Newsletter

Dear readers,

We hope that this newsletter finds you healthy! It seems that most parts of the world have left the pandemic behind and slowly return to usual business. Nevertheless, the period of irregularity has caused changes that are likely to last. People have become familiar with remote meetings, and we realize a dramatic reduction of effort for travel compared to some years ago. We are happy that we are now back from “zoom teaching” to face-to-face contact with our students, but we also profit from the pandemic time, where we have organized lessons by famous friends through the internet for our students, and this activity – well appreciated by our students – will last. For example, this summer Prof. David Goldsman (Georgia Tech, Atlanta) will provide two lessons on statistical background for simulationists.

Following the necessity to support the long-delayed turn to renewable energies, the simulation society ASIM is running a working group on modelling energy in simulation models. Last year, the results have been drawn together to a book with plenty application examples, which will appear with Springer International this summer.

Last September we have been able to celebrate the first twelve years of ITPL with a colloquium. We had reported from it in the last newsletter and the proceedings (in German) are still available for download from our web site. This was a nice chance to present most of our research endeavours, but additional ones could be started in the very last months. Two ITPL researchers could finish their Ph.D. studies with their oral exams in November. The books from both dissertations are published by Cuvillier. With some new topics, we have now 15 Ph.D. students

contributing to our research. We are also grateful that we could acquire two new full members for our team. Currently, the economy misses two million skilled personnel in Germany. Thus, we are glad that two of our finishing master students have decided to continue their work at ITPL with the goal of a dissertation. We are especially proud, that one of these is female – this is, unfortunately, still a challenge in mechanical engineering faculties.

Furthermore, ITPL has acquired a new sponsored project called DIONA in cooperation with two other chairs of TU Dortmund, a Fraunhofer Institute, and TU Chemnitz. The project builds an initiative to smoothen the path to sustainable mobility by cyclic value creation and lasts from October 2022 until September 2025. The goal is to implement a hub to promote cyclic value creation for various stakeholders, such as science, economy, social partners, or politics.

A selection of further ongoing research topics can be found in this newsletter. Several papers could be published in 2022 about our recent research, which you find listed in this letter. For now, we hope that you enjoy this little newsletter and stay healthy!

Markus Rabe

Teaching Concepts 2022

In 2022, the ITPL has also revised and further optimised its teaching for the mechanical engineering, industrial engineering and logistics degree programmes. The course "Introduction to Programming" was supplemented with extensive, voluntary course work. In addition, an expanded concept for study speech support is currently being designed at the ITPL as part of the university-wide initiative "Lerntipps2go". In addition, the ITPL continues to offer Bachelor students information technology supplements with the two elective modules "Fundamentals of Simulation Technology" and "IT Systems in Industrial Production". The modelling focus of the ITPL is supported by the module "Modelling of Digital Ecosystems in Production and Logistics". In addition, the ITPL department has prepared the subject area of simulation for students in the Bachelor of Logistics as part of the course Introduction to Logistics.

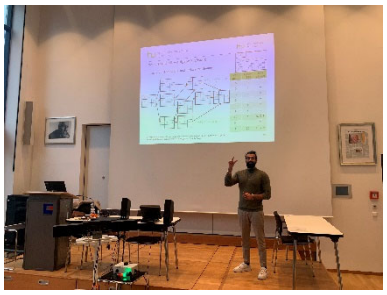
In the Master's programme, the department continues to offer a specific IT profile for the Mechanical Engineering degree programme and was once again pleased with the high level of interest in the course in 2022. In particular, the course Data Analysis and Knowledge Representation in Production and Logistics, which teaches key competences such as data mining and database analyses, is very popular, with an average of 100 participants in the exam.

Teaching Supported by Experts from Industry and Consulting

Cooperations with other departments, institutions, and industry partners have been strengthened and are reflected in numerous teaching formats. The specialist laboratory "Prototype like a Start-Up", which is a cooperation between the Centre for Entrepreneurship & Transfer and the ITPL, continues to enjoy great popularity. Dr. Ing. Christian Knobloch from the company Knobloch & Gröhn supported teaching in the Bachelor's degree programme with his own teaching module on process modelling.

Highly topical subjects that are the focus of our research activities could be transported into teaching through practical examples from industry. The lectures covered topics such as machine learning from PTC (Switzerland), test automation from Redbots, and data structures in the supply chain from Relex. We also had a very interesting guest lecture on web services from Capgemini and got an insight into digitalisation from KHS and from Prof. Stautner, head of research at ModuleWorks GmbH and professor at HRW.

The "Business Informatics Case Study", which has already been successfully carried out several times with the company CGI, continues to be a special facility. In 2022, around 25 students dealt with specialised questions from the field of Big Data Analytics and presented their results in small groups to the expert jury on a colloquium day. Some of the results were so promising that students with their Big Data projects subsequently sought advice at the CET regarding start-ups.



Evaluation of Automated Material Flow Systems in the Bidding Phase

Tobias Sohny (Dr.-Ing.) has finished his Ph.D. extending the static value stream method with dynamic modelling to support manufacturers of production equipment already in the bidding phase, in cooperation with the University of Applied Sciences Koblenz under the local guidance of Prof. Walter Wincheringer. He developed a suitable reference model that allows the planners to validate the throughput guarantees that they offer to their customers. He has submitted his thesis in August 2022 and passed his oral defence in November.

