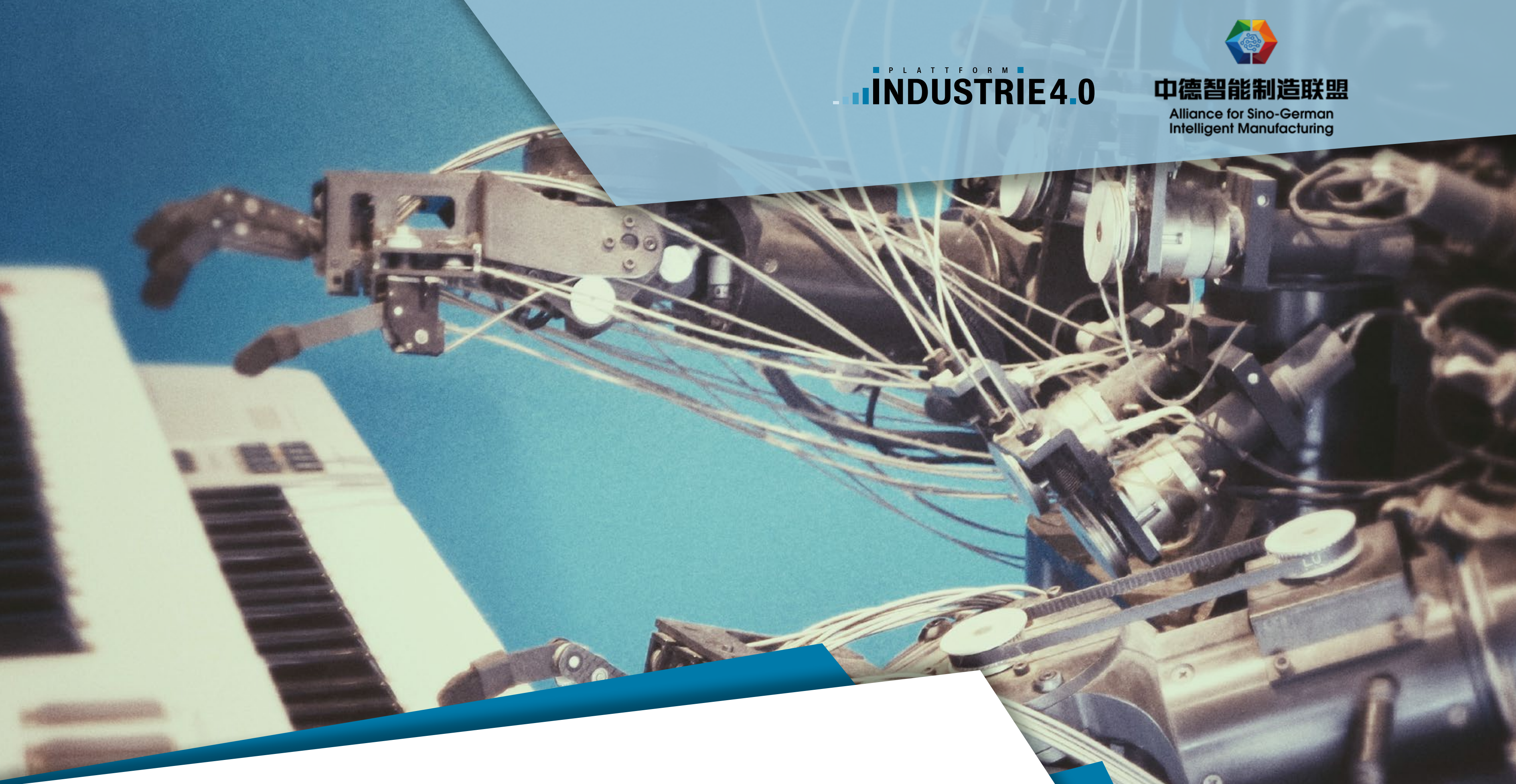
PLATTFORM INDUSTRIE 4.0

中德智能制造联盟
Alliance for Sino-German Intelligent Manufacturing



# AI Glossary

Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU)
Expert Group Artificial Intelligence

Published by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CCID 赛迪

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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This publication is a result of close cooperation between multiple entities in Germany and China including the Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU) Expert Group Artificial Intelligence in support of the MoU signed in 2015 between BMWi and MIIT following the 2014 joint action plan "Shaping Innovation Together."

Since 2016, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by BMWi, and the China Center for Information Industry Development (CCID) are the implementing bodies for the cooperation on the German and the Chinese side, respectively.



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## Introduction

In 2015, the German Federal Government laid the foundation for accelerating the digitalisation of the manufacturing sector. The Federal Ministry for Economic Affairs and Energy (BMWi) in Germany and the Ministry of Industry and Information Technology (MIIT) in China jointly agreed to establish a cooperation in the area of Industrie 4.0, based on a signed Memorandum of Understanding (MoU). The goal is to improve the business environment and regulatory framework for both German and Chinese enterprises and proactively shape the digital development of the manufacturing industry.

BMWi and MIIT commissioned the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the China Center for Information Industry Development (CCID) to support the implementation of the MoU. Under the direction of BMWi and MIIT, GIZ and CCID jointly established the Sino-German Company Working Group on Industrie 4.0 and Intelligent Manufacturing (AGU) in 2016.

The AGU functions as a platform for regular information and advisory exchange between German and Chinese enterprises as well as institutions from science and academia. The goal of the group is to better understand the existing business environment for companies, exchange best practices and formulate policy recommendations. The AGU's recommendations are directly channelled into the bilateral political dialogue. As part of the AGU, four Expert Groups on Digital Business Models, Training 4.0, Industrial Internet and Artificial Intelligence are working on formulating joint Sino-German positions and recommendations. The results of the Expert Groups are presented at the Sino-German Annual Conference of State Secretaries and Vice Ministers on Intelligent Manufacturing.

## Expert Group on Artificial Intelligence

Artificial Intelligence (AI) fundamentally changes the way companies and employees work. In the consumer goods and service sectors, the application of AI is advancing fast. How can AI be efficiently applied in the manufacturing industry as well?

In order to answer this question, the Sino-German Expert Group on Artificial Intelligence develops recommendations for political decision-makers and industry actors with the goal of effectively tapping into the potential of AI for the German and Chinese manufacturing industry. Through its work, the Expert Group increases the awareness for the newest technological developments and identifies opportunities and challenges for the future development of AI in the industry.

## Objective and Target Group

As one of the steps of the Expert Group's work, experts from German and Chinese companies co-authored this AI Glossary in order to develop a joint understanding and to give a comprehensive overview of what AI involves, which technologies it contains as well as the relevance to Industrie 4.0 and Intelligent Manufacturing. It includes 84 relevant AI terms, technologies, and definitions that summarise and explain AI-related key technologies and concepts.

The AI Glossary is primarily targeted at individuals and units of manufacturing companies as well as third-party consulting or service companies that continue to face challenges in leveraging AI technologies and systems to improve production processes and support services.

# About this AI Glossary

It is important to clarify and define the terminology of AI. AI expands rapidly into many industries including all areas of manufacturing, hence, relevant planners, policymakers and engineers now face new challenges vis-à-vis AI and its technologies. Therefore, there is an urgent need to develop a common understanding among experts to meet these challenges. AI is a big topic with a long history. It originates back to the 1950s when AI was defined to broadly simulate human intelligence. There are three levels of AI[1]:

- ANI (Artificial Narrow Intelligence): the first level that beat the world chess and Go champion, but with clear limitation.
- AGI (Artificial General Intelligence): AI that reaches and then exceed the human intelligence level. AGI has the ability to 'reason, plan, solve problems, think abstractly and learn from experience'[2].
- ASI (Artificial Super Intelligence): AI that is much smarter than the best human brain in practically every field, including scientific creativity, general wisdom and social skills[3].

AI is a dynamic field with a wide array of applications. For clarity's sake, however, this AI Glossary addresses core AI technologies relevant to Intelligent Manufacturing while excluding indirectly related technologies like Big Data and Internet of Things (IoT). We have also included promising methods that could be relevant for Intelligent Manufacturing in the near future. We classified the terms into five main categories: 1. AI Techniques, 2. AI Subarea, 3. AI Functional Applications, 4. AI Application Fields (restricted to the areas of Intelligent Manufacturing which are AI enabled) and 5. Other basic terms.

Most of the terms are AI techniques, functional applications or subareas of AI. For each term, the index also offers name variants, such as abbreviations, or synonyms, if these exist. This Glossary also provides the Chinese translation for each term. Each term is associated with a definition, which is phrased as a short explanation that functions as a minimal introduction. In addition to these definitions and minimal introductions, the index also summarises the relevance of each term for the application area in Intelligent Manufacturing. The publication does not aim to make a contribution to the scientific discussion but is intended to provide a handout for small and medium-sized companies that deal with the subject of AI in production. We have summarized existing knowledge from various sources to make it available to interested readers in an understandable and compact form. Sources as well as references for further explanation, such as introductory articles, books or websites can be found in the Annex of this Glossary. The selection does not reflect the intellectual origin or the history of the evolution of the concepts; instead, it is based on readability and accessibility of the sources.

1 Strelkova & Pasichnyk, "Three Types of Artificial Intelligence.", p. 1.

2 Gottfredson, Mainstream Science on Intelligence, p. 13.

3 Bostrom, "How Long before Superintelligence?", p. 1.

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| Index No. | Classification | Index Term | Term Variants, Abbreviations, Long Forms | Chinese Term | Short Definition in Simple Language | Relevance for Industrie 4.0 and Intelligent Manufacturing |
|---|---|---|---|---|---|---|
| 1 | AI Techniques | Abductive Reasoning | Abduction, Abductive Inference | 溯因推理 | Abductive reasoning is a form of logical inference which starts with one or several observations, then seeks to find the simplest and most likely explanation for the observations. This process, unlike deductive reasoning, yields a plausible conclusion but does not positively verify it. Much of diagnostic reasoning can be viewed as abduction, as in medical or technical diagnostics, meaning the most probable explanation is sought for the observed symptoms. Language understanding, and the interpretation of sentences and texts can also be seen as abduction. | Abductive reasoning is not used as a separate form of inference in Intelligent Manufacturing applications, except in its form of case-based reasoning (CBR). However, just like CBR, other forms of abductive inference may also be beneficial for symptom and failure diagnostics of machinery within troubleshooting and failure analysis, as it can utilise explicit knowledge about cause-effect relations for determining the cause of alarming symptoms and failure even if data on a sufficient number of similar cases is missing for statistical/neural machine learning. |
| 2 | AI Techniques | Adversarial Learning | Adversarial Machine Learning | 对抗性学习 | Adversarial learning is a new area in AI, dedicated to the study of (potential) threats for trained AI models that are caused by limitations on training data and could exploit their vulnerability. If these limitations can be identified intellectually or algorithmically, malicious input can be generated that results in misclassification. Examples are the generation of pictures or objects that would be wrongly classified by computer vision models or the intentional production of spam or fake news that cannot be recognized as such. In order to prevent successful attacks and develop countermeasures, both the weaknesses of the employed learning techniques and ways of detecting malicious input data are investigated. In a wider sense, the term adversarial machine learning applies to all schemes of training that involve the systematic generation of (potentially) misleading data for safeguarding or improving AI systems and, thus, also naturally extends to generative adversarial neural networks (GAN). | Adversarial machine learning is not yet systematically applied to increase the robustness and reliabilty of Industrie 4.0 AI. However, the threats and possible counter-measures are under investigation and it may just be a matter of time until existing methods will be systematically applied and adapted to AI in the Intelligent Manufacturing area. |

