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*** R:** Document, report (excluding the periodic and final reports)
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc.

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EXECUTIVE SUMMARY

This deliverable "Enabling Technologies for Smart Logistics" gives an overview to the most relevant digital technologies used in logistics in general. According to the grant agreement and its description of action the deliverable is a publication *describing the most important digital technologies for smart logistics*[1].

The deliverable is part of the activities in Task 2.1 *Collecting and summarizing relevant up-to-date knowledge on digital technologies for logistics*. This task is divided into two parts. The first part is a literature review which resulted in this deliverable as overview to the most relevant digital technologies in logistics. It will be followed by deliverable 2.2 "Agenda and outline of online mentoring sessions" which is the agenda and the outline of online mentoring sessions which will be conducted via the DIGILOGIC elearning portal as live sessions. The second part of task 2.1 was dedicated to interviews and discussions with experts on smart logistics which will lead to task 2.2 *facilitating ongoing logistics trend radar activities to map relevant digital technologies and industries' needs.* This task will result in the publication of deliverable 2.4, a trend radar on smart logistics both in Africa and Europe in month 30. An accompanying result of task 2.1 and 2.2 is the sequel of live sessions dedicated to smart logistics in Africa which first edition took place within the International Physical Internet Conference IPIC 2021[2] on June 15th[3].

This deliverable introduces in Chapter 1 the relation between digital technologies and logistics and supply chain operations, describes in Chapter 2 "Relevant Digital Technologies for Logistics" and their impact on logistics and supply chain management and mentions potential use cases, gives in Chapter 3 a summarizing description of artificial intelligence technologies and finally discusses in Chapter 4 the potential to improve logistics and related challenges.

[1] GRANT AGREEMENT NUMBER 101016583 — DIGILOGIC, Annex 1, Part A, page 14.

[2] See https://www.pi.events/IPIC2021/

[3] Live session available at https://digilogic.africa/digitising_logistics_in_africa/

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1 INTRODUCTION

1.1 OBJECTIVE

According to the grant agreement and its description of action, this deliverable is a publication *describing the most important digital technologies for smart logistics*[4]. For DIGILOGIC this deliverable "Enabling Technologies for Smart Logistics" is of importance as it provides an overview of the most relevant digital technologies used in logistics in general, and marks a starting point for discussions, live sessions, workshops and mentoring sessions maintained in work package 2, especially task 2.1 and 2.2.

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1.2 BACKGROUND AND CONTEXT

Increasing technology innovations are making big waves across industries, and logistics and the supply chain may be one of the most impacted sectors. Great attention has been given to big data, robotics, artificial intelligence (AI), computer science, and other digital technologies (ALICE 2015; Mosterman and Zander 2016; Khorram et al. 2017).

The Alliance for Logistics Innovation through collaboration in Europe ALICE - the European Technology Platform for the logistics industry officially recognised by the European Commission - published its roadmaps on five future challenges in 2014, already, and its roadmap to the Physical Internet 2030-2040[7], describing major challenges and technologies impact in global logistics and supply chains.

Digital technologies are changing manufacturing, trade, process industries and logistics and distribution processes and thus the related industrial sectors. Some recent summaries and analysis have been published to describe their application regarding the logistics and supply chain level focusing on (a) the link between Industry 4.0 and lean production (Buer et al. 2018); (b) the importance of internet of things (IoT) on logistics and supply chain (SC) management; (c) the impact of 3D printing on logistics processes and performances (Liu et al. 2014; Oettmeier and Hofmann 2016; Li et al. 2017); and, (d) the change in short-term logistics and supply chain scheduling in smart factories (Ivanov et al. 2016).

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[4] GRANT AGREEMENT NUMBER 101016583 — DIGILOGIC, Annex 1, Part A, page 14.
[5] See https://www.pi.events/IPIC2021/
[6] Live session available at https://digilogic.africa/digitising_logistics_in_africa/.
[7] See https://www.etp-logistics.eu/about-alice/documents-publications/.