Examination commission: Prof. Walter Wincheringer (University of Applied Sciences Koblenz), Prof. Axel Kuhn (emeritus TU Dortmund), Tobias Sohny, Prof. Markus Rabe (chair IT in Production and Logistics), Prof. Moritz Schulze Darup (chair of commission, chair Control and Cyberphysical Systems)

Reference Model Based on the Value Stream Method

Sohny, T.: *Referenzmodell basierend auf der Wertstrommethode zur Bewertung von automatisierten Materialflusssystemen der Produktion in der Angebotsphase. Göttingen: Cuvillier 2023.*

Automated material flow systems in production are highly dynamic and at the same time very complex. Suppliers have the challenge of guaranteeing a minimum throughput performance for such customised material flow systems when submitting their offer. Over-dimensioning, however, to ensure throughput, resulting in additional costs, leads to decreased competitiveness.

With simulation technology, executable models can represent dynamic and stochastic aspects of systems. Thus, alternatives can be evaluated. However, simulation is too time-consuming and cost-intensive at the time of the bidding phase. Therefore, it is regularly used only after an order has already been placed. Possible planning errors are recognised late and lead to cost-intensive adjustments.

In this work, a reference model based on the value stream method is developed, which contributes to a reduced modelling effort of simulation models for automated material flow systems at the time of the bidding phase. For efficient modelling, the user of the reference model has a construction scheme developed for this purpose, consisting of individual model elements with defined structures and relationships. Each model element represents a real system element of an automated material flow system with its characteristic properties, represented by system states, logic aspects, and attributes. The description of the system elements, with a suitable granularity for the bidding phase, is based on the value stream method, which is proven to be successful in the industrial environment, extended by the aspect of dynamics. The modular structure of the construction scheme and the description method allows for an application-specific parameterisation and the selection of specific model elements. The user is supported by a procedure for the specific use of the model elements, in a structured system analysis and the formal model description. With the execution of the modelling according to the reference model, the user receives a formalised model, which can be implemented simulator-specific in a simulation system without further explanation. This enables the supplier to secure his guaranteed throughput per offer in the shortest possible time and to increase his competitiveness by studying what-if scenarios.

Dr.-Ing. Tobias Sohny after the successful exam

The usability of the reference model is demonstrated by a simulation study of a real material flow system. It is shown that the given structure and the defined model elements support the designer in the system analysis and model formalisation in an application-specific way and, thus, reduce the modelling effort. The reliability and sufficiently accurate representation is proven by a phased verification and validation and the comparison with a detailed model.

Series “Fortschritte in der IT in Produktion und Logistik”, Vol 5, available in book stores and online; print 84,90 €; e-book 59,90 €.

A reference model for Quantitative Sales Planning in the Supply Chain

Daniel Büttner (Dr.-Ing.) has finished his Ph.D. on a systematic approach for quantitative sales planning at the example of electrical consumer appliances. He has developed a reference model that supports companies in estimating their own maturity with respect to sales planning, and helps them to select planning methods that are suitable to their goals and constraints. The research has been conducted in cooperation with the Graduate School of Logistics in Dortmund with a sponsorship of Vorwerk International & Co. kmG. He has submitted his thesis in August 2022 and passed his oral defence in November.

Examination Commission: Prof. Matthias Faes (chair of commission, chair Reliability Engineering), Prof. Katja Klingebiel (University of Applied Sciences Dortmund), Daniel Büttner, Prof. Markus Rabe (chair IT in Production and Logistics), Prof. Michael Henke (chair Enterprise Logistics)

A Reference Model for Quantitative Sales Planning

Büttner, D.: *Referenzmodell für die quantitative Absatzplanung innerhalb der Supply-Chain-Planung. Göttingen: Cuvillier 2023.*

Companies in the consumer goods industry often produce their products on stock to be able to serve the end consumer demand arising on the market as quickly as possible. The sales quantities resulting from the end consumer demand are, thus, unknown at the time of production. For this reason, a planning function exists in the context of Supply Chain Planning (SCP) that generates forecasts of future sales. In practice, forecasting is carried out using quantitative and qualitative methods, whereby the use of quantitative methods should serve as the information basis for SCP. In the field of quantitative sales planning (SP), challenges exist resulting from the increasing complexity of supply chains, unclear planning processes, the variety and complexity of forecasting methods, and the data used. This dissertation develops a reference model for the sales planning function using quantitative methods. The following research-guiding question is investigated: How should a reference model be designed to support sales planning and the use of data within quantitative forecasting methods?

Congratulation by the supervisor Prof. Markus Rabe

The goal of the reference model for quantitative sales planning (RSP) within SCP is to systematize the SP process, methods, and data. The RSP serves as a guideline for using company data to create sales forecasts. In doing so, the RSP supports the initial

integration of SP as well as its further improvement. Defined maturity levels guide in the implementation of SP.

If you are located at two institutions, you might get two trenchers!

A theoretical and practical analysis of the challenges and the state of research in the field of SP forms the starting point for the development of the RSP. A procedure model for reference modeling was used and a requirements catalog for the RSP was defined. A derivation of necessary functions to fulfill the requirements forms the basis for the design and development of the RSP. The components of the RSP, consisting of a process module, a method module, and a data module, were initially developed separately and integrated into one model. A case study is used to examine the achievement of the research objectives and evaluate the utility of the RSP.

The result is a comprehensive model that consists of three maturity levels and provides context between the SP's process, methods, and data. In the first maturity level, SP is systematized to be as simple as possible so that it can be implemented by many companies. As the maturity level increases, the complexity of the SP increases. By realizing the second and third maturity level, more data are used in methods that are more complex and further influencing factors of sales are taken into account in the creation of forecasts. The process module represents a structured procedural approach in SP with the help of superordinate process steps and further detailed subprocess steps. The methods module evaluates and categorizes 24 quantitative forecasting methods based on their complexity. The data module systematizes the forecast data into information classes, which are grouped according to their context. Furthermore, the data module shows which data are optional or obligatory for SP and in which process step they are relevant.

The RSP is the first reference model that systematizes the process, methods, and data of SP in a comprehensive way and, thus, provides orientation for practical integration in companies.