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| 3 | AI Techniques | Affective Computing | Artificial Emotional Intelligence, Emotion AI | 情感计算 | Affective computing is the study and development of systems and devices that can recognize, interpret, process, and simulate human emotions. The machine should interpret the emotional state of humans and adapt its behavior to them, giving an appropriate response to those emotions.One motivation for the research is the ability to simulate empathy, to recognize affects in human-machine interaction, especially in emotionally or cognitively demanding application scenarios as well as in clinical applications, and the immersive display of emotions in entertainment applications including games. | Affective computing is useful for situations of human-machine interaction in which the recognition of human emotion or the display of empathy can improve the outcome of a task. Such tasks can be human-robot interaction in tense situations, customer relationship management (CRM) scenarios with emotionally-aroused customers, search and rescue scenarios or mission-critical decision support systems when applied in conflict-of-intererest situations. |
| 4 | AI Functional Applications | AI for Data Analytics | Intelligent Data Analysis (IDA) | 用于数据分析的人工智能 | Intelligent data analysis (IDA) is concerned with the application of techniques coming from very different areas such as statistics, Artificial Intelligence, data mining, computational statistics, machine learning, optimization, dynamic programming to real-world data analysis problems. In fact, IDA has emerged as a branch of research to avoid the danger of drowning in information but starving for knowledge, and a considerable number of methods and software tools have been developed to solve data analysis problems. | Intelligent data analysis and real-time supervision (IDARTS) framework presents the guidelines for the implementation of scalable, flexible and pluggable data analysis and real-time supervision systems for manufacturing environments. IDARTS is aligned with the current Industrie 4.0 trend, being aimed at allowing manufacturers to translate their data into a business advantage through the integration of a cyber-physical system at the edge with cloud computing. |
| 5 | AI Application Fields (restricted to the areas of Intelligent Manufacturing which are AI enabled) | AIOps | AIOps | 智能运维 | AIOps (artificial intelligence for IT operation) refers to the use of machine learning, big data, data analytics and automated decision-making to enhance IT tasks. Thus, it is made possible to automate processes that would traditionally require significant manual intervention by humans. | 1. Anomaly detection: Perhaps the most basic use case for AIOps is detecting anomalies within data, then reacting to them as needed.<br>2. Causal analysis: AIOps also help IT operation teams automate root cause analysis, so that issues can be resolved quickly.<br>3. Prediction: AIOps allow tools to make automated predictions about the future, such as how user traffic is likely to change at a given point in time, then react accordingly.<br>4. Alarm management: AIOps play an increasingly important role in helping IT Ops teams to contend with the deluge of alerts that they must handle in order to support operations.<br>5. Intelligent remediation: AIOps drive closed loop remediation through automation tools without relying on human operators. |

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| 6 | AI Techniques | Analogical Reasoning | N/A | 类比推理 | Analogical reasoning is a form of inference based on the comparison of two objects. The similarities between the two compared objects may permit transferring inferences valid from one object to the other "by analogy". Case-based reasoning (CBR) is a special form of analogical reasoning, where the two objects are problem descriptions and where the known solution to one problem is transferred to the other one by analogical reasoning. | Like case-based reasoning (CBR) and other forms of abductive reasoning, analogical reasoning can be useful for symptom and failure diagnostics of machinery within troubleshooting and failure analysis as it can utilise explicit knowledge about cause-effect relations for determining the cause of alarming symptoms and failure even if data on a sufficient number of similar cases is missing for statistical/neural machine learning. |
| 7 | AI Functional Applications | Anomaly Detection | N/A | 异常检测 | Anomaly detection refers to the task of finding patterns in data that do not conform to expected behavior. These non-conforming patterns are often referred to as anomalies, outliers, discordant observations, exceptions, aberrations, surprises, peculiarities or contaminants in different application domains. Of these, anomalies and outliers are two most commonly used terms in the context of anomaly detection. | Anomaly detection finds extensive use in a wide variety of applications such as fraud detection for credit cards, insurance or health care, intrusion detection for cyber-security, fault detection in safety critical systems, and military surveillance for enemy activities. With respect to manufacturing, anomaly detection technology usually collects large amounts of data as the base. After automatic analysis and machine learning, a system of normal data structure will be formed, which is used for analysing new data coming into the system, while consequently identfying and warning of abnormal data or status of a machine. |
| 8 | AI Functional Applications | Argument Extraction | N/A | 参数提取 | Argument extraction is the task of identifying arguments, along with their components in text. Arguments can be usually decomposed into a claim and one or more premises justifying it. Argument extraction is the key step of event extraction and syntactic information has an important role in argument extraction. Argument extraction algorithms are usually employing machine learning techniques. | Argument extraction technology can help people identify the key contents of an article or a report in a relatively short period of time. If applied in the manufacturing industry, it can save a lot of time when people need to read technical reports or product catalogs. As long as a certain theme is specified, people can rely on argument extraction to fastly browse through the whole text and suggest key points with relevant contents. It is a good helper for improving people's reading efficiency. |

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| 9 | AI Techniques | Artificial Neural Network | ANN | 人工神经网络 | An artificial neural network (ANN) is a computational model inspired by the structure and functions of the biological neural network in the (human) brain. An ANN learns to model a complex function, e.g., for classification, translation, question-answering, prediction, from a sufficiently large set of training data. An ANN consists of nodes (vertices), called the neurons, which are connected with other neurons by edges, which in their function correspond to the synapses in the brain. Neurons produce an activation represented by a (real) number. The activation is computed by an activation function whose arguments are activation values transmitted from other neurons through incoming edges. Artificial neurons and edges typically have a weight that is determined by the learning data through the learning process. The weight increases or decreases the strength of the signal at a specific connection. Artificial neurons may have a threshold such that the signal is only sent if the aggregate signal crosses that threshold. Typically, artificial neurons are partitioned into layers. Multi-layered ANNs are also called deep neural networks. Different layers may perform different kinds of transformations on their inputs. Signals travel from the first layer (the input layer) to the last layer (the output layer), possibly after traversing the intermediate layers multiple times. Multilayered ANNs with deep learning algorithms have become the most successful instrument for machine learning. | Artificial neural networks are at the core of most AI applications in Intelligent Manufacturing such as predictive maintenance, anomaly detection, process optimisation, and visual quality monitoring. For most AI functionality based on machine learning, ANNs have proven to offer a stronger predictive power than earlier techniques of machine learning such as decision tree learning or support vector machines. |

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| 10 | AI Techniques | Automated Machine Learning | AutoML | 自动机器学习 | Automated machine learning (AutoML) is the process of automating end-to-end the process of applying machine learning to real-world problems. In a typical machine learning application, practitioners have a dataset to train on. The raw data itself may not be in a form that all algorithms may be applicable to it out of the box. An expert may have to apply the appropriate data pre-processing, feature engineering, feature extraction, and feature selection methods that make the dataset amenable for machine learning. Following those preprocessing steps, practitioners must then perform algorithm selection and hyperparameter optimization to maximize the predictive performance of their final machine learning model. As many of these steps are often beyond the abilities of non-experts, AutoML was proposed as an Artificial Intelligence-based solution to the ever-growing challenge of applying machine learning. Automating the process of applying machine learning end-to-end offers the advantages of producing simpler solutions, faster creation of those solutions, and models that often outperform the ones that were designed by hand. However, AutoML is not a silver bullet and cannot introduce additional parameters of its own, called hyperparameters, which may need some expertise to be set themselves. But it does make application of machine learning easier for non-experts. | Automated machine learning strongly facilitates the application of AI in nearly all application areas, since many of the processes that require complex skills and extensive experience for finding successful parametrisations and models have been automated. |

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| 11 | AI Functional Applications | Automatic Speech Recognition (ASR) | ASR | 自动语音识别（ASR） | Automatic speech recognition (ASR) subsumes the research area and technologies for automatically recognizing and transcribing spoken language. To this end, the continuous speech signal is broken up into frames (or segments), each of which will be represented by a vector that encodes its perception-relevant acoustic properties. Sequences of these vectors will then by mapped to units of language such as phonemes, syllables, words or commands. These recognized units can then be either directly used to trigger actions or they can be composed into a written representation of the spoken language signal. The latter is called speech-to-text conversion as, for instance, employed in dictation or as the input for automatic translation. ASR systems are usually trained by supervised machine learning, where the labeled data are speech recordings combined with their time-aligned transcriptions. | The field of smartphone manufacturers has already applied speech recognition technology. In addition, an important part of speech recognition is called „remote identification", which means that no matter where you go, identificiation is easily and quickly realised through voiceprint information. In smart home life, speech recognition technology can be applied to multiple scenes including voice-activated lights, voice-activated furniture, voice-activated multimedia, car voiceprint systems, etc. In manufacturing, ASR is utilised, e.g. for voice-controlled machinery and for human-robot interaction. |
| 12 | AI Techniques<br>AI Functional Applications | Autonomic Computing | N/A | 自主计算 | Automatic computing is a technology where information systems automatically manage themselves and maintain their reliability. The core of automatic computing is self-monitoring, self-configuration, self-optimization, and self-recovery. | Intelligent Manufacturing systems are multi-entity intelligent systems and their structure is gradually becoming more complex. It is becoming more and more difficult for humans to effectively manage these systems. Autonomic computing has a huge application potential in the future in relation to self-management of Intelligent Manufacturing systems. |
| 13 | AI Functional Applications | Brain-Computer Interface (BCI) | Direct Neural Interface, Brain-Machine Interface, Brain-Computer Interaction Technology (BCI) | 脑机接口 | A brain-computer interface (BCI) is a communication and control technology between a biological brain and an electronic device. To this end, bioelecectic signals of the brain are collected and processed. This technology enables people to express their wishes or manipulate devices directly through their brain without the use of speech or requiring them to perform body movements. Current research on brain-computer interface technology enables patients with neuromuscular diseases (e.g., muscle atrophy) as well as those with communication disorders to complete external communication. | In recent years, as a new human-computer interaction technology, the brain-computer interface (BCI) has been a hotspot in brain science and biomedical engineering. In the future, hybrid intelligence will be used to control industrial robots and Intelligent Manufacturing. |