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A comprehensive overview and methodological approach to map enabling technologies and describe their impact on logistics and supply chain has been recently published by the Horizon 2020 Coordination and Support Action *Mapping a path to future supply chains* "Next Net"[8]. In order to identify enabling technologies, the project analysed existing roadmaps and studies at different levels (regional, national, international and sector-specific). Nearly 400 technology and sector studies and roadmaps were reviewed, including scientific papers, reports and grey literature, with the intent of identifying enabling technologies for supply chains and smart logistics. Moreover, more than 60 current projects were taken into account considering the main EU programs, such as SPIRE—Sustainable Process Industry through Resource and Energy Efficiency (SPIRE 2020) and FOF—Factories of the Future (EFFRA 2020), TRANSPORT (European Commission 2020b) and ICT (European Commission 2020a) as well as other related programs, such as Interreg (Interreg Europe 2020) and Regional Funds. Over 60 technologies were identified in this first step of the technology scouting (Stute, Sardesai, Parlings, Senna, Fornasiero and Balech 2020).

According to the grant agreement and its description of action, this deliverable is a publication *describing the most important digital technologies for smart logistics*[9]. For DIGILOGIC this deliverable "Enabling Technologies for Smart Logistics" is of importance as it provides an overview of the most relevant digital technologies used in logistics in general, and marks a starting point for discussions, live sessions, workshops and mentoring sessions maintained in work package 2, especially task 2.1 and 2.2.

The deliverable is part of the activities in Task 2.1 *Collecting and summarizing relevant up-to-date knowledge on digital technologies for logistics*. This task is divided into two parts. The first part is a literature review which resulted in this deliverable as overview to the most relevant digital technologies in logistics. It will be followed by deliverable 2.2 which is the agenda and the outline of online mentoring sessions which will be conducted via the DIGILOGIC elearning portal as live sessions. The second part of task 2.1 is dedicated to interviews and discussions with experts on smart logistics which will lead to task 2.2 *facilitating ongoing logistics trend radar activities to map relevant digital technologies and industries' needs.* This task will result in the publication of deliverable 2.4, a trend radar on smart logistics both in Africa and Europe in month 30 of the DIGLOGIC project. An accompanying result of task 2.1 and 2.2 is the sequel of live sessions dedicated to smart logistics in Africa which first edition took place within the International Physical Internet Conference IPIC 2021[10] on June 15th, 2021[11].

According to current literature the provided technologies will have a huge impact on future logistics operations. The following sections will therefore give an overview of technologies and possible logistics use cases.

The question of whether these technologies are also relevant in Africa and what significance they have for current and future smart logistics in Africa will be explored in the upcoming activities of work package 2 and will be summarized and discussed in deliverable 2.4, the trend radar. In this respect, this overview of deliverable 2.1 should be understood in combination with the trend radar.

[8] See https://cordis.europa.eu/project/id/768884/de and https://nextnetproject.eu/.
[9] GRANT AGREEMENT NUMBER 101016583 — DIGILOGIC, Annex 1, Part A, page 14.
[10] See https://www.pi.events/IPIC2021/
[11] Live session available at https://digilogic.africa/digitising_logistics_in_africa/.

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2 RELEVANT DIGITAL TECHNOLOGIES FOR LOGISTICS

2.1 SECURE DATA EXCHANGE AND DATA SOVEREIGNTY

While the EU General Data Protection Regulation GDPR grants individuals the right to decide what data collectors are allowed to do with their personal data and what not, data spaces will provide the tools to exert these rights and stay in control over that data. However, European data spaces will not do so for individuals only, but also for companies/organisations and their data. Driven by sector-specific needs, data spaces will promote the development of tools to share, exchange and access all types of data, including data that is stored in smart objects and things. These tools will empower those entitled to the data to demand transparency as to where their data is stored and what access rights apply to it. They can use these tools to give or revoke their consent and to change access rights and specify new conditions of how their data can be accessed and used. Furthermore, they can choose to outsource data rights management to third parties (e.g. data intermediaries), just like users (individuals and organisations) today outsource the management of their financial balances to financial institutions (i.e. think investment profiles).

This future scenario highlights the notion of data sovereignty tools as enabling technologies for data spaces and a sovereign data sharing to be built on. Data sovereignty is the ability of a person or a corporate entity (=organisation or company) for exclusive self-determination with regard to its economic data goods (Otto 2017). This is the innovative and transformative concept underlying data spaces.

With regard to such data sovereignty tools, a nice analogy can be drawn with how users today control information about their bank accounts (balance) through their electronic payment cards. Every time a shopper uses their card for payment, there is a data-sharing transaction taking place. The card functions as an instrument to 'prove' to the merchant that the shopper's bank account holds enough balance to buy the goods. With each transaction, the card together with the PIN code acts as a data sovereignty tool for the user, through which a tiny piece of information ('enough balance: yes or no?') is shared by the shopper's bank with the bank of the merchant via electronic data systems.