Series “Fortschritte in der IT in Produktion und Logistik”, Vol 6, available in book stores and online; print 99,90 €; e-book 70,50 €.

Alexander Wuttke nominated for Hans-Uhde Award

ITPL is proud to report that our team member Alexander Wuttke has been nominated for the Hans-Uhde Award, which honours the most outstanding master graduations of the year. His master thesis on the topic *Development of a graph-based simulation tool for logistics networks in a data farming framework* discussed the need for novel simulation tools that are tailored towards processing highly connected graph data and simulation-based data generation. With a final degree for the thesis and for the entire master study of 1.0 (with 1=best and 4=passed), he will be dedicated the award in May 2023.

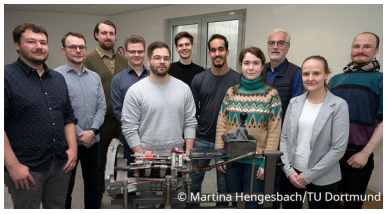
Research group networking (photo: ITPL)

New Research Project DIONA

Starting in 2023, ITPL participates in the DIONA project that aims to design a digital ecosystem for a sustainable circular economy in the automotive industry. The importance of sustainability can be illustrated by the so-called "Earth Overshoot Day", which shifts from year to year more and more towards the beginning of the year. It describes the day on which the natural resources of a year are consumed by mankind. For this reason, sustainability is becoming increasingly important and is discussed in research, politics, and industry. Since 2015, when the United Nations agreed on both the 1.5-degree maximum earth warming target and the Sustainable Development Goals, the desired guard rails for further global sustainable development have been set. Germany, too, is to become climate-neutral by 2045. However, the transportation sector in particular will not be able to meet the targeted emission reductions. The car as the main means of transport as well as the associated industry make a decisive contribution to this. Therefore, it seems necessary – also in the course of a transformation towards e-mobility – to understand products and production processes holistically and to share the knowledge gained in this way. In particular, the adaptation of a circular economy approach, i.e., a holistic product life cycle view, is explicitly part of the European and German sustainability strategies and promises to reduce both the need for raw materials and CO_2 emissions while promoting jobs and economic growth. Both decarbonizing the mobility sector and enabling sustainable, efficient, and innovative mobility is an explicit promise agreed among the ruling parties in the German coalition agreement for 2021–2025.

However, the status quo shows that many companies are unable to benefit from these advances related to sustainable value streams. Research illustrates that there is a lack of widespread guidelines and methods for establishing sustainability in industrial activities, even though sustainability has a major impact on ecology, economy, and society. Therefore, the

project *Digital Ecosystem for a Sustainable Circular Economy in the Automotive Industry* (DIONA) addresses the need for a joint elaboration of sustainability measures in order to obtain a holistic understanding of sustainability, challenges and problems. For a future sustainable development, it is necessary to identify best practices in the automotive industry as well as socio-political incentives or obstacles.



The project is carried out in collaboration with the Fraunhofer Institute for Software and Systems Engineering (Dortmund) as well as the departments of Industrial Information Management (TU Dortmund), Sociology of Technology (TU Dortmund), Business Informatics (TU Chemnitz), and Alternative Vehicle Drives (TU Chemnitz). DIONA is funded by the German Federal Ministry of Education and Research under "The Future of Value Creation – Research on Production, Service and Work" initiative. The main contact person for this project at ITPL is Joachim Hunker.

DIONA

www.diona-hub.de

Test and field data analysis for reliability prediction of heating systems

Sahil-Jai Arora (M. Sc.) is an external Ph.D. student at ITPL and member of the BOSCH Ph.D. programme. He is conducting his research in cooperation with the ITPL and the company Bosch Thermotechnology.

Modern heating systems are often continuously exposed to loads over a long period of time – usually up to 20 years. Due to the variable operating conditions, the actual lifetime in the field can only be estimated to a very limited extent. In particular, the superimposition of different component-specific damage mechanisms and load profiles is challenging.

Defective components are replaced during scheduled service visits or due to unexpected failures. A possible predictive reliability approach can lead to optimized maintenance and service concepts on the manufacturer side by evaluating field data for predictive fault detection. At the same time, existing lifetime models can be optimized through data-driven relation of system and operating conditions. Recording field data at the customer's site and processing it into load profiles enables customer-oriented dimensioning of heating systems even on component level.

Different industries face the challenge of developing a reliability prognosis model, hence necessitating standardization of model development. The research addresses this challenge by developing a reference model for reliability prediction of heating systems, which will enable the reuse of knowledge and practices in the form of a design scheme.

In order to strengthen the cooperation between ITPL and Bosch Thermotechnology, milestone meetings are conducted, which also offer opportunities such as a factory plant tour (photo).

Factory visit and work discussion at Bosch Thermotechnology in Wernau: Markus Rabe (supervising Professor), Sahil-Jai Arora (Ph.D. Candidate), Maik Effenberger (Reliability Expert), Linnan Du (Reliability Expert), Drazen Martinovic (Reliability Expert), Andreas Radde (Logistics Expert) (photo: Bosch Thermotechnology)

Urban Logistics Systems Modelling

Jorge Chicaiza-Vaca (M. Sc.) has been funded by a DAAD scholarship and is pursuing his Ph.D. at ITPL and head of the Transportation and Logistics Systems Research Center at the Freight Transportation Chamber in Ecuador.

His research focusses on automated parcel locker (APL) systems such as packstations or locker boxes. In this field, one of the main expectations of users is convenient localization. In this context, simulation and optimization techniques are used to define the system structure of APLs as an urban logistics solution. A model is designed that combines a system dynamics simulation model with a facility location model for a specific application of APLs in the cities of Dortmund (Germany) and Pamplona (Spain) as case studies. The proposed model aims to improve the system representation of APLs and provide a new evaluation tool for future implementations of this initiative as a last-mile logistics system for cities.