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| 14 | AI Techniques | Case-Based Reasoning | CBR | 基于案例推理 | Case-based reasoning (CBR) is a general method for solving new problems based on the solutions of similar past problems. It requires a store of previous cases, each consisting of a description of the problem and a description of a corresponding solution. Simple CBR does not have a statistical component. One good match of the problem with a single previously encountered problem suffices to retrieve a solution, which then may still have to be adapted to the new problem. However, CBR can also be combined with statistics to add a probabilistic component to the inference, which can associate decisions with confidence values. CBR differs from rule induction, which also learns on the basis of previous cases, since it retrieves, adapts and applies experience only on demand, i.e., when a new case of a certain kind is encountered. Applications are troubleshooting in maintenance or customer support, medical diagnostics or other decision support systems. | CBR is one of the most cited AI techniques in Intelligent Manufacturing. It is used, e.g., for diagnosis in symptom and failure analysis as well as for configuration and scheduling tasks. |
| 15 | AI Functional Applications | Chatbots | Chat Robots | 聊天机器人 / 对话机器人 | At the most basic level, a chatbot is a computer program that simulates and processes human conversation (either written or spoken), allowing humans to interact with digital devices as if they were communicating with a real person. Chatbots can be as simple as rudimentary programs that answer a simple query with a single-line response, or as sophisticated as digital assistants that learn and evolve to deliver increasing levels of personalization as they gather and process information. Today, most chatbots are accessed online via websites, or through virtual assistants such as Google Assistant, Amazon Alexa, or messaging apps such as Facebook Messenger or WeChat. | The current social media age has been made possible with the proliferation of smartphones and advancement of broadband wireless technology. With more and more people being digitally connected, it is not surprising that social chatbots have been developed as an alternative means for engagement. Chatbots can be used as means for humans to communicate more naturally with machines, for example to assign tasks or investigate problems. Specifically, people can directly use oral commands to communicate with machines for operations, which can further free hands for other tasks. By linking operations and human languages, chat robots can establish an intelligent database for simplifying operation, maintenance, and manufacturing processes. Chat robots can also use artificial intelligence to analyse relationships between people's commands and machine execution, to recognize emotion changes of the operator, and hence optimize manufacturing efficiency. |

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| 16 | AI Techniques | Cluster Analysis | N/A | 聚类分析 | see Clustering | |
| 17 | AI Techniques | Clustering | N/A | 聚类 | Clustering (or cluster analysis) is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (according to a specific similarity measure) to each other than to those in other groups (clusters). Clustering can be viewed as an unsupervised alternative to classification since it does not require labeled training data. If a specific task permits a mapping from the detected clusters to target classes, clustering can indeed be utilized as unsupervised classification. Usually, clustering is the main task of exploratory data mining and a common technique for statistical data analysis which is used in many fields, including machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, and computer graphics. Cluster analysis itself is not one specific algorithm but the general task to be solved. It can be achieved by various algorithms that differ significantly in their understanding of what constitutes a cluster and how to efficiently find them. Popular notions of clusters include groups with small distances between cluster members, dense areas of the data space, intervals or particular statistical distributions. Clustering can therefore be formulated as a multi-objective optimization problem. The appropriate clustering algorithm and parameter settings (including parameters such as the distance function to use, a density threshold or the number of expected clusters) depend on the individual data set and intended use of the results. Recently, deep learning techniques outperformed earlier methods for a number of standard clustering tasks. | Clustering is extensively used as the first and most basic step for data mining from large volumes of data. It can, for instance, be used to cluster certain events or situations from collections of process and sensor data for anomaly detection or maintenance scheduling. It can also be applied for unsupervised classification of perceived quality deviations. |

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| 18 | Other basic terms | Cognitive Computing | N/A | 认知计算 | Cognitive computing refers to systems that learn at scale, reason with purpose and interact with humans naturally. It is a mixture of computer science and cognitive science – that is, the understanding of the human brain and how it works. By means of self-teaching algorithms that use data mining, visual recognition, and natural language processing, the computer is able to solve problems and thereby optimize human processes. | Cognitive manufacturing transforms manufacturing in three focused ways:<br>1. Intelligent assets and equipment: utilising connected sensors, analytics, and cognitive capabilities to sense, communicate and self-diagnose issues in order to optimise performance and reduce unnecessary downtimes.<br>2. Cognitive processes and operations: analysing a variety of information from workflows, contexts, processes, and environment to drive quality, and enhance operations and decision-making.<br>3. Smarter resources and optimisation: combining various forms of data from individuals, location, usage, and expertise with cognitive insight to optimise and improve resources such as labor, workforce, and energy. |
| 19 | AI Techniques<br>Other basic terms | Common-Sense Knowledge | N/A | 常识性知识 | In Artificial Intelligence, common-sense knowledge is the set of background information (facts) that an individual is expected to know and the ability to use it when needed. It is a shared knowledge (between everybody or people in a particular culture or age group only). | By abstracting common sense knowledge from industrial processes, producers can use established data to bring in known mechanisms, enabling machines to have the ability to solve known problems. |
| 20 | AI Subarea<br>AI Functional Applications | Computer Vision | N/A | 计算机视觉 | Computer vision is an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos. The ultimate research goal of computer vision is to enable the computer to observe and understand the world through vision like human beings, and to have the ability to adapt to the environment autonomously. It is also a very important and interesting research field to study the mechanism of human vision with the method of computer information processing and establish the computational theory of human vision. | Computer vision, image processing, image analysis, robot vision and machine vision are closely related to each other. Many applications based on these technologies, like industrial cameras with image analysis, have been widely used in industries where automatic identification and analysis are needed. |

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| 21 | AI Functional Applications | Conversational User Interfaces | CUI | 会话用户界面 | Conversational user interfaces allow users to interact with computer-based applications such as databases and expert systems by using naturally spoken language. The origins of spoken dialogue systems can be traced back to Artificial Intelligence research in the 1950s concerned with developing conversational interfaces. However, it is only within the last decade or so, with major advances in speech technology, that large-scale working systems have been developed and, in some cases, introduced into commercial environments. As a result, many major telecommunications and software companies have become aware of the potential for spoken dialogue technology to provide solutions in newly developing areas such as computer-telephony integration. While there are a variety of interface brands, to date, there are two main categories of conversational interfaces: voice assistants and chatbots. | Conversational user interfaces provide humans one more option for information exchange with manufacturing systems and machines. Besides touch-based and vision-based systems, CUIs make use of acoustics analysis technology and links human conversations with machine execution. It has been widely used in machine guidance services, smart home appliances, auto-navigation system, etc. |

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| 22 | AI Techniques | Convolutional Neural Network | CNN, ConvNet | 卷积神经网络 | A convolutional neural network (CNN) is a type of neural network possessing one or several convolution layers, i.e., layers that are locally/spatially connected to preceding layers. The convolution layer's parameters consist of a set of learnable filters (or kernels), which have a small receptive field but extend through the full depth of the input volume. During the forward pass, each filter is convolved across the width and height of the input volume, computing the dot product between the entries of the filter and the input, and producing a two-dimensional activation map of that filter. As a result, the network learns filters that activate when it detects some specific type of feature at some spatial position in the input. The convolution layers are often followed by regular fully connected layers. Convolutional networks were inspired by biological processes in that the connectivity pattern between neurons resembles the organization of the animal visual cortex. Individual cortical neurons respond to stimuli only in a restricted region of the visual field known as the receptive field. The receptive fields of different neurons partially overlap such that they cover the entire visual field. CNNs use relatively little pre-processing compared to other image classification algorithms. This means that the network learns the filters that in traditional algorithms were hand-engineered. This independence from prior knowledge and human effort in feature design is a major advantage. CNNs are also known as (almost) shift invariant or space invariant artificial neural networks, based on their shared-weights architecture and translation invariance characteristics. They have applications in image and video recognition, recommender systems, image classification, medical image analysis, and natural language processing. | Convolutional neural networks are the most widespread model for all computer vision tasks including object classification or visual quality assessment. They are also occasionally applied to graph processing and to various NLP/speech processing tasks. They are the artificial neural network (ANN) architecture of choice for all tasks in which shift-invariance is important, especially for all tasks where the same patterns can occur in different regions of one-, two-, or three-dimensional input, often also in deformed variants. |

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| 23 | AI Functional Applications | Data Mining | Knowledge Discovery in Database (KDD) | 数据挖掘 | Data mining refers to discovering implicit, unknown, non-trivial and potentially valuable information or patterns from large databases or data warehouses. It is a new field of application value in database research, which combines theories and techniques of multiple fields such as databases, Artificial Intelligence, machine learning and statistics. Frequently employed tasks in data mining are: clustering, classification, regression, and anomaly detection. | Along with the rapid development of the manufacturing industry, big data mining technology with its unique advantages has been increasingly applied. This technology can effectively upgrade the intelligent transformation of manufacturing, link multiple segments such as design, manufacturing and production, further improve product design functions and product quality, contribute to production cost reductions and create even greater economic benefits. In steel manufacturing, production processes are complex. They involve numerous segments and the connections between these segments is close. Each segment needs to set up complex process parameters, which could give rise to different levels of defects, including cracks, scars, or scratches. These problems could affect the quality of manufacturing. The construction of a defect identification model through Big Data Mining technology makes it possible to identify and analyse defects in steel, understand the types of defects, find unqualified products in a timely manner, and look for reasonable measures to provide solutions. |
| 24 | AI Functional Applications | Decision Support Systems | DSS | 决策支持系统 | A decision support system (DSS) is a computer application system assisting decision-makers in making semi-structured or unstructured decisions through human-computer interaction, and possesses certain intelligent behaviors of human-machine interaction. As the latest development stage of information system research, DSS has become an important research topic in the field of system engineering and computer application. Nowadays, DSS is already widely used in disaster prediction and disaster prevention, enterprise production activity and corporate decision-making as well as economic predictions and policy decision-making. | The combination of simulation technology and DSS simulates the operation/process of manufacturing systems by establishing and utilising models to obtain the parameters and basic characteristics exported by the simulated system, providing data sources for DSS and offering support for the final decision-making of producers. |

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| 25 | AI Techniques | Deep Learning | N/A | 深度学习 | Deep learning is the name of a class of machine learning algorithms that use multiple layers to progressively extract higher levels of features at different levels of abstraction from raw input data. For example, in language processing, lower layers may identify word types, while higher layers identify grammatical relationships. The term was introduced for machine learning in 1986 by Rina Dechter and for ANNs in 2000 by Igor Aizenberg and colleagues. Today, deep learning almost exclusively refers to machine learning based on deep artificial neural networks, i.e. multi-layer ANNs, where the layers are vectors of vertices, so-called neurons. Deep learning can be supervised, semi-supervised or unsupervised. During the learning process, the weights are iteratively adjusted to accommodate the variation of data. Usually, weights are adjusted by backpropagation, the propagation of errors through the layers in reverse order. The weights are optimized by gradient descent to improve the network until it is able to perform the task for which it is being trained. | Deep learning is the learning paradigm for all industrial applications that use neural networks because all of these ANNs are multilayered nowadays. Artificial neural networks are at the core of most AI applications in Intelligent Manufacturing such as predictive maintenance, process optimisation, or visual quality monitoring. For most AI functionalities based on machine learning, ANNs have proven to offer a stronger predictive power than earlier techniques of machine learning such as decision tree learning or support vector machines. |
| 26 | AI Functional Applications | Digital Twin | N/A | 数字孪生 | Digital twin refers to a digital replica of a living or non-living physical entity. It can be used for simulating, monitoring, diagnosing, predicting and controlling the product's physical entity in the real environment of the production process, state and behavior. | Today's production model of enterprises is gradually changing from mass manufacturing to mass customisation. The implementation of mass customisation has already become an important symbol of Intelligent Manufacturing and the successful completion of this process requires a comprehensive digitalisation of manufacturing products. The establishment of the digital twin model of products can reduce the time consumed in the design and production processes, meet the customisation needs of the customers and supervise the product throughout the whole lifecycle in order to improve the reaction speed to market demand. |