The ecosystems of the actors involved in the process are kept together by a soft infrastructure consisting of rules and agreements of legal, functional, technical and operational nature. Similar to how we have learned to pay with these cards, new functions of sharing and exchanging data will arise from using data spaces and be adopted by users on a large scale. By regaining control over their data, and as data becomes portable between providers on a user-controlled consent basis. Users can switch between providers without losing their data and vendor lock-in will become a phenomenon of the past (International Data Spaces Association 2021).

Possible logistics use case

Through secure data exchange and data sovereignty several logistics applications can be realised. The transparency in supply chains can be raised, by continuously exchanging data on the location and status of objects in logistics networks. This can help to get higher efficiency and better utilisation of assets throughout value networks.

Additionally, the joint collaborative planning (of transports and production capacities) can be realised more easily by sharing data in a secure and sovereign way across several companies.

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2.2 INTERNET OF THINGS

The internet of things plays a big role in enabling technologies. The idea of devices equipped with sensors and actuators connected to the internet is reality in a lot of domains, like smart home solutions. Smart and connected devices have become cheaper and more reliable during the last years. Low-power hardware enables runtimes for several years, next-generation wireless networks enable world-wide connectivity.

The internet of things comprises the autonomous collection and exchange of data from a network of physical devices embedded with sensors, software, network connectivity, and computer capability (PwC 2017). Especially for the manufacturing and logistics sectors, there is broad applicability of IoT. IoT enables easier and faster collection and processing of data to monitor critical parameters. Connected systems will lead to more agility and transparency in the supply chain (Moser 2015; Prasse et al. 2014). Enabling better decision making and process optimisation, the IoT will reduce costs and result in more efficient use of resources (Prasse et al. 2014).

Possible logistics use case

The tracking and tracing of transports or the condition monitoring of goods are IoT-enabled logistics use cases. Smart devices can be transported along the supply chain and give real-time information about the location, status and environmental conditions. This information can be used for pooling and instant reconfiguration of transports.

2.3 BIG DATA ANALYTICS

The analysis of large sets of (unstructured) data and the automated extraction of information is the goal of big data analytics or data sciences as such. It can be defined as the application of quantitative and qualitative methods to solve relevant problems and predict outcomes using algorithms aimed at creating or extracting new information out of vast amounts of data (Cao 2017). The technology will have broad applicability over the industrial sectors. With large amounts of data available and the ability and willingness to share them efficiently, there will be an improvement of agility and process transparency in supply chains. Costs will be affected positively by more accurate forecasting and the prevention of disruptions (Wang et al. 2016). On the other hand, costs will be affected slightly negatively due to the need to collect and store the data. The negative effects will swiftly decrease as technology advances (McAfee and Brynjolfsson 2012).

Possible logistics use case

Big data analytics is often used in automated analysis and optimisation of logistics processes within supply networks.

2.4 3D PRINTING

3D printing or additive manufacturing (AM) offers a higher rate of customisation and reduces waste in comparison to traditional manufacturing processes. The manufacturing of parts, components or even whole products can be done on-demand without the need of doing complex and expensive reconfigurations. Today the use of 3D printed parts is limited and costs are often higher compared to mass-produced parts.

3D printing or additive manufacturing is a technology enabling the creation of lighter, stronger parts and systems through transformative approaches to industrial production. It is considered a genuinely disruptive technology that supports customisation while minimising waste due to more efficient use of resources (Boon and van Wee 2017). With these characteristics, AM is also seen as a critical technology for the development and improvement of future supply chains with a focus on manufacturing and the logistics industry.

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Possible logistics use case

For logistics, 3D printing can offer a variety of new use cases, like local on-demand production in warehouses or distribution centres instead of transporting and storing them. Logistic service providers will play a bigger role in the management and composition of manufacturing networks.

Manufacturing can become more regional and move closer to the final markets. This will also have an effect on existing routes and strategies but will offer new opportunities for the supply of printing materials.

2.5 AUTONOMOUS OPERATIONS AND ROBOTICS

The fully autonomous operation of physical systems based on robots, smart devices and transport can become reality in the next years. The step from automated and therefore inflexible systems to autonomous, self-configuring systems can already be seen in some areas. Robots learning how to handle parts and goods or swarm-based transport systems finding the best way from source to sink are just some examples.