Derived from Jorge's dissertation in collaboration with Prof. Kai Gutenschwager from Ostfalia University of Applied Sciences, Prof. Michael Kuhl from Rochester Institute of Technology, and Prof. Markus Rabe, a book chapter on energy consumption in the retail operations was written as part of our new Springer book on energy-related Material Flow Simulation in Production and Logistics to be published this summer. In this chapter, applications on fuel consumption of APL use compared to home delivery, simulation of product returns, and distribution structures in the food sector were described.

In addition, Jorge is the head and co-founder of the Transportation and Logistics Systems Research Center at the Ecuadorian Freight Transportation Chamber. It runs several research projects, e.g., (i) the development and implementation of cargo bikes for urban logistics in the city center and their

combination with APLs; (ii) the combination of passenger and freight transport using the new metro infrastructure in Quito (Ecuador), and (iii) implementing telemetry for trucks, using sensors and devices to obtain real-time (second-by-second) information on numerous engine parameters, such as distance traveled, revolutions per minute, instantaneous fuel consumption, speed, geographical position, and altitude. Nowadays, with more than 2,000 km of analysis, from three different types of heavy trucks and five drivers, Jorge is working on the implementation of an online platform that communicates these parameters into the transport management systems of companies. This information will be used to develop a national eco-driving program that aims to reduce fuel consumption, emissions, and increase road safety.

Adapting Data Preprocessing for Data Mining

Florian Hochkamp (M. Sc.) is a research assistant at ITPL since November 2020. His research interests include knowledge discovery in databases, data mining, data preparation, and data quality.

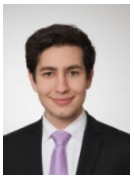
With growing amounts of data, knowledge discovery in databases is required to cope with analysis tasks. The fact that subject matter experts are also overwhelmed by the volume of data and that there is a shortage of subject matter experts at the same time underscores the relevance of more-sophisticated analysis methods such as data mining. For many manufacturing companies it is unclear, which methods to apply in data mining. An implementation of every data mining technology requires a data preprocessing matching the specific data mining algorithm that deals with data quality deficiencies and ensures the structuredness of the data. However, data preprocessing takes up to 80 % of the time for a knowledge discovery process and prevents a fast and precise analysis. To approach this issue, more-developed preprocessing methods are presented in the literature. These methods address automation potential in data preprocessing as well as increasing the overall preprocessing performance. The research focusses on an adaptation of the data preprocessing phase to create a framework combining advances in data preprocessing methods with a structuring approach. This approach targets to reduce deficits in data preprocessing in order to improve the overall data mining result and, thus, provide a more valuable knowledge discovery.

Combining Data Farming and Mining in a Logistics Assistance System

Joachim Hunker (M. Sc.) is a research assistant at ITPL since 2017. His research interests include simulation-based data generation, non-relational databases, and knowledge discovery in databases.

Nowadays, supply chains are fairly complex systems. Due to this complexity, decision-makers in supply chain management are confronted with various logistics tasks that can no longer be answered manually. Therefore, decision makers are supported by IT systems such as logistics assistance systems. A key factor in supporting decisions in supply chain management is gaining and visualizing knowledge. One of the widely established methods in theory and practice is known under the term knowledge discovery in databases. The core phase of the knowledge discovery process is known as data mining. Applying successful data mining, e.g., to find useful and previously unknown patterns, relies heavily on a valid and preprocessed input data basis, which is usually stored in a database. A challenge is that these consist of mainly observational data, which leads to different flaws. Typical examples are low data quality, e.g., missing or out-of-range data. A way to address this problem is simulation-based data generation, called data farming. The process of data farming uses large-scale experiments to grow massive amounts of synthetic data as simulation output. This enables the application of analytical methods on a well-suited database to support decision makers in supply chain management in answering complex logistics tasks. In this context, Joachim Hunker focuses in his research on combining data farming and data mining in a logistics assistance system to support decision makers in supply chain management.

Automated Machine Learning for Quality Control



Reza Jalali Sousanabady (Dipl.-Inf.) is an external Ph.D. student at ITPL and currently working as an IT consultant for Accenture AG in Zurich, Switzerland.

Today, the world stands on the brink of a technological revolution that will fundamentally alter every aspect of people and companies' existence. The scale, scope, and complexity of the transformation in the ways these entities live, work, and inter-relate to one another will be unlike anything mankind has ever experienced before. Manufacturing and logistics companies will not be exceptions. Various aspects including increased competition, demand for reduced time to market, as well as higher complexity of products and processes will be treated using new tools and methodologies. Among these methodologies is machine learning, through which additional knowledge can be obtained. This is achieved by extracting and accumulating critical data, detecting patterns, and extracting new hypotheses representing helpful knowledge. However, a drawback lies in the time-consuming procedures of data preparation and model development. Additionally, reusability of the models as well as the significant amount of resources required for adjustment of existing models pose as further factors that have to be considered. To address these problems, Automated Machine Learning (AutoML) can be applied for model generation in a variety of cases. Using AutoML increases the speed of model creation, but at the costs of the model quality due to the lack of domain knowledge utilization. The research

focuses on tackling this challenge in the domain of quality control in discrete manufacturing. The proposed methodology introduces a novel approach for the integration of domain information in the learning process of AutoML as well as compensating its intractability for the experts.

Digitalization of Control Processes in the Model Upgrade of Vehicles

Emre Kilic (M. Sc.) is an external Ph.D. student at ITPL and currently working at Volkswagen AG in Wolfsburg.

