternative pricing models were examined and discussed:

Pricing model	Description	Comments
Subscription-based pricing	Unlimited data use with a monthly fee	Pricing could be based on how many companies' data the customer chooses to subscribe to. Reacting to changes might be difficult for OEMs.
Dual licensing	Combination of general public licence (GPL) & commercial licence (CL)	This appears to be the most promising pricing model. Could function very well.
Paid certification of data	Selling a possibility to do service/product development	It is difficult to envision a business model for this pricing model. Could potentially work for third-party quality certification, where a customer gets access to data after training. Certification as part of the model.
Per-asset pricing	Buying access to individual OEM data	Differs from dual licensing in that there is no free general licence.
Tiered pricing	Different feature packages for different users (basic/ advanced/premium)	Bundling data from the provider's perspective does not necessarily work. There is a trade-off between customisation and the clarity of the offering, as well as the feasibility of administration.
Per usage pricing	Payments based on real-time actions done with different OEM datasets	Very low threshold for starting. The model would serve customers that have only occa-

Additional general notions in the pricing model are:

- The pricing model should not be too complex, so that administration remains feasible (does not become too costly).
- The pricing model should incentivise the OEMs to develop their offering. One option is to put a price on version updates.
- One question to be solved is the customers' need for support: how will the support be organised/offered?
- In the data ecosystem, the OEMs are also potential customers to each other and thus occupy multiple roles.
- The initial pricing model after the pilot may be a combination of the most promising models discussed.

- It is necessary that there is also a feedback channel from the data user to the provider so that the provider learns what data is relevant and important for the users and if there are some additional needs.

Overall, the business questions made it visible which aspects of the service development require more attention. If the customer needs to be addressed remain vague, responding to the business questions becomes exceedingly difficult.

3.2.2 Technology

The technology questions were discussed mainly in relation to the pilot phase. The pilot phase naturally serves as the basis for the commercial phase. The participants did identify, though, that the requirements for the system architecture had not yet been developed. In addition, the question on interfaces and related roadmaps and commitments focused solely on the pilot phase, and the participants did not yet see it relevant to examine the evolution beyond the pilot.

Discussion on data security and privacy was limited to the pilot phase. In terms of the data-related mitigations, it was commonly agreed that each company is responsible for upkeeping their own interface and the data behind it, and that confidential data is not to be shared.

The discussion on the mechanisms for monitoring and administering system and data use revealed that there is a need to agree on these on multiple levels (e.g. International Data Spaces (IDS) level, integration level, and ecosystem level).

There was a lot of discussion on data governance, and particularly on storing and destroying data. This is apparently a critical question when equipment status data is shared. Moreover, change management principles were discussed from the perspective of 1) removing data from the dataset, and 2) additions to the dataset. It was unclear what kind of visibility the parties involved have to the changes.

3.2.3 Data

The data questions were also largely discussed in relation to the pilot phase. **Storing of data** turned out to be a significant factor in relation to the data questions, too. Particular attention was given to the rulebook basic **assumption that the shared data can also be used after the contract is terminated**.

In the pilot phase, the participants perceived that the question of complementing data-based services in the data network is not relevant. The question on culture led to recognising that **data sharing is a major change for industrial companies.** It was perceived as possible that there are differing views on data sharing even within a company between units or functions. Thus, this question deserves significant attention.

Shared semantics was seen as very important. However, it was questioned whether this needs to be defined in the rulebook. It was agreed that this is to be discussed between the ecosystem participants in the preparation phase.

Finally, **data quality** is clearly the responsibility of the equipment provider. However, in the pilot phase, it needs to be noted that some equipment may be in the prototype stage, when there tends to be variability in the data quality.

3.2.4 Ethics

The ethical principles were examined briefly because of the time limitations. The participants shared the view that the matrix of ethical standards serves as a good basis to discuss the joint expectations of ethical behaviour. However, it was not possible to engage in thorough discussion on the content of the standards in the workshop. This theme would benefit from a dedicated workshop when the founding members of the consortium would have a sufficient picture of their level of expectations on the ethical questions.

3.2.5 Additional notes on specific questions:

- 2.3 Governance – 1.3.4 Data network setup: perceived as an unclear question
- 4.2 Core functionality – 3.2.3 Consents: the question needs to be examined with legal experts
- 4.2 Core functionality – 3.2.4 Transaction management: calls first of all for definition of what is meant by transaction
- 5.1 Governance – 4.1.7 Skills and capabilities: a difficult question to answer
- 5.2 Data structure – 4.2.1 Formats and structures: surprisingly technical questions in this section

4. Conclusions and recommendations

Based on the findings presented above, it is possible to draw conclusions on how the rulebook could serve emerging data networks in contexts like the one examined here, but partially also more generally in data networks between business organisations. Conventional bilateral agreements lack practicality in business settings where there are several partners involved. The rulebook is designed for sharing data in the industry 4.0 context.