Comprising the sub-technologies of autonomous vehicles (e.g., trucks, trains and ships) and drones, the technology has broad applicability across all industrial sectors. Autonomous transport systems will create opportunities to reduce costs and increase reliability and sustainability by improving resource efficiency due to emissions reductions, fuel efficient driving, improvement of traffic and most likely fewer accidents (Heard et al. 2018; Bugdahn 2017; Chung et al. 2018). Furthermore, the technology will lead to more agility due to easily reconfigurable systems and to increased transparency due to better communication in real-time between and within the systems (Nowak et al. 2016).

Robots with their superior sensor technology, control and intelligence, especially in combination with artificial intelligence, have the ability to automate or support human activities and thus have a strong influence on the labour market (Wisskirchen et al. 2017). Main sub-technologies for robots include collaborative robots, which physically interact with humans in shared environments, and autonomous robots, designed for self-reliance and being capable of operating without human assistance or interaction (Djuric et al. 2016). Robots have broad applicability especially in the manufacturing and logistics sector with positive implications on agility and costs (DHL Customer Solutions and Innovation 2016).

Possible logistics use case

In logistics autonomous operations are especially interesting for warehouses, distribution centres and manufacturing sites. A higher flexibility and scalability will make the use of autonomous systems more interesting. A typical use case can be the autonomous loading and unloading of trucks and consolidation of new loads at the same time.

2.6 DIGITAL TWINS

A digital twin is virtual model of one or more entities (the “system”) of the real world used for various decision-making tasks. Examples of these entities are individual machines, production facilities, a warehouse, a plant or even a whole supply chain. The digital twin simulates both the physical state and behaviour of these entities and is connected with some or all entities it is modelling. This connection is used to gather input data (e.g., state of machines and transactional data) for the models as well as to transmit commands to the entities (e.g., a production schedule, load list, pick orders). Furthermore, digital twins visualise the current state of the entities it is modelling and provide functions for analysing the current state. Moreover, digital twins provide means to simulate the effects of future system changes to the system (e.g., new customer demands, changes in the availability of resources, disruptive events) and different actions to be considered. Hence, digital twins can be used to support decision-making with the simulation of “what if scenarios”.

Possible logistics use case

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Due to its broad nature a digital twin can be developed and applied for plethora of tasks. The DHL Trend radar gives the following examples[12]:

- Digital Twins for packaging
- Digital Twins for shipments
- Digital Twins of Warehouses and Distribution Centres
- Digital Twins of Logistics Infrastructure (ports, airports, rail stations, terminals)
- Digital twins of Logistics Networks

2.7 DISTRIBUTED LEDGER TECHNOLOGIES (DLT)

DLT solutions and especially blockchain enable distributed data storage which is resistant to modifications. The decentralised character of blockchain technology ensures high reliability, enables non-restrictive data transparency throughout the entire supply chain, and allows standardised and transparent business processes (Liang et al. 2017; Jakob et al. 2018). By reducing settlement time as the need for intermediaries is eliminated, and due to the increased and faster sharing of information and the instant access to data, this technology will improve the agility and responsiveness of supply chains across all sectors (Dieterich et al. 2017; Jakob et al. 2018). Combined with IoT, this technology is critical for the development of future supply chains, especially in the logistics sector.

Possible logistics use case

Distributed ledger technologies are used widely in smart contracting and payment use cases.

2.8 AUGMENTED & VIRTUAL REALITY

Augmented reality (AR) is the blending of the physical and virtual world by the use of dedicated AR devices like Google glasses or Microsoft Hololens. Digital information can be projected as an overlay to the real world and therefore show context-sensitive information directly in the viewpoint of the user.

Virtual reality (VR) also uses glasses-like devices but without the integration of the real world. In VR users are fully embedded into artificial digital environments and can virtually interact with the system.

Both technologies are often used to support gamification, which means that normal processes are enriched by game-like mechanisms and reward systems.

[12] https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf.

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Possible logistics use case

Smart assistance systems based on AR can be used to support workers with on-demand information about their current job. One example is AR-supported packing of pallets and bins to find best-fit packing schemes.

With the use of VR immersive training systems can be realised to help workers to better understand new processes and workflows without the need to be physically at the workplace.