The automotive industry must deal with wide-reaching challenges and changes. A continuous gain of significant competitive advantages in a highly competitive market requires automotive manufacturers to produce new products with a large diversity of variants at ever-shorter time intervals. As a result, the frequency of series launches has increased and the need for a sophisticated vehicle project management and an efficient handling of vehicle changes and model updates along the product process has gained significant importance. However, current project management practices and frameworks utilized by automotive manufacturers do not effectively address this demand, e.g., the goal of increasing operational efficiency and productivity as well as establishing continuous improvement are not sufficiently achieved. While these goals are traditionally common place in certain fields of the automotive manufacturing, e.g., in production, logistics, or warehousing, their dedicated consideration in the vehicle change management and model update of vehicles has not been examined thoroughly in the required extend.

A conceivable solution to establish a progressive and digitally supported vehicle change management and an advanced control of model updates of vehicles is the Digital Twin approach. However, there is still little research regarding the applicability of the digital twin on operational business processes with the aim to increase operational efficiency and productivity. Therefore, a novel concept of a business-process-related digital twin is designed and proposed to provide a substantial leverage to reach the aspired operational excellence in the management of vehicle changes and model updates of vehicles in the automotive industry.

Final assembly line of the ID.3 in a production plant (photo: Volkswagen)

Data Farming for Sales Planning in Omni-Channel Distribution

Tobias Klima (M. Sc.) is a member of the Graduate School of Logistics in Dortmund. He is conducting his doctorate research at the ITPL and is sponsored by the company Vorwerk.

In supply chain management, the focus has shifted to more sustainability and resilience. Demand forecasting is often the basis for process planning and has a major impact on production. In order to act in a more customer-oriented way and satisfy customer needs quickly, forecasting future sales based on historical data is essential for sales. Accurate sales planning helps to provide the demanded products in advance of the emerging customer demand. The research of Tobias Klima investigates how simulation can support the creation of sales forecasts in multi-channel sales. For this purpose, it will be investigated whether simulation methods from logistics and production can be transferred to multi-channel sales and which other methods of forecasting can be combined with simulation. To validate the simulation model, it is applied to the product distribution of a large German household goods manufacturer. Sales and marketing data from the company are used to create the model.

Embedding Track & Trace Solutions

Henrik Körsgen (M. Sc.) is an external Ph.D. student at ITPL and currently working as a SCM IT consultant with dxk GmbH in Zurich, Switzerland.

Disruptions in the supply chain are not an exception anymore. Geopolitical tensions, the climate crisis and faster life cycles demand for adequate logistical solutions. Traceability of the goods flow in the supply chain is considered a must today and – even more – in the future. Track & trace solutions are an important technical basis to reach this goal.

The current supply chain system landscape undergoes daily changes and must exhibit stability. The question is how to implement track & trace solutions such that the complete scope of logistics operations within the supply chain system landscape is covered. Our research addresses this challenge by designing a framework that guides enterprises in the precision engineering industry where to start with the integration of track & trace solutions and which procedures to follow in their planning. In the first step of this investigation, information has been collected about the technical options that are available to organizations. In a second step, their resulting benefits are evaluated.

Track & trace solutions comprise the three major steps (i) identifying the item, (ii) receiving its status, and (iii) triggering the follow-up action. To put this into practice, organizations require detailed information about the set-up of the solution and how to integrate the related processes. Eventually, the digital enterprise architecture represents a suitable basis for the track & trace application.

For this purpose, a track & trace maturity assessment reference model that facilitates embedding track & trace solutions is designed, considering the entire digital enterprise archi-

tecture. Additionally, blockchain technology for track & trace solutions is compared to other technologies. The next step is to outline the value of the digital enterprise architecture for the implementation of track & trace solutions.

Automated Order Picking for Heavy Flatpacks in Retail and Wholesale

Trang Nguyen-Krogull (M. Sc.) is an external Ph.D. student at ITPL and currently working as Automation Integration Leader in Customer Fulfilment with Automation integration of INGKA IKEA.

The ongoing market and e-commerce developments, combined with the increasing customer expectations in omnichannel customer points and shorter lead times, the home furnisher companies have an increased interest in automated order picking systems. Although technologies for automated order picking processes are developing rapidly, picking of the unergonomically heavy flatpacks is mostly conducted manually. This is due to the flexibility of manual processes, but also to the long planning and evaluation time of these complex processes. Automated order picking solutions support the requirement of a more-ergonomic working environment and can provide more density and productivity. However, it also makes the overall intralogistics process more complex, leading to a more time-consuming and complex planning and evaluation process.

Currently, the planning and evaluation still involve years of preliminary studies, development projects, data collection, and evaluation to reach the successful implementation of an automated order picking process of heavy flatpacks. Furthermore, the existing guidelines for the generic determination of performance availability lead to a time-consuming discussion in the specification phase, as they are not specifically dedicated to the technology that is used in intralogistics solutions for heavy flatpacks.

The aim of the research is to develop a reference model to support the decision-making during the planning and evaluation phase for automated order picking processes of heavy flatpacks. The reference model shall provide a conceptual framework with standard process descriptions and best-in-practices. It builds up the foundation for the planning process by providing the planner an understanding of significant concepts, entities and relationships that need to be considered. A major benefit of the reference model is the more efficient and costs-saving planning and evaluation phase. Furthermore, the usage of the reference model in combination with an early integration of simulation into the planning process has the benefit that the complex intralogistics solutions can be validated and verified in an early stage. The application of simulation gives the possibility to consider the pre- and post-processes in addition to the generic guidelines.

Creating Customized Actions for the Simulation of Logistic Networks

Dominik Schmitt (Dipl.-Inf.) is an external Ph.D. student at ITPL and currently working at the Fraunhofer Institute for Material Flow and Logistics, Dortmund, as a research associate.

Today's logistics networks are very complex systems, which are influenced by many external and internal factors. To adjust the system in order to pay attention to these effects and to guarantee an almost perfect performance of the networks, continuous changes in its structure and configuration are needed. The kind of these changes depends on multiple objectives such as increasing the profit, changing the range of goods, or adding new suppliers.

