AI everywhere – Generative AI for production and business operations

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Introduction

Motivation and objective

The rapid development and spread of Generative Artificial Intelligence (AI) in recent years has the potential to profoundly transform various areas of business and manufacturing [55]. From the automation of creative processes to the optimization of industrial production workflows - the potential applications are diverse and promising. Nevertheless, due to the novelty of the technology and the diversity of AI-generated modalities, the potential for the industry is often difficult to grasp. In order to realize the potential of Generative AI by increasing the effectiveness and efficiency of processes through the automated generation of content, this study aims to provide companies with an introduction to the world of Generative AI and its use cases in industry.

The complete results of this study were made available to ICNAP members in an interactive web application (Figure 19). It is integrated into the ICNAP Explorer [56], an interactive website to explore the projects of ICNAP. In addition to the use cases of Generative AI in an industrial context, structured by application area, the website also provides information on the various modalities of Generative AI, available tools and the technical background. Furthermore, detailed information is provided on specific use cases that ICNAP members consider to be particularly relevant. The web application is aimed both at users who are AI beginners and want to gain an impression of this technology and its potential, as well as at technology experts who are interested in implementing specific Generative AI use cases.

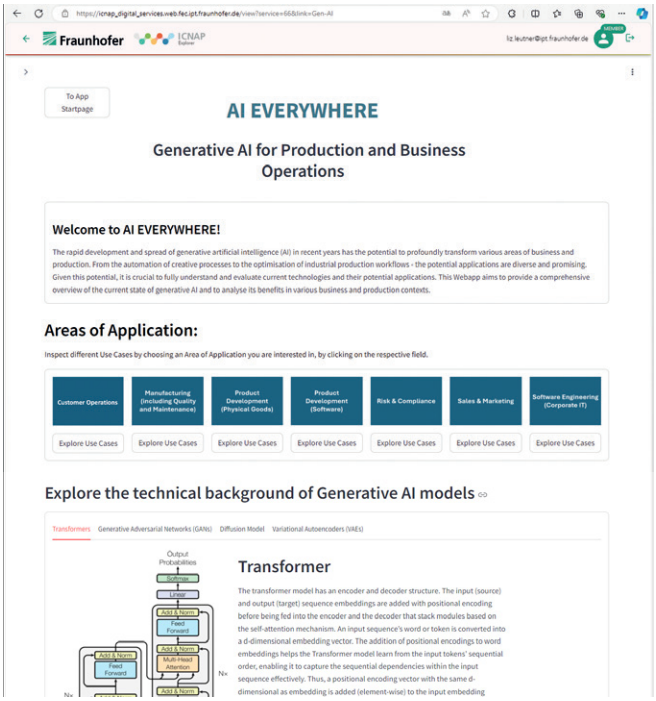

Figure 19: Excerpt from the web application for the interactive provision of information on use cases of Generative AI in an industrial context, including modalities and technical backgrounds.

This report starts with a definition and brief technical introduction to Generative AI. It lists the modalities and application areas and describes corresponding examples of use cases in the various areas. A framework for the development of Generative AI applications will then be presented before the report draws a conclusion.

Definition of Generative Artificial Intelligence

Generative Artificial Intelligence (GenAI) describes a class of computational techniques that are able to generate seemingly new and meaningful content such as text, images or audio from training data [57]. This technology is currently revolutionizing the way we work and communicate, with examples such as DALL-E 2 [58], GPT-4 [59] and the Siemens Industrial Copilot [60].

The main models of Generative AI include different architectures like Generative Adversarial Networks (GANs) [61], Transformer models [62] and Variational Autoencoders (VAEs) [63].

The models are designed for different modalities and tasks. The training of the models is elementary and is carried out using data, through which the model learns how to generate corresponding new data. For example, the GPT (Generative Pre-trained Transformer) models are used to generate text [64]. During training, huge amounts of text data are used, whereby the model learns structures and contexts of language. To achieve this, these models require an extremely high number of parameters. For example, GPT-3 from OpenAI [65] has 175 billion parameters and was trained with a filtered Common Crawl dataset [66], a version of the WebText dataset (expanded) [67], two books corpora and Wikipedia [65].

Modalities and areas of application of GenAI

The modalities of GenAI are diverse and include the generation of text, images, videos, music and even complex code [57]. However, we have additionally emphasized and differentiated modalities such as processes and CAD/3D models, as these are particularly relevant for business and production applications.