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| 27 | AI Techniques<br>AI Functional Applications | Edge AI | N/A | 边缘人工智能，边缘智能 | Edge AI is a paradigm where AI algorithms are processed locally on an (edge or IoT) device, to improve response times and save bandwidth. Usually, the algorithms are accessing data (sensors or other signals) that are created on the device itself. In order to work properly, a device using Edge AI does not need to be connected to a network. An example of edge AI is face recognition to unlock a smart-phone. | The development and combination of these trends can hopefully make it possible to execute AI algorithms closer to where operations are taking place. Edge computing will not be a replacement for the power of the cloud. It can, however, make AI's operation model resemble that of humans: perform routine and time-critical decisions at the edge and refer to the cloud where more intensive computation and historical analysis is needed. With the development of IoT, billions or even trillions of devices will generate massive amounts of unstructured data. Artificial Intelligence (AI) is needed to translate this data into meaningful and actionable information. The current cloud computing model will not be able to cope with the amount of data and requirements on network speed. A new model is required – real time AI on the edge. |
| 28 | AI Techniques<br>AI Subarea | Embodied AI | Behaviorism AI | 具身人工智能 | The AI avatar possesses a body and can enter the real world through a physical body. This body is usually equipped with sensors in order to import data from the world around it. | Intelligent Manufacturing scenarios mostly involve the use of physicalised AI avatars (robots, etc.) that are linked to other physical entities (extensive application of processing, manufacturing, assembly, maintenance, etc.). If better progress can be made on embodied AI, then more applications in Intelligent Manufacturing are possible. |

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| 29 | AI Techniques<br>AI Functional Applications | Emotion AI | Artificial Emotional Intelligence, Affective Computing, Emotion Recognition, Emotion Detection Technology | 情感智能 | Artificial emotional intelligence or emotion AI is also known as emotion recognition or emotion detection technology. Its aim is to understand emotions expressed through non-verbal cues, such as facial expressions, gestures, body language and tone of voice. | Emotion AI enables everyday objects to detect, analyse, process and respond to people's emotional states and moods. This technology can be used to create more personalised user experiences. Personal assistant robots (PARs) are also prime candidates for developing emotion AI. Many already contain some human characteristics, which can be expanded upon to create PARs that can adapt to different emotional contexts and people. The more interactions a PAR has with a specific person, the more it will develop a personality. For example, IBM and startups such as Emoshape are developing techniques to add human-like qualities to robotic systems. Many car manufacturers are exploring the implementation of in-car emotion detection systems. These systems will detect the driver's moods and be aware of their emotions, which in return, could improve road safety by managing the driver's anger, frustration, drowsiness and anxiety. We believe that in the future, more and more smart devices will be able to capture human emotions and moods in relation to certain data and facts, and to analyse situations accordingly. For that, technology strategy planners can take advantage of this technology to build and market the device portfolio of the future. |
| 30 | AI Techniques<br>AI Subarea | Evolutionary Computation | N/A | 进化计算 | A type of search optimization algorithm inspired by biological evolution and genetic principles. In evolutionary computation, an initial set of candidate solutions is generated and iteratively updated. Each new generation is produced by stochastically removing less desired solutions, and introducing small random changes. As a result, the population will gradually evolve to increase in fitness, in this case the chosen fitness function of the algorithm. Evolutionary algorithms form a subset of evolutionary computation. | Evolutionary computation as an algorithm can be used in arithmetic partly related to Intelligent Manufacturing, however, this aspect of relation is currently not seen often. |

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| 31 | AI Techniques<br>AI Functional Applications | Explainable AI | XAI | 可解释的人工智能 | Explainable AI (XAI) is an emerging field in machine learning that aims to explain how black box decisions of AI systems are made. This area inspects and tries to understand the steps and models involved in making decisions. The US Defense Advanced Research Project Agency (DARPA) is pursuing efforts to produce explainable AI solutions through a number of funded research initiatives. DARPA describes AI explainability in three parts which include: prediction accuracy which means XAI models will explain how conclusions are reached to improve future decision making, decision understanding and trust from human users and operators, as well as inspection and traceability of actions undertaken by the AI systems. Traceability will enable humans to get into AI decision loops and have the ability to stop or control its tasks whenever need arises. An AI system is not only expected to perform a certain task or impose decisions but also to have a model with the ability to give a transparent report of why it took specific conclusions. | Apart from a solution of the above scenarios, XAI offers manufacturers deeper business benefits such as: 1) Improves AI Model performance as explanations help pinpoint issues in data and feature behaviors; 2) Better decision-making as explanations provide added info and confidence for man-in-middle to act wisely and decisively; 3) Gives a sense of control as an AI system owner clearly knows levers for its AI system's behavior and boundary; 4) Gives a sense of safety as each decision can be subjected to pass through safety guidelines and alerts on its violation; 5) Builds trust with stakeholders who can see through all the reasoning of each and every decision made; 6) Monitors for ethical issues and violations due to bias in training data; 7) Better mechanism to comply with accountability requirements within the organization for auditing and other purposes; 8) Better adherence to regulatory requirements (like GDPR) where 'Right to Explain' is a must-have for a system. |
| 32 | AI Techniques<br>Other basic terms | Explicit Knowledge | Expressive knowledge | 显性知识 | Explicit knowledge (also expressive knowledge) is knowledge that can be readily articulated, codified, stored and accessed. It can be easily transmitted to others. In contrast, implicit knowledge can be acquired by learning certain skills such as speaking or walking. Usually, neither humans nor machines can explain, how they articulate a word or how they keep balance while walking. Nearly all applications of deep learning only acquire skills and implicit knowledge. Explicit knowledge constitutes a central part of expert systems and task-driven chatbots. It is represented in logical formulae, rules, constraints or knowledge graphs. | Today, most of the successful AI applications in manufacturing do not have explicit knowledge. When industrial AI applications go beyond applications of narrow AI such as simple perception, robot action and analytics tasks, especially if they are supposed to help in making decisions, in communicating with customers or in training employees, they need explicit knowledge about products and processes. Examples would be decision support systems such as expert or advanced analytics systems or chatbots. |

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| 33 | AI Functional Applications | Facial Recognition | N/A | 人脸识别 | Facial recognition refers to the authentication and differentiation of a single person or multiple persons in a static image or dynamic video by utilizing databases consisting of facial images of already known identities. Facial recognition can be used in mobile user verification or for marketing purposes. | In manufacturing, facial recognition can be used for authentification. It can give specific operators a certain level of access to a machine or production unit. A maintenance mechanic recognised could get a different access than a normal operator. |
| 34 | AI Techniques | Few-shot Learning | N-shot Learning | 小样本学习 | Few-shot learning refers to approaches in machine learning that can train a classifier even if some or all classes are only represented by a very small set of examples (often 2-5) in the training data, whereas the training of traditional classifiers requires many (sometimes hundreds or thousands) of instances per class. A special case of few-shot learning is one-shot learning, where every class is represented by just one training example. An even more radical attempt to reduce the number of minimally required training examples per class is zero-shot learning, where the learning does not rely on training examples but instead starts from known properties of the sets to be distinguished, therefore, the classes are represented by metadata instead of actual data. | As one of the main methods of industrial data analysis and mining, machine learning has effectively extracted information from Intelligent Manufacturing data. However, in the dataset, it is often the case that some samples are missing due to the difficulty of sampling the samples. Few-shot learning can solve the problem of small sample size or difficult sampling. |
| 35 | AI Functional Applications | Gait Recognition | N/A | 步态识别 | Gait recognition aims to identify people according to their manner of walking. Compared with other biometric recognition technologies (such as fingerprints, face, etc.), gait recognition has the advantages of being non-contact, non-invasive, difficult to hide or misrepresent oneself. Furthermore, it allows to identify individuals even if body parts (e.g., faces) are obscured. | N/A |

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| 36 | AI Techniques | Generative Adversarial Networks | GAN | 生成对抗网络 | Generative adversarial networks (GAN) are a deep learning model and one of the most promising methods for unsupervised learning in complex distribution in recent years. Adversarial neural networks or adversarial training of neural networks is an approach for improving networks for some given tasks by letting them compete with each other. In a game such as Go or Chess or in certain other real or simulated situations, there is an outside objective that decides which network has won. The generative adversarial network (GAN) is a special type of adversarial neural network that consists of two competing artificial neural networks (ANN), a generative ANN producing new data with the same distribution to classes as a natural training set, and a discriminative network that classifies the generated data. The generator scores by generating examples that the discriminator cannot properly classify and the discriminator scores by correctly classifying this data. Each network continuously improves its performance based on the improvement of the other one. In its original form, the game-like scheme was realised as unsupervised learning but it can be extended by labeled data to a semi-supervised setup. | The generated confrontation network can be used for image generation in modern manufacturing such as super-resolution tasks, semantic segmentation and others. GAN generated images can also be used for data enhancement. GANs can, for instance, create photorealistic images or reconstruct 3D models of objects from images. A variation of the GANs are used in training a network to generate optimal control inputs to nonlinear dynamical systems. |
| 37 | AI Techniques | Genetic Algorithm | GA | 遗传算法 | Genetic algorithm (GA) is a computational model that simulates the natural evolution of Darwin's biological evolution and the evolutionary process of genetics, by introducing genetic operators (i.e., mutation, crossover, and selection) between generations of candidate solutions (individual algorithms to solve a specific task). Each candidate solution has a set of properties (chromosome) which can be altered by the algorithm. During each generation the fittest candidates are selected to breed a new generation of candidate solutions. The next generation of solutions is bred (by mutation and crossover) from the pool of previously selected fit solutions. This process is repeated until a termination condition has been reached. | The genetic algorithm can be applied to combinatorial optimisation, which is very effective for solving the Non-deterministic Polynomial Complete (NP) problem in combinatorial optimisation. It has also been widely used in production scheduling problems, automatic control, robotics, image processing and so on. |