Optimizing such complex systems can become a huge challenge for managers. Facing this problem, ITPL has developed a decision support system (DSS) that supports the user by suggesting promising actions for the given logistics network. This DSS addresses different logistic areas of the network and chooses the best integrated action sets from a given catalogue of actions to be applied while respecting their interdependencies.

Unfortunately, these suggested changes are typically predefined within the simulation program. To increase the flexibility and usability of the DSS, a concept of deriving specific actions from generic action types has been created. To realize this concept, a method to generate, integrate and execute user-generated generic action types is a precondition.

ITPL is addressing this challenge by creating a formal description of changes in DES models for large logistics networks. Based on the formal description of actions, it is possible to transform the changes from a very technical-level into a more intuitively accessible way, e.g., in a graphical editor. On this abstraction level, it is possible for the user to modify or create new actions and apply these to the simulation model.

Method for Real-time Forecasting of Production Key Figures

Erwin Sirovnik (Dipl. Wirt.-Ing.) is an external Ph.D. student at ITPL and working for thyssenkrupp Rasselstein GmbH in Andernach.

Nowadays the production scheduling pursues several objectives inside a flexible flow production in the steel industry, which are mainly located in the field of logistics. Besides an adherence to delivery dates, the primary target within a steel industry – characterized by capital-intensive plants – is represented by running at full capacity. Further objectives based on production key figures like maximized material productivity, minimized energy costs, improved quality, etc. are only covered to some extent, if any, manually by a responsible planner with few general rules. Although there are individual isolated solutions for specific plant-related objectives, e.g., on the subject of quality, a holistic

view is still missing. These aspects are gaining importance – especially in situations of unplanned events like plant or material failures within an intermediate production step – regarding re-scheduling of the planning objects in the short-term.

Packaging steel (photo: thyssenkrupp Rasselstein)

In order to cover this resulting complexity, a production scheduling has to be developed that generates optimized production plans for each individual material unit at each production step considering all available data from the shop floor. Thereby, the multi-objective optimization must be supported by a real-time-capable forecasting of all relevant production key figures derived from machine learning and data mining approaches on data concerning quality, orders, maintenance and further relevant information. On this basis, transparency regarding all key performance indicators concerning the production as well as an immediate reaction to critical situations like insufficient target values will be enabled.

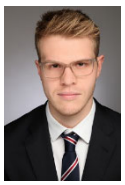
World's largest production site for packaging steel premises in Andernach (photo: thyssenkrupp Rasselstein)

Modeling of Intralogistic Processes for the Implementation of WMS

Felix Stadler (M. Sc.) is external Ph.D. student at ITPL and working in the IT consultancy of Windmöller & Hölscher KG in Lengerich.

Due to the growing complexity of intralogistics systems, the use of warehouse management systems (WMS) is becoming increasingly attractive for companies. As an often business-critical management system of internal material flows, however, their implementation or change is complex and carries risks. Especially the insufficient knowledge of companies about their own processes leads to a high capacity and cost burden due to the time-consuming involvement of their own experts and, often, also contracted WMS consultants. In this context, models and modeling methods are gaining additional importance. But, particularly in intralogistics, with its special demands and characteristics, there is a lack of methodological support for mapping and transferring process knowledge appropriate for the WMS implementation. The consequences, besides a low level of acceptance among the affected employees, are project abortions and production downtimes. Therefore, we are conducting research to collect experiences from industrial practice during the implementation of WMS. With the assumption that a supporting method is urgently required in this context, we work on a modeling language for mapping intralogistic processes in line with the requirements for the implementation of WMS as well as procedural method components that support the generation and transmission of the process knowledge.

Simulation and Machine Learning for Agile Production Networks



Willian Vent (M. Sc.) is an external Ph.D. student at ITPL and currently working in the manufacturing department of Gira Giersiepen GmbH & Co. KG in Radevormwald.

Determining ideal structures of production networks poses a challenging task for manufacturing companies nowadays. In order to gain competitive advantages, companies are trying to make their production activities more agile.

In recent decades, the term agility has been coined by agile software development and adapted for various disciplines and applications. Currently, agility is experiencing a renaissance in the context of production and is seen as a promising field of research for the production of the future and as the answer to rapid and disruptive change. The challenge of agile production networks is the complexity in their design. Due to the size of the solution space, inadmissible simplifications arise as a result of human preference. Here, it is only partially comprehensible how individual network adjustments can have an effect. As a result, only a few network configurations emerge, which are too quickly inferior to the network variants that become known in the advanced design process.

A way to address this problem is a combined approach of simulation and machine learning. As an approach, besides the generation of a database by simulation, machine learning can be used to generate design strategies for production networks that differ from known solutions patterns.

Simulation-based Digital Twin for Predictive Maintenance of Machines

Alexander Wuttke (M. Sc.) is a research assistant at ITPL since 2022. His research focuses on simulation, digital twins, and analytics on data collected by sensors.

Digital Twins have gained a lot of attention in research as well as in industrial applications. They are the virtual representation of real-world objects and used to find answers to numerous questions concerning their real counterparts. An important source of data for the Digital Twin is constituted by sensors at the objects themselves.

A specific task that Digital Twins are useful for is Predictive Maintenance (PM). For PM, the object and its current state are monitored and analyzed in order to predict when maintenance is required rather than conducting preventive maintenance. Utilizing PM can

result in a major saving of costs and is, therefore, of great interest for industrial applications.

In cooperation with an industrial partner, a Digital Twin for the purpose of PM of industrial furnaces is currently worked on and implemented. This includes a simulation model, which is used to gain in-depth insights of the industrial furnace and to generate additional data for the data basis of proven methods for PM.