2.9 NEXT-GENERATION WIRELESS TECHNOLOGIES

The next generation of wireless communication systems, like 5G or WIFI6, offer high bandwidths with low latency and enable real-time communication and interaction. The next-generation wireless technologies will help to close connectivity gaps globally. Among other things, this can be used to increase the degree of automation, allow remote access to machines and systems and fundamentally increase operational transparency and efficiency.

Possible logistics use case

Based on the next-generation wireless technologies the real-time remote control and monitoring of automated transport will become possible. Remote work and interaction can easily be done globally without the need to be at the local site or in the local system.

2.10 DRIVERLESS VEHICLES AND PLATOONING

Autonomous vehicles are able to drive without human intervention by constantly sensing their environment and taking decisions automatically. Higher safety, lower emissions and better efficiency are expected by using autonomous driverless vehicles.

Platooning can be seen as a first step to fully autonomous driving. Platooning describes the coupling of several trucks to one group, where the first trucks take control (either manually controlled by a human driver or self-driving). The distance between the trucks within the group will be very short. By this fuel can be saved, which leads to lower costs and emissions. Only one truck driver is needed for the movement of several trucks.

Possible logistics use case

Three different levels can be identified for the use of driverless vehicles in logistics: driverless trucks on public roads can connect logistics nodes, autonomous vehicles or shuttles can be used on-site in private or shared spaces and last-mile delivery vehicles can build the link to the private home.

2.11 DIGITAL PLATFORMS AND ONLINE MARKET-PLACES

Digital platforms and online marketplaces enable the interactions of a large number of participants, e.g. to connect potential buyers and sellers, establish collaboration or achieve a common outcome. The role of the platform or the platform company is to establish a governance structure, standards and processes that enable the above interactions. Platforms rely on the network effect to reach a large number of users in a short time and enable a high number of interactions. Platforms and marketplaces are currently dominating the B2C-world and offer easy-to-use services as an all-in-one offering.

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Possible logistics use case

Platform models can also be used in business-to-business logistics to realise sharing and collaboration platforms, e.g., for transport. The platforms can help to consolidate shipments and get better utilisation of the available assets and the existing infrastructure. Provider and customers can show their offerings and needs on the platform and easily conclude contracts.

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3 ARTIFICIAL INTELLIGENCE (AI) AS AN INTEGRATING TECHNOLOGY

Machine Learning (ML) as the current application of AI enables machines to access and learn from data automatically. AI will greatly affect the performance and development of the future supply chain industry given its central role in autonomous systems, robots and data science (Chui et al. 2018). Especially for the manufacturing and the logistics sector, the applicability of AI is broad and could be understood as an integrating technology. Therefore, artificial intelligence is described in this chapter more comprehensively.

The implications on supply chain performance are mostly positive, but transparency may suffer as complex models and algorithms are often seen as a black box and decisions cannot be retraced (Dickson 2017; iapp 2017; Kuang 2018). Nevertheless, AI has the potential to decrease inventory, transportation, labour and disruption management costs due to cycle time and scrap reductions and to improve resource utilisation (McKinsey 2017; Murrenhof, Friedrich, Witthaut 2021).

In addition to new areas of application, such as image recognition and interpretation, ML and AI are also being used to replace previous forecasting and optimisation procedures and optimisation methods and thus achieve more accurate results. In a study by INFORM and Logistik heute, experts from different logistics disciplines see the most important areas of application for ML in demand forecasting and planning, transport optimisation (e.g. through autonomous transport systems) and production and production optimisation (INFORM 2018). AI and ML offer the possibility of different data streams in a single model and thus to discover facts and interdependencies. This results in more accurate predictions, which form the basis for planning. The McKinsey Global Institute estimates that in most use cases, the application of AI in logistics and SCM leads to an increase in resource efficiency. With less personnel effort dependencies implicit in the data are recognised and better decisions are better decisions can be made.

The building blocks of AI according to the periodic table of AI

The German Association for Information Technology, Telecommunications and New Media (Bitkom) is the industry association of the German information and telecommunications industry. Bitkom proposes a framework to describe application cases of AI through the use of building blocks, which are grouped in a so-called periodic table.

The periodic table of artificial intelligence helps to map the concept of AI to business processes and build an understanding of the elements - similar to the periodic table of chemical elements. The approach helps in understanding and estimating market readiness, effort, required machine training, and staff knowledge and experience.

Artificial intelligence in this sense is seen as the combination of basic elements, similar to different LEGO bricks. Each AI element represents a sub-function that has historically been established as an encapsulated functionality of a certain complexity and power. A total of 28 AI elements are defined, which can be combined according to general criteria.