After an initial, broad research on use cases of Generative AI, we examined meta-analyses that list application areas of GenAI for the industry and evaluate them in terms of their relevance and potential [68]-[70]. Based on the insights gained, we decided on the following areas of application and assessed their relevance for the ICNAP members in order to be able to set priorities for the subsequent identification of corresponding use cases (Figure 20):

In the following section, exemplary use cases are presented for each application area in order to provide an impression of the diversity and potential of the use of Generative AI in the context of production and business operations.

Figure 20: Overview of the application areas of GenAI for production and business operations for which use cases were identified as part of this study.

Selection of use cases

GenAI has shown high potential for transforming customer interactions in various business areas. A selection of exemplary use cases of Generative AI from the previously introduced application areas is presented below. First, use cases of GenAI for customer operations are considered.

Chatbots for personalized customer support in real-time
One important application is the use of GenAI-enabled virtual agents like chatbots [71], [72]. These agents are designed to improve customer interaction by providing personalized support in real time. By using advanced natural language processing (NLP) and speech-to-text technologies, these virtual agents can mimic human-like qualities such as empathy and personalized communication, which are crucial for building trust and relationships with customers. This technology not only speeds up the response to customer queries, but also enables human agents to focus on more complex and differentiated issues, optimizing the allocation of resources within customer support.

Generation of research-based reports of customer data
Another important application of GenAI in customer operations is the creation of research-based reports on customer data. During the onboarding process, GenAI can be used to create comprehensive reports that provide valuable insights for decision-making [73], [74]. By automating the analysis and synthesis of large volumes of customer data, this application reduces the time spent on manual research, and improves the accuracy and relevance of the information provided to employees. This leads to more informed decisions and better management of customer relationships.

Voice assistants for a high-quality customer experience
In addition, GenAI is integrated into customer support through AI-powered voice assistants [72]. These assistants are able to process customer requests quickly and in accordance with company guidelines, thus maintaining or even increasing customer satisfaction. GenAI's ability to quickly process and respond to customer inquiries not only improves the efficiency of customer support, but also ensures a consistent and high-quality customer experience.

Software engineering (corporate IT)

GenAI becomes increasingly important in software engineering, especially in corporate IT. It can be used to improve various stages of software development, making processes faster, more accurate, and more innovative. Use cases of this application area are described below.

Data management (analysis, cleaning, and labeling of large amounts of data)
One of the primary areas where GenAI is making a difference is in data management [70], [74]. By automating the analysis, cleaning, and labeling of large amounts of data (such as user feedback and system logs) GenAI helps to process data more efficiently and accurately. This capability transforms raw data into valuable insights that supports the decision-making process and leads to more reliable software development.

Support in the design of IT architectures
GenAI is also transforming the way IT architecture is designed [75], [76]. Typically, creating IT systems is a complex process that involves exploring different configurations to meet requirements like performance and security. GenAI speeds up this process by allowing engineers to quickly generate and test multiple design options. This reduces the time needed to develop systems and improves overall design quality, enabling companies to respond more quickly to changes in technology and business needs.

Generation of test cases and data to ensure the robustness of IT systems
Additionally, GenAI is improving quality assurance in software development [74]. It automates the creation of test cases and data, making it easier to perform thorough testing, especially in stress scenarios where systems need to be tested under heavy load. This ensures that IT systems are more reliable and less prone to failures.

Product development (software)

GenAI also plays a crucial role in enhancing the software product development process. Next, some typical use cases in this area of application are presented:

Automating routine coding tasks
GenAI enhances the efficiency and consistency of software development [74]. By assisting developers in creating and maintaining multiple applications and platforms, GenAI streamlines the development process. It automates routine coding tasks, provides useful suggestions by generating code snippets, and serves as a resource for finding information quickly. This allows developers to concentrate on more complex and creative aspects of product development which leads to faster development cycles and more consistent quality across different software products.

Generation of test cases and data to ensure the functionality of software
In the area of quality assurance, GenAI is transforming traditional testing processes [74]. It automates the generation of test cases and test data, making functional and performance testing more efficient and comprehensive. This automates the time-consuming manual generation of tests to check extensive code and can increase test coverage and quality. The use of GenAI in quality assurance helps in identifying potential issues early, reducing the risk of post-launch failures.

Content creation
Finally, GenAI is revolutionizing content creation within software development [70], [74]. By integrating GenAI tools into content management and creation processes, it minimizes the need for manual editing and optimizes the management of large volumes of content. This is especially useful for tasks like editing videos and images, where efficiency and accuracy are critical. GenAI enables content creators to meet tight deadlines with high-quality outputs, ultimately enhancing the overall product development lifecycle.