From a legal point of view, the IHAN rulebook forms a coherent framework of contracts between the parties. However, we suggest that in an early phase of the contract negotiation process, the participating companies clarify how their existing contracts relate to the data network contract that is being prepared. In particular, what do the contracts with the customer outline about the ownership of data and the rights to use it? Clarifying this is a necessary condition for the company to be able to define what is feasible under existing contracts, whether there is a need to amend some existing contracts, and whether there is a need to modify new contracts. This also largely determines which roles the customer has in the rulebook contracts (End User or also Data Provider).

It is critical that the network participants come to a shared understanding on their stance regarding the underlying assumptions of the rulebook (in Table 1) and agree which assumptions serve their network and which need modification. In the InDEx test case, permission to use data after the contract ends appeared to be an aspect that needs careful consideration. Furthermore, the question of the data being free of charge or subject to charge was noted as an assumption that calls for amendment.

In addition, the general governance structure in the contractual framework is a topic that calls for attention. The role and particularly the authority of the network steering group may be a critical question for participating companies.

The testing of the rulebook added to our understanding of the process of preparing to implement a data-sharing network between companies. The rulebook is not the starting point of the process, but it is a set of tools that helps the network participants to manage the implementation process. The rulebook adds to the transparency of the process by making visible all the important but also the less obvious questions.

This brings up the need for the participating companies to agree on the scope of the business that they are discussing. This is especially the case when the network is in the process of creating new services. The answers to the checklist questions may change significantly when moving from the pilot phase to the commercial phase of the service.

All in all, the testing showed that the rulebook and the contractual framework serve data network formation between industrial companies well. In this case, the process was facilitated by a neutral actor external to the data network, which may have played a role in the success of the process. A more significant factor for the process was that the data network participants agreed on all the focal questions.

To make the rulebook framework easier to understand and apply, we suggest adding an exemplar of a well-defined dataset to the framework. In addition, a picture or some other means of visualising the different roles in the data network would be helpful.

If this process were to be repeated, it would be advisable to do some things differently. Handling the checklist questions in a workshop mode was effective, and it sparked good discussion on many of the themes. However, the checklists are extensive, and covering all of them in two workshops was nearly overwhelming. Therefore, it is advisable to add to the number of workshops and shorten their duration: for example, one checklist theme per 1.5-hour workshop.

In addition, the timing of the workshops should be such that the participating organisations have sufficient vision of, for example, the business case, to enable fruitful discussion on the ways in which the data will be leveraged. On the other hand, if the network participants are willing to engage in co-creation, it can be beneficial to discuss the questions already in a very early phase and return to them at a later stage to recalibrate the development process.

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Service Experience Design

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Introduction

It is not easy to invent ways to utilize the unused data in industrial production. Inventing new data-intensive services in an ecosystem of companies may become easier if the customer is placed in the center, and if focus on the user experience aspects in new service co-creation. This is what the Service Experience Design method is for. The method integrates two powerful design methods: Service Design and Experience Design.

During the InDEx project Aalto University facilitated service co-creation between the technological capability layer and the business needs by using Service Experience Design method. The work included two cases. Smart Factory case with Konecranes, Fastems, and Danfoss, and Customership Journey case with Elekmerk and HT Laser.

Service Experience Design method

Service Experience Design includes seven steps from Customer insight to a Service concept:

1. Customer insight

Collect customer insights from discussions or interviews that address the current use of those products of yours that provide potential data for new services. Address also the customers' future needs and values. What makes them tick is as important as their problems. Customer quotes and themes emerged from the discussions are good starting points for co-creation of new services. Fresh customer research opportunities in the specific topic are valuable to but previous related customer research by the companies can be reused and reframed with analysis to provide some customer insight.

Example:

- *In InDEx customer insight were derived in the Smart Factory case from customer research by one company and it was shared among the partners in a workshop. Analysing customer needs further helped to focus on the relevant. Laddering analysis of the customer interview data revealed the underlying smart factory needs before the third workshop for the case. Customer needs like, "identifying bottlenecks" or "tracking productivity", became customer goals "Production optimization" and "reducing machine idle time".*
- *In the Customership Journey case, the sales team representatives from the companies with lot of daily customer contact was prompted to vocalize customer quotes work with persona categorizations of their customers.*

2. Customer journey

Based on the customer insight from step 1, build the current customer journey map [1]. Place the customer needs along the journey map. The customer journey method is a way to get a more holistic perspective of the customer's world and how the new service could fit into it. For this reason, the method is at the core of service design practice.