Each AI element falls into one of three groups. The selection of at least one AI element from each group represents the typical processing step of an AI-driven use case as an "AI element triple", namely Assess, all green elements, (e.g. detect the traffic situation around a robot car in milliseconds), Infer, all yellow elements, (e.g. calculate the probability of a rear-end collision for the next 3 seconds) and Respond, all red elements, (e.g. initiate the braking or evasive manoeuvre of the robot car).

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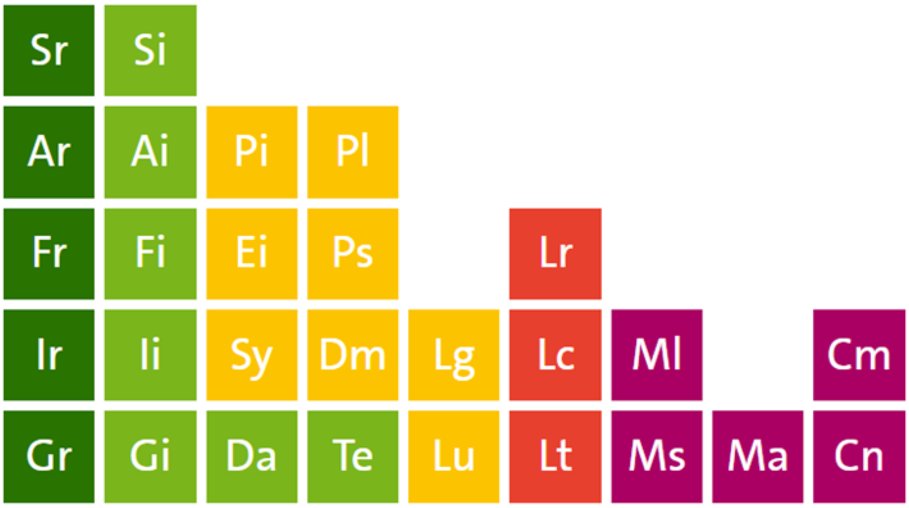

FIGURE 1: PERIODIC TABLE OF AI, SOURCE HTTPS://PERIODENSYSTEM-KI.DE/MIT-LEGOSTEINEN-DIE-KUENSTLICHE-INTELLIGENZ-BAUEN

Group of the typical processing step "Assess" (green):

Sr: Speech Recognition (The recognition of spoken language and/or emotional states in general in an audio signal.)

Ar: Audio Recognition (The detection of certain types of sounds (alarms, equipment stress, car engine) in an audio signal)

Fr: Face Recognition (The recognition of faces and emotional states in images or video signals.)

Ir: Image Recognition (The recognition of certain types of objects in images or video signals.

Gr: General Recognition (Analysing sensor data to recognise object types and/or situations from the signal alone)

Si: Speech Identification (The recognition of an individual voice in an audio signal)

Ai: Audio Identification (The recognition of audio signatures (a particular motor or doorbell) from audio signals.

Fi: Face identification (The identification of individual human beings in pictures or video signals).

Ii: Image Identification (The recognition of a specific object in an image or video)

Gi: General Identification (Analysing sensor data to recognise objects and/or situations from the signal alone.)

Da: Data Analytics (Analysing data to identify specific facts and/or events that the data represents.)

Te: Text Extraction (Analysing texts to extract information about entities, time, places and facts that are exclusively contained in the text.)

Group of the typical processing step "Infer" (yellow):

Pi: Predictive Inference (The prediction of events or conditions in the future based on an understanding of a current state of the world and how the world works.)

Ei: Explanatory Inference (Explaining events or conditions in the real world based on an understanding of previous conditions.

Sy: Synthetic Reasoning (The use of evidence to support inferences about the real state of the world, a prediction or an explanation.)

Pl: Planning (Creating an action plan based on a set of goals, an understanding of the real state of the world and knowledge about actions and their consequences.)

Ps: Problem Solving (The creation of a solution to a problem, which may or may not involve the use of actions (see Planning [Pl]).

Dm: Decision Making (Selecting a particular plan or solution based on available evidence, alternative solutions and a set of objectives.)

Lg: Language Generation (Creating natural language texts and/or explanations based on some understanding of the world.)

Lu: Language Understanding (Creating a semantic representation of the meaning of a text that shows context and some understanding of how the world works.)