Product development (physical goods)

In the previous section the development of software products was considered. Some use cases of Generative AI for the development of physical goods are listed here:

Supporting virtual simulation processes
Virtual simulations are another area where GenAI is having a transformative impact [70]. By integrating generative deep learning design techniques, GenAI significantly improves the efficiency, accuracy and innovation of simulation processes. These advanced simulations enable companies to test and refine product designs in a virtual environment, reducing the need for costly physical prototypes and accelerating the development cycle.

Proposing designs and materials for products
In materials science, GenAI enables designers to explore a wider design space and optimize material properties more effectively. The process of discovering and developing new materials is inherently complex and time-consuming, but GenAI accelerates this process by identifying the most promising methods for optimizing materials and reducing the number of experiments required. This results in faster development of innovative materials with optimised properties, which ultimately improves product performance.

Efficient introduction of new products by automating the generation of documents
In addition, GenAI streamlines new product inventory management by automatically creating descriptions based on existing inventory data or user-provided information [76]. This automation can be seamlessly integrated with enterprise resource planning systems such as SAP, Oracle or Microsoft Dynamics, ensuring that product metadata is accurately and efficiently managed. This feature not only improves inventory management, but also increases the overall efficiency of product lifecycle management.

Manufacturing (including quality and maintenance)

GenAI is fundamentally changing the manufacturing industry, particularly in the areas of quality, maintenance and operational efficiency. Its applications range from improving decision-making and streamlining troubleshooting processes to optimizing production and inventory management. Examples of the use of GenAI in the field of manufacturing are described here. This application area was considered particularly relevant by the ICNAP members.

Virtual field assistance / customized chatbots to provide real-time support
One important use case is the integration of GenAI-enabled virtual field assistants into technical workflows [72], [74]. These virtual assistants increase operational efficiency by providing real-time support and improving decision-making processes on the factory floor. This application is particularly valuable in complex industrial environments where fast and accurate decision-making is crucial.GenAI is also being used to streamline information gathering in production environments, particularly in companies that have grown through mergers and acquisitions [70], [74]. The resulting fragmentation of systems and processes can make it difficult to quickly access the information needed. AI-powered bots solve this challenge by enabling faster and more accurate information retrieval, thus increasing employee productivity and reducing downtime.

Support in system diagnostics
AI plays a crucial role in system diagnostics and maintenance by analysing system logs, user feedback and performance data [70], [74]. This analysis helps engineers to diagnose problems, suggest solutions and predict areas that need improvement, ultimately increasing the efficiency and effectiveness of maintenance work.

Improvement of asset maintenance planning
Generative AI also improves asset maintenance planning [77]. By integrating AI into maintenance strategies, companies can increase asset availability, reduce costs and improve operational efficiency. This application is particularly beneficial in industries such as mining and oil and gas, where effective maintenance is critical to avoiding costly downtime and repairs.

Sales and marketing

Generative AI has a high impact on sales and marketing, as it improves the way companies gather market knowledge, create content and plan promotions. Next, some use cases of GenAI in the application area sales and marketing are described:

Identifying market trends by analyzing data
A key area of application for GenAI is analyzing large volumes of unstructured data, such as social media posts, news articles, research reports and customer feedback [73]. By processing this information, GenAI helps sales and marketing teams to better understand market trends and customer needs. This enables more targeted and effective communication with customers and helps companies to reach the right audience with the right message.

GenAI is also changing the way companies plan and execute trade promotions, particularly in the consumer goods sector [74]. It helps companies analyze data quickly, predict outcomes and adjust their strategies, making the promotion process more efficient and increasing the chances of success when negotiating with retailers.

Content creation: generate marketing materials
When it comes to content creation, GenAI helps to produce consistent and personalized marketing materials, whether they are product descriptions, images, videos or audio [74]. This helps companies maintain a consistent brand message across different platforms and ensures that content is optimized for specific purposes, such as improving search engine placement or creating effective email campaigns. In addition, GenAI helps companies create marketing materials that comply with regional regulations and cultural norms [74]. This is particularly useful for companies operating in multiple countries to ensure that their marketing efforts are both effective and compliant.

Support efficient marketing management across large and diverse product portfolios
Finally, GenAI supports the efficient management of marketing content across large and diverse product portfolios [78]. It enables companies to quickly create and update content in multiple languages to ensure consistency and a unified brand experience for customers around the world.