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| 38 | AI Functional Applications | Gesture Recognition | N/A | 手势识别 | Gesture recognition technology is divided into static recognition technology and dynamic recognition technology. Static gesture recognition mainly refers to the direction, shape and texture of human gestures. Dynamic gesture recognition mainly tracks and recognizes the movement processes and trajectory of a gesture. According to the purpose of recognition, gestures can also be divided into operational gestures and communication gestures. The former refers to people's specific operational behavior, involving virtual reality technology and augmented reality technology in the design domain. The latter refers to gestures as the most natural means of interaction with equipment. | N/A |
| 39 | AI Techniques | Heuristic Search Techniques | Informed Search Techniques | 启发式搜索技术 | Heuristic search, also known as informed search, is a search technology for Artificial Intelligence. It uses the heuristic information possessed by the problem to guide the search, which reduces the scope of search and reduces the complexity of the problem. Heuristic search is used to find an approximate solution, but does not explore the complete search space. Therefore, heuristic searches are not guaranteed to find the single best solution, but may be useful to find a good solution. | Heuristic search technology can extract the most valuable information from a large amount of information, avoid excessive irrelevant information, and greatly improve the accuracy of search. Heuristic search can be applied to web search and data query. |
| 40 | AI Techniques<br>Other basic terms | Human-Computation | Human-based Computation, HBC | 人机协同 | Human-computation is a computer science technique in which a machine performs its function by outsourcing certain steps to humans, usually as microwork. This approach uses differences in abilities and alternative costs between humans and computer agents to achieve symbiotic human-computer interaction. The outsourcing step is often implemented as crowdsourcing task (e.g., Amazon Mechanical Turk) or as game with a purpose. | Human computation can perform intelligent activities such as analysis, reasoning, judgment, conception and decision-making in the manufacturing process. Through the cooperation of humans and intelligent machines, we will expand, extend and partially replace the mental work of human experts in the manufacturing process. It extends the concept of manufacturing automation to be flexible, intelligent and highly integrated. |

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| 41 | AI Functional Applications | Human-Computer Interaction | HCI | 人机交互 | Human-computer interaction (HCI) refers to the process of exchanging information between people and computers to accomplish specific tasks. The interaction can happen through various combinations of input devices (e.g., keyboard, mouse, touchpad, microphone, touchscreen) and output devices (e.g., screen, graphical user interface, loudspeaker, VR display). HCI specifically studies the design of interfaces. AI comes into play when human language or gestures are used as a communication medium. | In Intelligent Manufacturing, all equipment, factories and people can be connected among themselves and directly to the cloud. Through the human-computer interaction platform, technicians can be transformed from the original design and industrial arts route, selection tools, direct operation equipment and other manual intervention to "data analysis users" of output data, evaluation data, interpretation of data, utilisation of data and optimisation data. Human-computer interaction also indirectly interacts with machine equipment through virtual reality technology to achieve the following in today's Intelligent Manufacturing:<br>1. Monitoring production processes and quality by invoking sensitive and important information and data;<br>2. Pre-designing standards for building models by simulating production processes via VR technology;<br>3. Collecting and using data through dynamic visualisation movement terminals, checking equipment failure or predicting defects through data streams, intervening in production processes if needed, and providing real-time manual support;<br>4. Establishing a learning-based production organisation, constantly improving production efficiency based on human-computer interaction, satisfying personalised batch customisation and innovating production and service models. |
| 42 | AI Techniques | Human-in-the-Loop (HITL) testing | HITL testing | 人机回圈 (HITL) 测试 | Human-in-the-loop testing or HITL testing is defined as a test model that requires human interaction. HITL is associated with modeling and simulation (M&S) in the live, virtual, and constructive taxonomy. HITL models may conform to human factor requirements as in the case of a mockup. In this type of simulation, a human is always part of the simulation and consequently influences the outcome in a way that is difficult, if not impossible, to reproduce accurately. HITL also readily allows the identification of problems and requirements that may not be easily identified by other means of simulation. | HITL testing can increase business productivity and save costs. Humans can help solve problems that AI is not (yet) able to handle or to provide feedback, i.e. for reinforcement learning. Introducing human workers can reduce costs when the cost of residual errors is expensive. When only small volumes of training data are available, humans can judge at an early stage or provide the missing data by their own actions, so that AI can improve through their contributions. |

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| 43 | AI Subarea<br>AI Functional Applications | Image and Video Retrieval | Binary Large Objects (BLOBs), Content-Based Image and Video Retrieval (CBIVR) | 图像和视频检索 | Image retrieval is concerned with retrieving images relevant to users' queries from a large image data collection. Relevance is determined by the nature of the application. Many relational database systems support binary large objects (BLOBs) and facilitate access through user-defined attributes such as date, time, media type, image resolution and source. A content-based image retrieval (CBIR) system is the application of computer vision techniques in order to extract similar images from a large image database. Video retrieval involves content analysis and feature extraction, content modeling, indexing and querying. A video naturally has a hierarchy of units with individual frames at the base level and higher level segments such as shot scenes and episodes. An important task in analyzing video content is to detect segment boundaries. | Image and video retrieval has numerous applications in Industrie 4.0, including but not limited to knowledge base, predictive maintance, security, etc. |
| 44 | AI Functional Applications | Image Recognition | N/A | 图像识别 | Image recognition refers to the utilization of computer vision, pattern recognition, machine learning and other technical methods to automatically identify one or more (pre-specified) semantic concepts existing in an image. Image recognition also includes conducting an image area positioning of the identified concepts. Image recognition technology can satisfy the user's visual application demands in different scenarios, mainly including internet-oriented image retrieval and mining, human-machine dialogue and information services for intelligent terminals such as mobile devices and robots. | Image recognition uses machine vision technology's image processing, analysis and understanding functions to accurately identify a pre-set target or object pattern. The main applications in the industrial field are bar code reading, QR code scanning recognition, etc. In the past, multi-purpose NFC tags and other carriers were often used for information reading, which required close contact with the products. Along with the upgrading of hardware equipment such as industrial cameras and QR codes, other identifications can be read and recognised from a long distance, and the information carried is more abundant. In the future, all product information will be written as QR codes without the need to check information online. |

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| 45 | AI Subarea<br>AI Functional Applications | Intelligent User Interfaces | IUIs | 智能用户界面 | An intelligent user interface (IUI) tries to infer and evaluate the user's goals, and adapt its behavior to the user and the current tasks. IUI deals with topics at the intersection of human-machine interaction and machine learning. The main focus is on the practical application and adaptation of techniques and algorithms in the field of machine learning and artificial intelligence to aspects of human-machine interaction. | IUIs enable a wide range of possibilities, from email filters and email response systems to spoken dialogue systems, and head-worn user interfaces. |
| 46 | AI Functional Applications | Knowledge Acquisition | N/A | 知识获取 | Knowledge acquisition refers to the process of extracting knowledge and converting it into rules or ontologies required for a knowledge-based system. It includes defining, implementing and improving facts and relationships established by the experts. Potential knowledge sources here include the human experts themselves, but also papers, books, databases, etc. | Intelligent Manufacturing domain knowledge is complex, dynamic and stochastic. Therefore, the key to building various expert systems in Intelligent Manufacturing is to acquire knowledge from experts. This process is important yet difficult: knowledge acquisition is not only an important part of an expert system but also a significant bottleneck. |
| 47 | AI Techniques | Knowledge Graph | KG | 知识图谱 | Knowledge graphs (KG) are a knowledge base Google, Bing, Baidu and other search engines use to enhance their search capabilities. In essence, the knowledge graph is intended to describe the various entities or concepts by their relationships that exist in the real world. In this sense, the KG is a huge semantic network, in which the entities or concepts are nodes and the relationships among them are the edges. KGs can be stored in graph data bases. Today, knowledge graphs are being used for large-scale knowledge bases in a variety of knowledge domains. | Products and processes can be described in knowledge graphs. Knowledge graphs can be applied in anomaly analysis to find and handle anomalies in complex industrial processes or in given data. |
| 48 | AI Functional Applications | Language recognition | Language ID | 语言识别 | Language recognition identifies which language in a given speech fragment is expressed. According to the different recognition information used in the research, the methods can be summarized into four main methods: one based on acoustic characteristics, another on prosodic features, another on phoneme recognition and another method based on high-level language information. | N/A |

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| 49 | AI Subarea<br>AI Functional Applications<br>Other basic terms | Linked Open Data | Linked Data | 关联开放数据 | Linked Data is about using the Web to connect related data that wasn't previously linked. By interlinking the data it becomes more useful through semantic queries. The interlinked data results in a worldwide network, also known as Linked Open Data Cloud. The Term Linked Open Data is usually used when the linkage is implemented for open data. | The internet has fundamentally changed the way we share knowledge with its convenient way of information publishing and accessing. In web browsers, hypertext links allow free access to internet information. A search engine is used to retrieve the required information. By analysing the structure of links, we can also infer the relationship between different searches. The implementation of these functions is attributed to linked open data. Relevant technology and methodology can be also applied in manufacturing for data sharing and searching. |
| 50 | AI Techniques | Long Short-Term Memory (LSTM) | LSTM | 长期短期记忆 (LSTM) | Long short-term memory (LSTM) is an artificial recurrent neural network (RNN) architecture used in the field of deep learning. Unlike standard feedforward neural networks, LSTM has feedback connections that make it a "general purpose computer" (that is, it can compute anything that a Turing machine can). It can not only process single data points, but also entire sequences of data (such as speeches, videos, or time series). LSTM are a type of RNN that uses memory cells in order to maintain information in memory for long periods of time. | Applications of LSTM include: robot control, time-series prediction, handwriting recognition and several prediciton tasks in the area of process management. |
| 51 | AI Techniques | Machine Learning | ML | 机器学习 | Machine learning is a subfield of computer science that evolved from the study of pattern recognition and computational learning theory in Artificial Intelligence. In 1959, Arthur Samuel defined machine learning as a "Field of study that gives computers the ability to learn without being explicitly programmed". | Machine learning, mainly used for pattern recognition, has been vastly applied in modern manufacturing processes, for instance for visual recognition, natural language understanding and robotics. Multi-objective dynamic programming and pattern recognition is based on the characteristics that have been set. The identification model is given by the parameter setting method to achieve a discriminating purpose, a focus on solving the sensing problem of small data change and single business targets, such as production signal processing, image recognition and SPC control. Machine learning can use standard algorithms to learn historical samples to select and extract features to build and continuously optimise models. Consequently, the original system in the enterprise increases the ability of independent learning, solves uncertain business in the production process, and enhances the intelligent transformation of the system level. |

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| 52 | AI Subarea<br>AI Functional Applications | Machine Perception | N/A | 机器感知 | Machine perception is a way to enable a computer to gather, interpret, and transform sensory data. It aims to give a machine the ability to explain, in a human manner, why it is making its decisions, to warn when it is about to fail, and to provide an understandable characterization of its failures. | Machine perception is implemented in the core of Industrie 4.0, including but not limited to predictive maintenance, Intelligent Manufacturing, failure detection, etc. |
| 53 | AI Functional Applications | Machine Translation | MT, Automatic Translation | 机器翻译 | Machine translation (MT) subsumes a class of technologies and applications for translating written or spoken language from one language to another. The main paradigms of MT, rule-based MT (RBMT), example-based MT (EBMT) and statistical MT (SMT) have by now been almost completely replaced by various forms of neural machine translation (NMT). Just like statistical MT, NMT systems learn from large volumes of labeled data, where these data are usually sentence-aligned parallel texts, i.e., texts broken up into sentences, each associated with its translation by a human translator. Systems can either translate directly from language A to language B, which requires a separate translation model for each language pair, or they can translate via a selected interlingua (pivot language), usually English. | In the age of globalised industries, the workforce including supplier and maintenance partners is often multilingual. Design, production and maintenance records as well as instructions and warnings often have to be understood by staff who does not have a sufficient command of the original language. Here, MT comes in, which in technical domains often reaches human translation proficiency. |
| 54 | AI Functional Applications | Motion Detection | N/A | 运动检测 | Motion detection refers to the identification of motion and the location of an object, usually with respect to the surroundings. The detected region can provide a reference area for subsequent tasks such as target recognition and tracking, behavior analysis, etc. | Motion detection technology can enable robots to follow users to provide all-round services when working, such as helping the elderly or the disabled carry shopping bags in shopping malls or supermarkets. |