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Group of the typical processing step "Respond" (red):

Lr: Relationship Learning (Identifying relationships between features that can be used to predict the presence of a set of hidden features when others are visible (e.g. correlation between rejected calls and customer churn).

Lc: Category Learning (The recognition of new categories of semantic values based on feature collections.)

Lt: Knowledge Refinement (Revising knowledge or rules that already exist in response to using them to support actions or conclusions.)

Ml: Mobility Large (Driving autonomous vehicles that interact with other vehicles first and foremost.)

Ms: Mobility Small (Controlling robots that move through indoor spaces, work and interact with people.)

Ma: Manipulation (Handling of objects)

Cm: Communication (support of different forms of human machine interaction)

Cn: Control (control of other machines when no manipulation or action in the physical world is required (e.g. automated trading).

Possible logistics use case

Murrenhof, Friedrich, Witthaut (2021) used the periodic table of AI to structure application cases for AI to increase efficiency in logistics and supply chain management:

- Localising, identifying and counting of objects (packages, trays, …)
- Speech, gesture and facial expression recognition for human machine interaction
- Identification of supply risks
- Condition monitoring of facilities
- Analysing customer behaviour and subsequent customer classification and demand forecasting
- Supply rating and supplier selection
- Assessment of machine performance
- Document analysis to classify paper document and to extract transactional data
- Master production planning
- Inventory management
- Unloading and storing
- In-house transport
- Picking, packing, and loading
- Autonomous driving on public roads

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4 DIGITAL TECHNOLOGIES HAVE THE POTENTIAL TO IMPROVE LOGISTICS IN MANY WAYS

Digital technologies have the potential to improve logistics in many ways. It is important to emphasize that the technologies described here are fundamentally complementary, and that combinations and systems of these technologies therefore enable stronger capability for future logistics and supply chains (Sanjiv 2017). This means that the effects of technologies can be more powerful when used as an overarching system.

However, careful evaluation is needed of all technologies before their implementation. This is because their successful implementation can depend upon many inter-related enablers, which may not be available everywhere or all the time. For example, the successful implementation of many digital technologies can be dependent upon fast reliable Internet connectivity and very sophisticated hardware. Moreover, the implementation of many technologies can have unintended negative consequences. For example, digital ledger technologies can drive up energy consumption to unsustainable levels. A broader implementation challenge is to determine which digital and non-digital technologies should be combined in logistics chains.

This challenge can be addressed by applying the predictive theory at the centre of digital innovation: Information Theory. That is the primary theory for the scientific study of the quantification, storage, and communication of digital information. Applications of fundamental topics of Information Theory include lossless data compression (e.g. ZIP files), lossy data compression (e.g. MP3s and JPEGs), and channel coding (e.g. for DSL). Information Theory has been crucial to the invention of the compact disc, the feasibility of mobile phones, the development of the Internet, and the success of the Voyager missions to deep space. A key measure in Information Theory is information entropy. This quantifies the amount of uncertainty involved in a process, and crucially is fundamentally linked to action, energy and survival. For example, providing a truck driver with ambiguous out-of-date route instructions (i.e. high information entropy) can increase the potential for getting lost (i.e. high thermodynamic entropy) and driving around without reaching intended destination (i.e. high unproductive energy expenditure) so becoming fatigued, running out of fuel (i.e. low thermodynamic free energy) and not completing the deliveries that are necessary to retain customers (i.e. does not survive in delivery business) (Fox 2021a).

Accordingly, each digital innovation should be analysed carefully for its potential to minimise information entropy. Such analyses need to be situated in the context where the digital innovation is intended to be implemented. For example, augmented reality has potential to reduce information entropy in the communication of work instructions in some situations but physical paper can have better potential in other situations. Accordingly, it is important to consider where selective targeted introduction of digital innovations can reduce overall information entropy, and so action and energy, across logistics chains (Fox 2021 b).

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5 CONCLUSIONS

It is up to the beneficiaries of the DIGILOGIC Research and Innovation Action and the experts and logistics practitioners involved in the various consultations, live session, workshops and discussions in the upcoming two and a half years to explore leapfrogging opportunities for technologies despite the infrastructural deficits and along the levers of change described in the deliverable D1.2 “Map of ecosystem and video narration brief on levers of change”.

The findings, inputs and dialogues will be continuously collected and added to a trend radar which will be published in month 30 of the DIGILOGIC project as deliverable D2.4 “Trend radar as meta-study”.

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