Reference Model for Process-oriented Lot Sizing along the Value Stream

Gökhan Yücel (M. Eng.) is an external Ph.D. student and is working as director of operations at a manufacturer for safety systems.

The globalization, the integration of supply chains, and the lean management philosophy represent challenges to the definition of lot sizes. The reduction of stocks and the just-in-time supply of customers show a considerable effect on supply chains. However, the past years have shown how sensitively global supply chains react to political developments and natural disasters. Therefore, many companies are building up safety stocks despite the lean philosophy.

In this environment, the question arises whether lot sizing can remain a purely internal activity. Irrespective of the costs and the pass-through or process-oriented approach, the question arises whether the lot size modelling needs to be extended along the supply chain, and which factors have an influence on the consideration of the supply chain in the lot size calculation and have, therefore, to be taken into account.

A simulation-supported reference model for process-oriented lot sizing along the value stream is under development to support the production planner in ensuring a continuous process flow and, thus, delivery reliability.

Lectures Given by ITPL

Bachelor

- Introduction to Programming
- Fundamentals of Simulation Technology
- IT-Systems in Industrial Production
- Modelling Digital Ecosystems in Production and Logistics
- Introduction to Logistics

Master

- Information Exchange of Manufacturing Companies
- IT Design in Production and Logistics
- Data Analysis and Knowledge Representation in Production and Logistics
- Case Study Information Systems
- Material Flow Simulation
- Planning and Implementation of IT Projects
- Lab “Prototype like a Start-Up”

Contributions to Bodies

Association of German Engineers (VDI)

- VDI GPL Fachausschuss 204 Modellierung und Simulation; Member Markus Rabe
- VDI International Gremium Digital Information (IGDT), Member Markus Rabe
- VDI Richtlinienausschuss (Guideline Committee) 3633.10 “Geschäftsprozessmodellierung” (Business Process Modelling); Chairman Markus Rabe, Member Joachim Hunker
- VDI Richtlinienausschuss (Guideline Committee) 3633.13 “Verifikation und Validierung” (Verification and Validation); Chairman Markus Rabe
- VDI-Richtlinienausschuss (Guideline Committee) 3633.3 „Experimentplanung” (Experiment Planning); Members Markus Rabe and Anne Antonia Scheidler

German Simulation Society (ASIM)

- Working Group “Simulation in Production und Logistics” (SPL); Deputy Chairman Markus Rabe
- Expert Group “Dedicated Conferences”; Chairman Markus Rabe
- Expert Group “Consideration of Energetic Impact Factors in SPL”; Member Markus Rabe

Conference Organization

- ASIM Dedicated Conference “Simulation in Produktion und Logistik”; Chairman Markus Rabe 1998, 2000, 2004, 2008, 2015
- ASIM Dedicated Conference “Simulation in Produktion und Logistik”; Program Committee Markus Rabe 1993-2023
- Winter Simulation Conference; Local Chair Markus Rabe 2012 (Berlin)
- Winter Simulation Conference; Lead Proceedings Chair Markus Rabe 2018; Proceedings Chair Markus Rabe 2019.
- Winter Simulation Conference; Track Chair Markus Rabe 2012, 2013, 2014, 2016–2023.

Board memberships

- Graduate School of Logistics; Board Member Markus Rabe

Journals

- Advisory Board Journal of Simulation (Taylor & Francis); Member Markus Rabe

Publications 2022

Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik - Festkolloquium September 2022. Göttingen: Cuvillier 2022.

Arora, S.-J.; Cecollini; C.; Rabe, M.: Approach to Reference Models for Building Performance Simulation. In: Pires, L.F.; Hammoudi, S.; Seidewitz, E. (eds.): Proceedings of the 10th International Conference on Model-Driven Engineering and Software Development (MODELSWARD) 2022. Virtual Conference, 6th-8th February 2022, pp. 271-278.

Christiansen-Lenger, S.P.; Rabe, M.: Literaturbasierte Untersuchung der Data-driven-Prozessmerkmale im Anwendungsfeld der Produktion. In: Proceedings 26. Symposium Simulationstechnik, Wien, 25th-27th July 2022, pp. 9-14.

Hochkamp, F.; Rabe. M.: Outlier detection in Data Mining: Exclusion of errors or loss of information? In Proceedings Hamburg International Conference of Logistics 2022, Hamburg, 20th-23rd September 2022, pp. 91-117.

Hunker, J.; Scheidler, A.-A.; Rabe, M.: A new data farming procedure model for a farming for mining method in logistics networks. In: Feng, B.; Pedrielli, G.; Peng Y.; Shashaani, S.; Song, E.; Corlu, C.G.; Lee, L.H.; Chew, E.P.; Roeder, T.; Lendermann, P. (eds.): Proceedings of the 2022 Winter Simulation Conference. IEEE: Piscataway 2022, pp. 1461-1472.

Langenbach, K.; Scheidler, A.-A.; Rabe, M.: Untersuchung der anwendungsspezifischen Verifikation- und Validierungstechniken unter Berücksichtigung einer veränderten Datenlage. In: Proceedings Kurzbeiträge ASIM Symposium Simulationstechnik, Wien, 25th-27th July 2022, pp. 81-84.

Rabe, M.; Kilic, E.: Concept of a business-process-related digital twin based on systems theory and operational excellence. In Proceedings 28th IEEE ICE/ITMC Conference, Nancy, 19th 23rd June 2022, pp. 233-241.