Risk and compliance

Generative AI plays an important role in improving risk management and compliance in various industries, particularly in areas such as intellectual property protection, workplace safety and internal control.

Finally, examples of GenAI use cases in the area of risk and compliance are described.

Automating the analysis of patents
In the manufacturing industry, protecting intellectual property (IP) is crucial, but often challenging due to complex patent portfolios and evolving legal frameworks. GenAI helps by automating the analysis of patents, simplifying legal processes and strengthening IP protection strategies [79]. This allows companies to navigate the complex legal landscape more efficiently and maintain solid protection for their innovations.

Ensuring compliance with regulations through monitoring
Safety in the workplace is another area where AI is making a significant contribution [74]. AI systems can monitor and enforce safety protocols in real time, ensuring compliance with regulations such as social distancing and the use of personal protective equipment (PPE). By analyzing historical safety data, GenAI can identify potential risks and enable proactive measures to prevent accidents. This continuous monitoring helps companies maintain a safe working environment and avoid regulatory fines.

Identifying risks through processing large amounts of data
GenAI also strengthens internal controls and corporate governance [74]. By analyzing large data sets in real time, GenAI can identify anomalies and potential risks that could indicate fraud or non-compliance. This improves transparency and accountability within organizations and supports more effective decision-making. AI-driven systems can also adapt to emerging risks, ensuring that governance frameworks evolve in line with changing business and regulatory environments.

Deep dives

To explore specific use cases in greater detail, deep dives were conducted into three distinct areas, focusing on the foundational aspects of each application, the technical solutions involved, and their practical implementation. The objective was to gain a comprehensive understanding of potential solutions and to provide a clear overview of the current state of development in these areas. The selected deep dives are for the use cases Quality Control in Manufacturing, Process Mining with LLMs and Industrial chatbots and are accessible to ICNAP members. The same applies to the entire overview of all identified use cases.

To support the realization of these use cases, the next section introduces the most important steps in the development of corresponding GenAI applications.

Framework for implementing GenAI applications

In this chapter, a framework that summarizes the implementation of GenAI for various use cases is presented (Figure 21). It outlines a systematic approach to the development, deployment and maintenance of GenAI models that ensures that they are both effective and consistent with best practices in data handling and model training [80]. While there are specific approaches for specific models and use cases of GenerativeAI, the following framework is a general guideline to support first implementations [81].

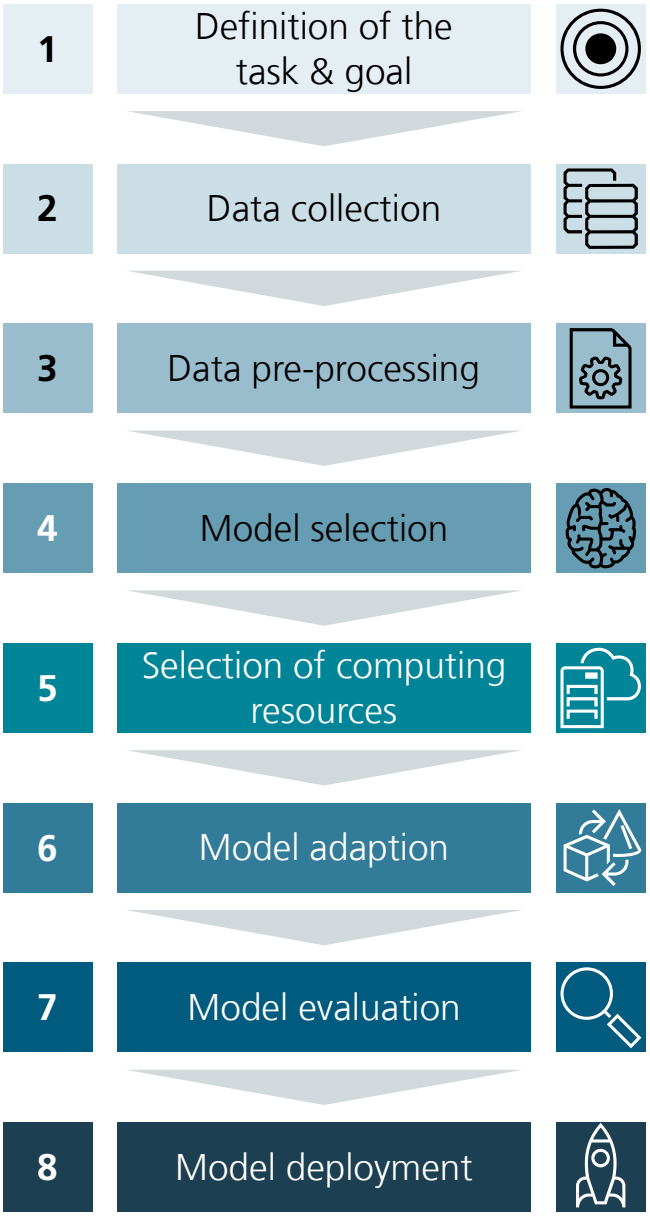

Figure 21: Framework for the development of Generative AI applications. It can serve as a general guideline for initial developments.