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| 55 | AI Functional Applications<br>AI Application Fields (restricted to the areas of Intelligent Manufacturing which are AI enabled) | Multi-Robot Systems | MRS | 多任务协同机器人系统 | The idea behind the multi-robot systems (MRS) is that multiple robots can cooperate to perform complex tasks that would otherwise be impossible for one single robot to accomplish. The fundamental theory behind multi-agent robotics suggests dispatching smaller sub-problems to individual robots in a group and allowing them to interact with each other to find solutions to complex problems. Simple robots can be built and made to cooperate with each other to achieve complex behaviors. It has been observed that multi-robot systems are very cost-effective as compared to building a single costly robot with all capabilities needed. As these systems are usually decentralized, distributed and inherently redundant, they are fault-tolerant and improve the reliability and robustness of the system. | Multi-robot systems can be helpful in manufacturing, supply chain management, warehouse management, etc. |
| 56 | AI Functional Applications | Named Entity Recognition | NER; Named Entity Recognition and Classification, Named Entity Classification, Entity Identification, Entity Extraction, Entity Chunking | 命名实体识别 | Named entity recognition (NER) is a task of finding entities of interest in text. Categories of named entities range from generic concepts, such as person names or time expressions, to specific concepts, such as medical codes or product names.It is a sub-task of information extraction (IE), seeking to locate and classify named entities in text into pre-defined categories. The three major approaches to NER are lexicon, rules, and machine learning algorithms. Modern approaches often employ recurrent neural network technology. | Named entity recognition can be incorporated into the following scenarios:<br>1. Automatic extraction of triples from unstructured text<br>2. Automatic extraction of structured user evaluation information<br>3. Product annotation<br>4. Identify categories of product mention elements |
| 57 | AI Subarea | Natural Language Processing (NLP) | NLP | 自然语言处理 | Natural language processing (NLP) is understanding and interpreting human languages, spoken or written, using machine processing. NLP is useful in a variety of applications including speech recognition, language translations, summarization, question answering, speech generation, and search applications. NLP is an area of research which has proven to be difficult to master. Deep learning techniques have started to solve some of the issues involved in natural language processing. | Natural language processing can be used as a cloud service or a local service, and is used in information extraction, problem answering, machine translation, etc., and is suitable for reporting in many vertical industries such as automotive, retail and consumer goods, high-tech electronics, government public administration, banking, business, financial services and insurance, healthcare and life sciences, research and education, media and entertainment, etc. |

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| 58 | AI Techniques | No-code Machine Learning | N/A | 无代码器学习 | No-code machine learning comprises a group of methods, tools and platforms that enable users to apply machine learning techniques to data sets without having to write program codes or scripts that require programming skills. The concept overlaps with the idea of automated machine learning but it also applies to rather simple applications of ready-made ML tools such as the extended Waikato Environment for Knowledge Analysis (WEKA) tools without offering the automated search for optimal hyperparameters and other (partially AI driven) automated methods for stepwise performance enhancement. | No-code machine learning is now offered for an increasing set of application types by the providers of powerful multi-purpose AI platforms such as the ones of AWS, Azure or Baidu. |
| 59 | AI Functional Applications | Object Detection | N/A | 目标检测 | Object detection is a task in computer vision dealing the detection of instances of semantic objects of a certain class (such as humans, faces, buildings, or cars) in digital images, videos or 3D frames. Recent advances came with the use of deep convolutional neural networks (DCNN). Typical methods employ one of the two main alternatives:<br>1. A single-stage model such as SSD (Single Shot MultiBox Detector), YOLO (You Only Look Once) or RetinaNet<br>2. A two-stage model such as R-CNN (Regional convolutional neural networks), Fast RCNN, Faster RCNN, Feature Pyramid Network (FPN) | Object detection by using machine learning techniques supports the analysis of manufacturing information, such as quality management/control, sorting, assembly line of manufacturing process.<br>1. Real-time object detection and tracking;<br>2. Apply to industrial robot control;<br>3. Automated inspection (automate inefficiency out of its production processes and bringing in high-speed consistency; example: Seagate) |
| 60 | AI Functional Applications | Object Recognition | N/A | 物体识别 | Object recognition is a computer vision technique for identifying objects in images or videos. The recognition procedure consists of the following steps:<br>1. Extract local features from both the training and test images independently.<br>2. Match the feature sets to find putative correspondences.<br>3. Verify if the matched features occur in a consistent geometric configuration. | Object recognition solutions are widely perceived as one of the emerging technologies driving the innovation of Industrie 4.0.<br>1. Applied in a robotic machine and automated guided vehicles (AGVs)<br>2. High-speed camera for moving object recognition and scanning<br>3. Quality control and defects inspection<br>4. Inventory management |

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| 61 | AI Functional Applications | Opinion Mining/ Opinion Extraction | Opinion Extraction | 意见挖掘 / 意见提取 | Given a set of text documents that contain opinions (or sentiments) about an object, opinion mining aims at extracting attributes and components of the object that have been commented on in each document, and determining whether the comments are positive, negative or neutral. It has two main research directions: document-level opinion mining and feature-level opinion mining. AI Technologies used for opinion extraction help to efficiently and effectively analyze text and to discover valuable and relevant knowledge from it in the form of structured information.<br>Note: To clarify, 'opinion' and 'sentiment' are treated as similar terminology, although they are not exactly equivalent. The term ‚opinion' has broader coverage, which includes terms such as sentiment, evaluation, appraisal, attitude, or emotion. | First, opinion mining and extraction could be applied to evaluate customer satisfaction or be used to find out customer needs for the production of customised products.<br>Second, opinion extraction in combination with AI-driven NLP could be deployed in remote virtual assistant or an interactive AI robot to empower human machine dialogue or communication. The feature helps with troubleshooting and ordering Pay-Per-View events in various industries including intelligent manufacturing setting. (Tata Consultancy Services, 2020, https://www.tcs.com/content/dam/tcs/pdf/Industries/communication-media-and-technology/Abstract/Making-NLP-Work.pdf). |
| 62 | AI Functional Applications | Predictive Analytics | N/A | 预测分析 | Predictive analytics encompasses a variety of statistical techniques from data mining, predictive modeling, and machine learning, that analyze current and historical facts to make predictions about future or otherwise unknown events.  A predictive model can, for instance, help detect fraudulent transactions. Relevant analytics techniques are primarily based on statistical models (especially regression and time-series analysis techniques) and are subdivided into two groups. The first group attempts to discover historical patterns in the outcome variable(s) and extrapolate them to the future, such as moving average. The second aims to capture the interdependencies between outcome variable(s) and explanatory variables, and exploit them to make predictions. | Predictive analytics operates at the core of the Industrial Internet of Things (IIoT), where it takes connected sensors and intelligent devices and integrates them directly on the manufacturing floor, collecting data for AI-driven predictive analytics.<br>With predictive analytics, three capabilities are leveraged to solve problem for industries, which are (1) predict probability of outcomes, (2) forecast, (3) value function estimation. In an telligent manufacturing scenarios, the techniques are embodied in the typical processes such as:<br>1. Fault detection and failure prediction (makes a probabilistic diagnosis of the cause of failure and suggests remedies). Also, with sensor data collected and the maching learning, it enables the industries to build an early warning systems with artificial intelligence predict defects<br>2. Quality control modeling, when using forecasting of process outcomes based on the values of variables<br>3. Product demand forecasting<br>4. Cost modeling for pricing |

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| 63 | AI Functional Applications | Predictive Maintenance | N/A | 预测性维护 | Predictive maintenance techniques are designed to help determine the condition of in-service equipment (e.g., railways, streets or parts of a power plant) in order to estimate when maintenance should be performed. Narrowly speaking, it provides a tool for monitoring the critical processes, machinery efficiencies and other parameters that can severely limit productivity and product quality. Through the monitoring, operating costs can be reduced, as , tasks are performed only when required. However, a comprehensive predictive maintenance program must include other monitoring and diagnostic techniques, for instance, vibration monitoring, thermography, tribology, process parameters, visual inspection, ultrasonics, and other nondestructive testing techniques. | Predictive maintenance allows manufacturers to dynamically enhance maintenance management decisions so that the total operating costs (associated with unexpected breaks and unexploited equipment lifetime that can occur over time) are minimised.<br><br>Predictive maintenance can be applied for quality improvement, scheduled or planned maintenance, as well as predicting the lifecycle of equipment. |
| 64 | AI Techniques | Recurrent Neural Network (RNN) | RNN | 循环神经网络 | A recurrent neural network (RNN) is a class of artificial neural network where connections between units form a directed acyclic cycle. This creates an internal state of the network which allows it to exhibit dynamic temporal behavior. Unlike feedforward neural networks, RNNs can use their internal memory to process arbitrary sequences of inputs. RNNs performs the same function for every input of data while the output of the current input depends on the previous computation. Standard RNNs suffer from vanishing and exploding gradient problems. Therefore, Long Short Term Memory (LSTM) or Gated Recurrent Units (GRU) are more frequently employed than standard RNNs. | Applications of recurrent neural networks include: machine translation, robot control, time-series prediction, human action recognition and predicting subcellular localisation of proteins. |

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| 65 | AI Techniques | Reinforcement Learning | RL | 强化学习 | Reinforcement learning (RL) is an area of machine learning concerned with how software agents ought to take actions in an environment so as to maximize some notion of cumulative reward. Reinforcement learning is one of three basic machine learning paradigms, alongside supervised learning and unsupervised learning. Reinforcement learning differs from supervised learning in not needing labeled input/output pairs and the agent is not shown which action is the best in which situation, but receives a reward/punishment at certain times. Using these rewards, the agent approximates a utility function that describes the value of a certain state or action. | Applications of reinforcement learning include: intelligent robotics, dialogue system and autonomous driving. |
| 66 | AI Techniques | Relational/ Graph-Based Learning | N/A | 基于关系 / 图谱的学习 | Graph-based learning is a machine learning algorithm that uses the underlying structure in the data to jointly model known information (annotated information) and new information (unannotated information) to mine data relationships and combine them into a single graphical representation to learn these data. | The algorithm is now widely used to recognize and understand concepts in natural language, images, videos and queries, and supports many applications and products, including: reminders, Q & A, language translation, visual object world, dialogue understanding, etc. |
| 67 | AI Subarea<br>AI Functional Applications | Robotics | Robot Technology, Robot Engineering | 机器人学 | In 1988, Espio of France defined robotics as: "Robotics is the design of a pre-planned operating system based on sensor information, and the use of the system as the research object". Robotics is a science related to the design, manufacturing and application of robots. Also known as robotics or robotic engineering, it mainly studies the relationship between the control of robots and the object being processed. Robotics is a new and comprehensive subject, which involves mechanical engineering, electrical engineering, microelectronic engineering, computer engineering, control engineering, information sensing engineering, acoustic engineering, bionics engineering and Artificial Intelligence engineering. | Robotics is the theoretical basis for manufacturing various types of robots. Industrial robots are the most representative equipment for Intelligent Manufacturing. The application of industrial robots requires the comprehensive combination of Artificial Intelligence, sensors, mechanical, electrical, control, and many other technologies, and it has become a more and more important manufacturing methodology in the manufacturing industry. |