Stadler, F.; Rabe, M.; Modeling of Intralogistic Processes for the Implementation of Warehouse Management Systems. In: Pires, L.F.; Hammoudi, S.; Seidewitz, E. (eds.): Proceedings of the 10th International Conference on Model-Driven Engineering and Software Development (MODELSWARD) 2022. Virtual Conference, 6th-8th February 2022, pp. 271-278.

van der Valk, H.; Winkelmann, S.; Ramge, F.; Hunker, J.; Langenbach, K.; Rabe, M.: Characteristics of simulation. A Meta-Review of Modern Simulation Applications. In: Feng, B.; Pedrielli, G.; Peng Y.; Shashaani, S.; Song, E.; Corlu, C.G.; Lee, L.H.; Chew, E.P.; Roeder, T.; Lendermann, P. (eds.): Proceedings of the 2022 Winter Simulation Conference. IEEE, Piscataway 2022, pp. 2558-2569.

Wuttke, A.; Hunker, J.; Scheidler, A. A.; Rabe, M.: Synthetic Demand Generation with Seasonality for Data Mining on a Data-Farmed Data Basis of a Two-Echelon Supply Chain. Procedia Computer Science 204 (2022), pp. 226-234.

Arora, S.-J.: Referenzmodell zur Zuverlässigkeitsprognose von Heizsystemen basierend auf Test- und Felddaten. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 37-38.

Büttner, D.: Referenzmodell für die quantitative Absatzplanung innerhalb der Supply-Chain-Planung. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 41-42.

Christiansen-Lenger, S. P.: Echtzeitfähige datengetriebene Prozesse in Produktion und Logistik. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 35-36.

Hochkamp, F.: Mehrstufige Methode zur Wissensentdeckung in der Domäne der Produktion. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 33-34.

Hunker, J.: Farming for Mining: Simulationsbasierte Wissensentdeckung in Logistischen Assistenzsystemen für Werkstoffhandelsnetzwerke. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 19-20.

Jalali Sousanabady, R.: Methode für AutoML-basierte Lösung von Qualitätssicherungsaufgaben im Bereich diskreter Produktion. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 31-32.

Klima, T.: Analyse des Absatzes im Omni-Channel-Vertrieb durch mit Data Farming ergänzte Daten aus Synthese des Systemverhaltens. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 21-22.

Körsgen, H.: Integrierte Nachverfolgbarkeit – Einbindung in die Unternehmensarchitektur. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 25-26.

Sirovnik, E.: Methode für die Echtzeit-Prognose von Produktionskennzahlen zur multikriteriellen Maschinenbelegungsplanung für eine flexible Fließfertigung in der Stahlindustrie. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 27-28.

Sohny, T.: Effiziente Modellierung von Materialflusssystemen in der Angebotsphase durch ein Referenzmodell basierend auf der Wertstrommethode. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 39-41.

Stadler, F.: Modellierungsmethodik für intralogistische Prozesse zur Einführung von Warehouse-Management-Systemen. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik – Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 23-24.

Vent, W.: Gestaltungsmethodik für agile Produktionsnetzwerke auf Basis von Simulation und Machine Learning. In: Rabe, M.; Scheidler, A.-A. (eds.): Drei Dutzend Jahre Simulationstechnik - Festkolloquium September 2022. Göttingen: Cuvillier 2022, pp. 29-30.

A complete list of our publications is available at www.itpl.mb.tu-dortmund.de/rabe/?lang=en&page=publica.

Theses and Scientific Project Works 2022

Elter, F.: Data Mining: Identifizierung und regressionsbasierte Modellierung von Wirkzusammenhängen zwischen Prozessparametern bei der Herstellung von Edelstahllangprodukten am Beispiel der Deutschen Edelstahlwerke Specialty Steel GmbH & Co. KG. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Henn, E.: Entwicklung einer Monitoringumgebung zur Sorptionsberechnung von Polyamid 6 Probekörpern. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Klein, T.: Systematisierung von Data-Mining-Verfahren in Klassifikatoren und deren prototypische Implementierung und Validierung in RapidMiner. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Klöcker, S. B.: Entscheidungsbaumgestützte Auswahl von Data-Mining-Verfahren im produktionslogistischen Umfeld. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Kuhlmann, L.: Model selection of clustering and classification problems in production and logistics. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Langenbach, K.: Untersuchung der Automatisierbarkeit von Verifikations- und Validierungstechniken anhand von Kriterien in der Simulationsdomäne. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Lehmkemper, A.-L.: Data Farming in Logistiknetzwerken des Handels – Konzeption und Umsetzung einer Data Farming Studie in einem Farming-for-Mining-Framework. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Willerscheid, J.: Validierung, Erweiterung und automatisierte Adaption eines Prozessmodells für Kaltwalzanlagen. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Wuttke, A.: Entwicklung eines graphbasierten Simulators zur Simulation von Logistiknetzwerken in einem Data-Farming-Framework. TU Dortmund University, Department IT in Production and Logistics, master thesis, 2022.

Acar, A.: Kategorisierung der Ausreißerbehandlung in der Produktion mittels umfassender Literaturrecherche. TU Dortmund University, Department IT in Production and Logistics, bachelor thesis, 2022.

Biallas, F. R.: Konzeptionierung eines Datenanalysetools für die Optimierung von Heizungsanlagen. TU Dortmund University, Department IT in Production and Logistics, bachelor thesis, 2022.

Biallas, F. R.: Analyse unterschiedlicher Funkstandards des Smart Home Sektors für den Einsatz in vernetzten Einzelraumregelungen. TU Dortmund University, Department IT in Production and Logistics, project thesis, 2022.

All our ITPL student theses can be downloaded from our homepage.

Contact

Univ.-Prof. Dr.-Ing. Markus Rabe

Phone: +49 231 755-8020
Fax: +49 231 755- 8022
Mail: markus.rabe@tu-dortmund.de
Web: www.itpl.mb.tu-dortmund.de

Technische Universität Dortmund
Fakultät Maschinenbau
FG IT in Produktion und Logistik
Leonhard-Euler-Str. 5
44227 Dortmund