Example:

- *In the Smart Factory case a hypothetical customer journey of smart factory owner was sketched in an online whiteboard, using the current knowledge of the case companies about their customer processes. The smartness related phases of the factory construction were in special focus and much of the first workshop was used to form a best guess of the smart factory customer perspective. Customer journey analysis showed the stakeholders of Smart Factory and potential relations. Here the idea or the need for a joint operation as work cell integrator emerged.*
- *In the Customership Journey case the customer journey was built around the company's current model of the customer journey. The sales team used their expertise to document customer actions to the journey map, which was built on the wall of the workshop room.*

3. Touchpoints

For each customer need in the customer journey map, add a touchpoint [1] that meets the need. Often several touchpoints are needed to meet one need, and one touchpoint may help for many needs. Draw these connections between the needs and touchpoints.

Example:

- *In the Smart Factory case the potential touchpoints for data-based service were identified. In a certain part of the factory data management, the needs of data-based service support by the factory items provider. The touchpoints were collected in online whiteboard in the end of the first virtual workshop.*
- *In the Customership Journey case touchpoints were added to the walls of the room customer journey model. The sales team lacked some perspective to outside touchpoints of the company. The only workshop was with physical wall and sticky notes.*

4. Experience vision

After analyzing the customer needs and how to meet the needs, it is time to take a birds-eye view to the customer experience. By understanding and empathizing with the overarching theme of the needs it is possible to set an experience vision, which acts as a strategic experience value proposition. The Experience vision states the high-level goal of customer experience, and it should act as the guiding star in service creation [2].

Example:

- *In the Smart Factory case the Experience vision became "Smartness at your service" at the start of the second workshop for the case. The statement offered a shared vision for the data-intensive services that the network would create.*
- *In the Customership Journey case the experience vision was fixed with the brand promise.*

5. Experience goals

The experience vision will then be used to set experience goals for each customer journey phase or even touchpoint. An experience goal states the emotional value for the customer, and together the experience goals should realize the experience vision.

Example:

- *In the Smart Factory case Experience goals (Trust, Pride/Competence, Fluency) were built before the experience vision as it seemed more natural by the workshop participants. Customer insight guided the creation of experience goals in a major way, as the pain-points had become clear in the first workshop.*
- *In the Customership Journey case Experience goals (Companionship, Reliability) were similarly created with customer insight in mind during the one workshop.*

6. Experience actions

Write down ideas on how one or more experience goals could be realized in each touchpoint.

Example:

- *In the Smart Factory case, there was an area on Miro board with columns for selected touchpoints and rows for all three experience goals. There was an individual exercise where participants wrote down experience actions for realizing an experience goal in a touchpoint.*
- *In the Customership Journey case the work was divided into two: Improving the current practices and ideating for new services along the customer journey. Current practices that support companionship were for example regular calls that the sales team did with the customers. New capabilities were ideated for the demonstration of reliability for the customer.*

7. **Service concept** – Search customer value creation mechanism using insight, customer experience goals and potential service components

Example:

- *In the Smart Factory case a third virtual workshop was organized to create a concrete service concept after the more technical work packages had been completed to ensure technological capability of the network. The service concept tied together the other research and development work and it was used to communicate the results towards the business side of the organizations. The concept illustrated how the physical machine layer and software layer enable a certain type* *of mechanism for value creation regarding to the value proposition that was meeting the customer needs. The relationships of the networked companies in shared service offering was discussed.*

- *In the Customership Journey case, two groups worked on different service concepts based on the outcome of the service ideation along the customer journey. Each team concentrated on a different part of the customer journey.*

Conclusion Service Experience Design combines techniques from service design, such as customer journey mapping and co-design workshops, with techniques from experience design, such as experience vision and experience goals. After testing the process in the two cases we can make the following conclusions.

The overall process was able to bring at least a human-centered, even a experience-driven perspective to development of data-intensive services in industrial context. Starting with customer insight enabled realistic customer journey mapping, which then enabled the definition of suitable experience goals in different phases of the journey. Setting goals for customer experience was a new activity for the participants, but the customer insights and the list of experience goals made goal setting considerably easier. The higher level we went with the experience goals, e.g., the overall customership experience, the more difficult it became to set the goals. Defining the experience vision was the most difficult step, which will need additional support. While it might be helpful to define the overall experience vision before the specific experience goals in specific points of the journey, an easier route seems to be from experience goals in concrete points towards the experience vision for the whole customership journey. Experience vision will then help in communicating the key idea of the new service concept inside and potentially also outside the organization.

The service concept development starts from concrete experience actions in touchpoints. Also here, it depends on the case whether there should be an overall service concept created before the touchpoints. Even if the customer journey was on high level, defining experience actions was quite easy and concrete ideas emerged for the abstract service.

Overall, the participants appreciated taking both a service and experience perspective to new service development. Starting from the customer insight laid the focus on the customer-centric design, and experience design opened up a new viewpoint to serving customers. The outcome from the exercise is a service concept, which is rooted in real customer needs and common interest in data utilization. We hope to see the service concepts taken forward in the partner companies.

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