Definition of the task & goal
The process begins with problem definition and goal setting , where the specific challenge or need is identified. This includes determining the appropriate output modality (e.g. text or image) and considering key requirements such as language, resolution and style. Understanding the capabilities and limitations of the model is critical at this stage, as it helps to define the quantitative evaluation metrics that will guide the model's performance assessment [80], [81].

Data collection
Data collection then takes place to gather the necessary information from reliable sources such as databases, web scraping or APIs [82]. Ensuring data quality and diversity is crucial, as is compliance with legal and ethical standards, especially when dealing with copyrighted or sensitive information. Data protection laws must be observed, and data should be stored securely, with encryption and appropriate anonymization [80], [83].

Data pre-processing
The collected data is then pre-processed, where it is cleaned to remove inconsistencies, normalized to ensure consistent scales, and augmented to increase the robustness of the dataset. Accurate labelling is essential for supervised learning tasks, and the data is split into training, validation and test sets to support effective model development [80].

Model selection
At the same time, a foundation model is selected based on the specific task, the compatibility of the dataset and the computational requirements. Popular models such as GPT-4, LLaMA or Google Gemini are considered, paying attention to their transfer learning capabilities and community support to ensure that they meet the project's requirements [81], [84].

Selection of computing resources
In parallel, the selection of hardware or cloud service is crucial to meet the model's requirements in terms of computing power, memory and storage. The choice of hardware – whether CPUs, GPUs or TPUs – depends on the complexity of the model, while cloud services from providers such as AWS, GCP or Azure are evaluated for cost efficiency, scalability and compatibility with machine learning tools [80].

Model adaption
Next, the model undergoes training, fine-tuning and retrieval augmented generation (RAG). In this phase, the weights and parameters of the model are adapted to the respective tasks, with regularization techniques being used to prevent overfitting [85]. RAG is implemented to improve the generative results by retrieving relevant information and integrating it into the model's responses to provide richer, contextually informed responses [80].

Model evaluation
This is followed by the evaluation phase, where metrics such as FID, BLEU and ROUGE are used to assess the performance of the model [85]. Validation and test sets are crucial here for fine-tuning the hyperparameters and ensuring good generalisation of the model. In addition, qualitative analysis helps to identify and correct biases or errors, and feedback loops are set up for ongoing refinement and monitoring of data deviation [83].

Model deployment
Finally, the model is deployed to ensure that it is operational in a real-world environment. This includes setting up the necessary hardware infrastructure, using containerisation tools such as Docker and orchestration systems such as Kubernetes for consistent deployment [86]. The model is integrated with APIs for application access, and ongoing monitoring ensures that key performance indicators are met, ethical considerations are taken into account and security measures are in place to protect the deployment infrastructure.

This framework provides a comprehensive overview of the key steps in implementing GenAI applications and offers a structured approach to ensure that these models are used in a way that is both effective and efficient in a range of use cases [80]. The framework is not exclusively intended to support the development of industrial GenKI applications but can also be used in this area to optimize the development of corresponding applications for the optimization of processes from production and business operations. It is particularly suitable for supporting the development of proof-of-concepts or prototypes for a specific use case that is relevant for an enterprise in order to gain an impression of the suitability of GenAI for fulfilling the specific requirements of the company and the task.

Conclusion

This study provides an introduction to the world of Generative AI in the field of production and business operations. Technical backgrounds were described and structured use cases were introduced in various areas. A framework for the implementation of Generative AI applications was also presented. This helps companies to gain an impression of the potential of this new technology and to identify and implement relevant use cases according to their own requirements.

Nevertheless, the challenges of using GenAI in industrial contexts must also be considered. These include the lack of explainability and transparency of model outputs, the production of false information (hallucination) by language models, the high computing capacity often required and the lack of availability of high-quality data and data sources in an industrial context, as well as unresolved issues relating to data security [41], [87], [88]. Future research must address these challenges in order to support the industrial use of GenAI.

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