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| 68 | AI Functional Applications | Scene Analysis | Visual Analysis | 场景分析 | Scene analysis deals with the examination of 2D or 3D, static or dynamic scenes. Early scene analysis systems were primarily concerned with static scenes. (Dynamic) scene analysis, referred to as analyzing time-varying imagery, is concerned with the processing of a sequence or a collection of images. The input for scene analysis is a sequence of image frames involving multi-viewpoint, multi-category object detection, which requires a large amount of data being processed by the machine. | In industrial automation, there is an increasing demand for computer vision systems and scene analysis systems. They can be applied to:<br>1. Quality monitoring such as inspection and fault detection during production<br>2. Workspace mechanical manipulators with interactive 3D scene segmentation and analysis<br>3. Maintenance aids<br>4. Real-time 3D tracker |
| 69 | AI Techniques | Search and Constraint Satisfaction | N/A | 搜索和约束满足 | Constraint satisfaction problems (CSPs) are mathematical questions defined as a set of objects whose state must satisfy a number of constraints. The problem is solved, iff all constraints for all introduced variables satisfied. Many of these problems exhibit a high complexity and therefore a large search space. To this end, a combination of heuristics and combinatorial search methods are used to find a solution. | The constraint satisfaction problem and its searching method are a common method which can be used in many scenarios such as Intelligent Manufacturing. |
| 70 | AI Functional Applications | Semantic Product Memory | SemProM, Semantic Product Memories | 语义产品记忆 | Semantic product memory is an open-loop product memory, employs smart labels in order to give products a digital memory, thus, supporting intelligent applications along the product's lifecycle. Semantic product memory is also categorized as a type of digital product memories (DPMs). It enables the products to act as an information container, agent and observer by empowering them with integrated dynamic digital storage, sensing, and wireless communication capabilities. | By utilising integrated sensors, relations in the production processes become transparent and supply chains as well as environmental influences retraceable. Semantic product memory could be applied to: Distributed production control; Tracking of critical parameters; Self-diagnosis and condition-based maintenance. |

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| 71 | AI Functional Applications | Semantic Web | N/A | 语义网 | Semantic web represents is an extension of the world wide web through standards by the world wide web consortium (W3C), so as to semantically link relationships between web resources, real world resources, and concepts through the use of linked data. Therefore, the Semantic Web is about making links between datasets that are understandable not only to humans, but also to machines, and Linked Data provides the best practices for making these links possible. According to the W3C, the semantic web provides a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries. | There has been much emphasis on building the Digital Object Architecture for Industrial Internet based on semantic net technologies, to address the cross-domain interoperability problems. A lack of interoperability in Automation Systems (AS) used in the manufacturing process makes it harder to digitalize and automate the manufacturing process. Semantic modeling of the Web of Things -enabled devices, their services and applications provide un-ambiguous and machine-readable device descriptions and also creates interoperability between the devices and their services across domains. (Siemens AG, 2017)<br><br>As proposed by International Telecommunication Union, a unified Digital Object Architecture aims to formulate a framework for interoperability.<br><br>In the Joint EU-China White Paper on IoT Identification, they bring up an integrated solution of semantic interoperability with specified standards on IoT identifiers (Object Identifiers, Communication Identifiers, Application Identifiers), in order to leverage data and services from multiple heterogeneous IoT systems.<br><br>Such IoT Identifiers could be leveraged in Energy Management Applications, Supply Chain Management and Logistic, Urban Mobility Applications, Defense and Intelligence Application. |

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| 72 | AI Subarea | Semi-supervised Learning | SSL | 半监督学习 | Semi-supervised learning (SSL) refers to methods that attempt to take advantage of unlabeled data for supervised learning or to incorporate prior information such as class labels, pairwise constraints or cluster membership in the context of unsupervised learning. SSL falls between unsupervised learning (with no labeled training data) and supervised learning (with only labeled training data). | Semi-supervised learning will be most useful whenever there are far more unlabeled data than labeled. This is likely to occur if obtaining data points is cheap but obtaining the labels costs a lot of time, effort, or money. This is the case in many application areas of machine learning. For example, in speech recognition, it costs almost nothing to record huge amounts of speech but labeling it requires some human to listen to it and type a transcript. Billions of webpages are directly available for automated processing, but to classify them reliably, humans have to read them. Protein sequences are nowadays acquired at industrial speed (by genome sequencing, computational gene finding, and automatic translation) but to resolve a three-dimensional (3D) structure or to determine the functions of a single protein may require years of scientific work. |
| 73 | AI Functional Applications | Sentiment Analysis | Opinion Mining | 情绪分析 | Sentiment analysis, also called opinion mining, is the field of study that analyzes people's opinions, sentiments, evaluations, appraisals, attitudes, and emotions towards entities such as products, services, organizations, individuals, issues, events, topics, and their attributes (Liu, 2012). Generally speaking, sentiment analysis aims to determine the attitude of a speaker, writer, or other subjects for some topics or the overall contextual polarity or emotional reaction to a document, interaction, or event. The attitude may be a judgment or evaluation, affective state, or the intended emotional communication. | The application could be related to evaluating customer satisfaction but it is still of low relevance to Industrie 4.0.<br><br>Sentiment analysis is widely applied to the voice of the customer such as in reviews and survey responses, online and social media, and healthcare materials for applications that range from marketing to customer service to clinical medicine. |

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| 74 | AI Functional Applications<br>Other basic terms | Social Cognition and Interaction | N/A | 社会认知与互动 | Social cognition is a sub-topic of social psychology that focuses on how people process, store, and apply information about other people and social situations. Thus, it is concerned with the role that cognitive processes play in social interactions. Human-robot symbiosis requires not only channels of explicit/implicit communication but also the capability to access and/or anticipate the partner's internal states and intentions during a cooperative task. For example, a verbal exchange may be sufficient to identify the goal of a shared task but the skilled sequence of actions that follow require a deep mutual understanding of what is going on, including both overt and covert actions of both partners. This means that a symbiotic robot must share an overall cognitive architecture with the human partners. | In Industrie 4.0, robots, as cyber-physical systems, will have to interact safely with human colleagues as cooperating robots or "cobots," with the final goal of achieving intelligent cobot technologies with full cognitive capabilities. |
| 75 | AI Functional Applications | Speaker Recognition | Voice Recognition | 说话者识别 / 声纹识别 | Speaker recognition is the task of recognizing individuals from their voices. Speaker recognition is based on the extraction and modeling of acoustic features of speech that can differentiate individuals. These features conveys two kinds of biometric information: physiological properties (anatomical configuration of the vocal apparatus) and behavioral traits (speaking style). Hennebert J. (2009) declines automatic speaker recognition technology into four major tasks, speaker identification, speaker verification, speaker segmentation, and speaker tracking. | Manufacturers are increasingly implementing voice-driven technologies in the industrial environment. Considering an industrial environment involving human-machine collaboration, voice control facilitates access to information through hands-free, intuitive and efficient interaction. Hence, it can be integrated with process management devices and systems, and enterprise resources management (ERP). It could also be deployed in automation to support manufacturing. |

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| 76 | AI Subarea<br>AI Functional Applications | Speech Processing | N/A | 语音处理 | Speech processing is the study of speech signals and processing methods. The speech signals are usually processed in a digital representation, so that it can be regarded as a special case of digital signal processing. Aspects of speech processing include the acquisition, manipulation, storage, transfer, and output of speech signals. Speech processing technologies are used for digital speech coding, spoken language dialog systems, text-to-speech synthesis, and automatic speech recognition. Information (such as speaker, gender, language identification, or speech recognition) can also be extracted from speech. | The application of speech processing in Intelligent Manufacturing can be used among others for speech recognition, speaker verification, interactive voice responding system and more. |
| 77 | AI Functional Applications | Speech Synthesis | Speech Generation, Text-To-Speech (TTS) | 语音生成，语音合成 | Speech generation is the artificial production of human speech. It is also termed as speech synthesis or text-to-speech (TTS). A text-to-speech system is composed of two parts: a front-end and a back-end. Broadly, the front-end takes input in the form of text and outputs a symbolic linguistic representation. The back-end takes the symbolic linguistic representation as input and outputs the synthesized speech waveform. | By integrating speech synthesis into solutions, manufacturers can achieve an automatic intelligent quality assessment, replacing the process of human workers collecting customer feedback and reviews. Also, TTS can be embedded into customer service to streamline the work of agent. |
| 78 | AI Functional Applications | Speech Translation | N/A | 语音翻译 | Speech translation is the process of conversationally spoken phrases being instantly translated and spoken aloud in a second language. Such systems have usually been broken into three separate components: automatic speech recognition to transcribe the source speech as text, machine translation to translate the transcribed text into the target language, and text-to-speech synthesis (TTS) to synthesize speech in the target language. | Industrie 4.0 is a worldwide process relying on several technologies with users being from multiple locations and speaking different languages that need to handle a growing volume of data adding to the multiplicity of communication formats and channels. Speech translation eliminates the language bottleneck and enables systematic communication and information exchange. |

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| 79 | AI Functional Applications | Speech Verification | Utterence Verification (UV) | 语音验证 | Utterance verification (UV) is a process by which the output of a speech recognizer is used to determine if the input speech includes specific keyword(s). To some extend this ensures the correctness of the output of a speech recognition algorithm. | In automatic speech recognition applications, it is often necessary to provide a mechanism for verifying the accuracy of portions of recognition hypotheses. Utterance Verification is most often considered as a hypothesis testing problem. Existing techniques rely on a speech recogniser to produce a hypothesised word or string of words along with hypothesised word boundaries obtained through viterbi segmentation of the utterance. A measure of confidence is then assigned to the hypothesised string, and the hypothesised word labels are accepted or rejected by comparing the confidence measure to a decision threshold. |
| 80 | AI Techniques | Supervised Learning | N/A | 监督学习 | Supervised learning is the machine learning task of learning a function that maps an input to an output based on example input-output pairs (i.e., training data). Each example pair consists of the respective input and the desired output value. The supervised learning algorithm analyzes the training data and produces an inferred function, which can be used to label new, previously unseen, examples. This requires the learning algorithm to generalize from the training data to unseen data. | Bioinformatics, cheminformatics, quantitative structure–activity relationship, database marketing, handwriting recognition, information retrieval, information extraction, object recognition in computer vision, optical character recognition, spam detection, and pattern recognition. |
| 81 | AI Functional Applications | Text Mining | N/A | 文本挖掘 | Text mining is the process of analyzing written resources in order to capture key concepts, themes or uncover hidden relationships and trends. The overarching goal essentially is to turn text into data for analysis, by the use of natural language processing techniques. Text mining may involve many tasks, such as information extraction, information retrieval, data-visualization, and many more. | Text mining has the potential to be the next generation decision-making technology for sustainable knowledge management solutions in any industrial environment. It can obtain valuable information in free text fields from maintenance protocols, thus, boosting the performance of predictive maintance algorithms. |

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| 82 | AI Techniques | Transfer Learning | N/A | 迁移学习 | Transfer learning is a machine learning method that reuses a pre-trained model for another, usually somehow related, task. For example, a model capable of identifying cars in images should be transferable to recognize trucks. In many cases, transfer learning is achieved by presenting the model a small number of training instances for the novel task. Transfer learning is therefore a useful technique to reduce the burden to label new training data. | By using transfer learning, the in an Intelligent Manufacturing scenario pre-trained model can also be applied to another similar but unlabeled Intelligent Manufacturing scenario, thereby, training an applicable model. This will revolutionise the production, acquisition, application and transmission efficiency of Intelligent Manufacturing knowledge and significantly improve innovation and service capabilities. |
| 83 | AI Functional Applications | Trend Spotting | N/A | 趋势发现 | Trend spotting refers to the identification of new trends, opportunities and patterns. Machine learning algorithms significantly improve the abilities to analyze big data in order to find trends that may otherwise be overlooked. | Trend Spotting fosters "Supply Chain 4.0", promising to reduce inefficiencies and lower costs while improving flexibility. |
| 84 | AI Techniques | Unsupervised Learning | N/A | 无监督学习 | Unsupervised learning is a type of machine learning in which an algorithm solves all kinds of pattern/model recognition problems on the basis of training samples whose categories are unknown (not labeled). Frequently found examples for unsupervised machine learning algorithms are some clustering-techniques, neural autoencoders, or latent variable modeling. | Intelligent Manufacturing scenarios are complex and diverse, and the amount of training samples is immense. If all of them rely on labeled data, the overall progress will be very slow. The application of effective unsupervised learning methods can alleviate the need for labeled data in Intelligent Manufacturing scenario training, thus, improving the training efficiency and accuracy. |

# Annex
## Sources and further literature:


Aäron van den Oord and etc., "WAVENET: A General Model For Raw Audio", 2016.

Abhang, Priyanka & Gawali, Bharti & Mehrotra, Suresh. (2016). Technological Basics of EEG Recording and Operation of Apparatus. 10.1016/B978-0-12-804490-2.00002-6.

About text mining. https://www.ibm.com/support/knowledgecenter/SSQNUZ_2.5.0/wsd/nodes/_nodes_TA_intro.html

Ahmed, M., Riyaz, R., & Afzal, S. (2013). A comparative study of various approaches for dialogue management. Compusoft, 2(4), 89.

AI Security White Paper, Huawei 2018, https://www-file.huawei.com/-/media/corporate/pdf/cyber-security/ai-security-white-paper-en.pdf

Andres Felipe Barco Santa, Élise Vareilles, Paul Gaborit, Jean-Guillaume Fages, Michel Aldanondo. Industrialized Building Renovation: Manufacturing Through a Constraint-Based On-line Support System. IEEM 2015 - IEEE International Conference on Industrial Engineering and Engineering Management, Dec 2015, Singapore, Singapore. pp.947-951. ffhal-01599433f

Appen (2019) What is Human-in-the-Loop Machine Learning? https://appen.com/blog/human-in-the-loop/

Artificial Intelligence, Machine Learning and Cognitive Computing. https://www.ibm.com/blogs/nordic-msp/artificial-intelligence-machine-learning-cognitive-computing

AutoML: The Next Wave of Machine Learning in September, 2020. https://favouriteblog.com/automl-the-next-wave-of-machine-learning

Bäck, T., Fogel, D. B., & Michalewicz, Z. (1997). Handbook of evolutionary computation. CRC Press.

Bastian Leibe, Nico Cornelis, Kurt Cornelis, Luc Van Gool, "Dynamic 3D Scene Analysis from a Moving Vehicle", https://ieeexplore.ieee.org/abstract/document/4270171

Bates, J. (1994). The role of emotion in believable agents. Communications of the ACM, 37(7), 122-125.

Bengio, Samy; Goodfellow, Ian J.; Kurakin, Alexey (2017). "Adversarial Machine Learning at Scale". Google AI. Retrieved 2018-12-13.

Berthold M R , Borgelt C , Frank Höppner, et al. Intelligent Data Analysis[J]. Technometrics, 1998, 42(4):442-442.

Bing Liu. "Sentiment Analysis and Opinion Mining", Morgan & Claypool Publishers, May 2012.

Bizer C, Heath T, Idehen K, et al. Linked data on the web (LDOW2008)[C]//Proceedings of the 17th international conference on World Wide Web. ACM, 2008: 1265-1266.

Brooks, R. Cambrian Intelligence: The Early History of the New AI, Cambridge, MA:MIT Press, 1999.

Burden, D. J. (2008, December). Deploying embodied AI into virtual worlds. In International Conference on Innovative Techniques and Applications of Artificial Intelligence (pp. 103-115). Springer, London

Cambria, E., Olsher, D., & Rajagopal, D. (2014, June). SenticNet 3: a common and common-sense knowledge base for cognition-driven sentiment analysis. In Twenty-eighth AAAI conference on artificial intelligence.

Chandola V, Banerjee A, Kumar V. Anomaly Detection: A Survey[J]. Acm Computing Surveys, 2009, 41(3):1-58.

Chandola, V., Banerjee, A., & Kumar, V. (2009). Anomaly detection: A survey. ACM computing surveys (CSUR), 41(3), 1-58.

Chapelle, O., B. Schölkopf and A. Zien. Semi-Supervised Learning. in Pacific-asia Conference on Advances in Knowledge Discovery & Data Mining. 2009.

Chigier B . Automatic speech recognition[J]. The Journal of the Acoustical Society of America, 1998, 103(1):19-20.

Chowdhury G G . Natural language processing[J]. Annual Review of Information Science and Technology, 2005, 37(1):51-89.

Collins, H. (2010). Tacit and explicit knowledge. University of Chicago Press.

Collobert R, Weston J, Bottou L, et al. Natural language processing (almost) from scratch[J]. Journal of machine learning research, 2011, 12(Aug): 2493-2537.

Craig, John J. Introduction to Robotics: Mechanics and Control[M]. 1955.

Dave, Kushal, and et al, "Mining the Peanut Gallery: Opinion Extraction and

David Nadeau, Satoshi Sekine, "A survey of named entity recognition and classification", New York University, https://nlp.cs.nyu.edu/sekine/papers/li07.pdf

Design and Implementation of Text-To-Speech/Audio System. https://iproject.com.ng/computer-science/design-and-implementation-of-text-to-speechaudio-system/index.html

DG Lowe, "Distinctive Image Features From Scale-Invariant Keypoints", International Journal of Computer Vision (2004), https://www.cs.ubc.ca/~lowe/papers/ijcv04.pdf

DG Lowe., "Object Recognition from Local ScaleInvariant Features", (1999), https://www.cs.ubc.ca/~lowe/papers/iccv99.pdf

Digital Twin Technology. Zongyan, W. (2018). https://www.intechopen.com/books/industry-4-0-impact-on-intelligent-logistics-and-manufacturing/digital-twin-technology

Dong Shihai. Progress and challenges of human-computer interaction[J]. Journal of Computer Aided Design and Graphics. 2004, 16 (1): 1 – 13.

Edge AI Use Cases: https://www.imagimob.com/resources/tags:White%20papers

Elaine Marsh, Dennis Perzanowski, "MUC-7 Evaluation of IE Technology: Overview of Results", April 1998, https://www-nlpir.nist.gov/related_projects/muc/proceedings/muc_7_proceedings/marsh_slides.pdf

Elie Aljalbout, Vladimir Golkov, Yawar Siddiqui, Maximilian Strobel, Daniel Cremers: Clustering with Deep Learning: Taxonomy and New Methods arXiv:1801.07648

Encyclopedia of Cognitive Science, Semantic Networks, 2016 January, John F. Sowa, https://onlinelibrary.wiley.com/doi/abs/10.1002/0470018860.s00065

Ferguson, M. K., Ronay, A., Lee, Y. T. T., & Law, K. H. (2018). Detection and Segmentation of Manufacturing Defects with Convolutional Neural Networks and Transfer Learning. Smart and sustainable manufacturing systems, 2.

Feurer M, Klein A, Eggensperger K, Springenberg J, Blum M, Hutter F (2015). "Efficient and Robust Automated Machine Learning". Advances in Neural Information Processing Systems 28 (NIPS 2015): 2962–2970.

Fogel, D. B. (2006). Evolutionary computation: toward a new philosophy of machine intelligence (Vol. 1). John Wiley & Sons.

Franklin, S. (1997). Autonomous agents as embodied AI. Cybernetics & Systems, 28(6), 499-520.

Goldberg, David (1989). Genetic Algorithms in Search, Optimization and Machine Learning. Reading, MA: Addison-Wesley Professional. ISBN 978-0201157673.

Goodfellow, Ian; Pouget-Abadie, Jean; Mirza, Mehdi; Xu, Bing; Warde-Farley, David; Ozair, Sherjil; Courville, Aaron; Bengio, Yoshua (2014). Generative Adversarial Networks (PDF). Proceedings of the International Conference on Neural Information Processing Systems (NIPS 2014). pp. 2672–2680

Google Team, "TACOTRON: Towards End-To-End Speech Synthesis", 2017.

Gorecky, Dominic & Schmitt, Mathias & Loskyll, Matthias & Zühlke, Detlef. (2014). Human-machine-interaction in the industry 4.0 era. 289-294. 10.1109/INDIN.2014.6945523.

Goudas, T., Louizos, C., Petasis, G., & Karkaletsis, V. (2014, May). Argument extraction from news, blogs, and social media. In Hellenic Conference on Artificial Intelligence (pp. 287-299). Springer, Cham.

Gryaznov, N. and A. Lopota, Computer Vision for Mobile On-Ground Robotics. Procedia Engineering, 2015. 100: p. 1376-1380.

Gunning, D. (2017). Explainable artificial intelligence (xai). Defense Advanced Research Projects Agency (DARPA), nd Web, 2.

Guo Liang. Progress in the Application of Digital Twin in Manufacturing [J]. Mechanical Science and Technology. 2019: 1 – 12.

Hady, M.F.A. and F. Schwenker, Semi-supervised Learning. Journal of the Royal Statistical Society, 2006. 172(2): p. 530-530.

Hansen, E. A., & Zhou, R. (2007). Anytime heuristic search. Journal of Artificial Intelligence Research, 28, 267-297.

Harsh, P. (2016). The best explanation of Convolutional Neural Networks on the Internet! https://medium.com/technologymadeeasy/the-best-explanation-of-convolutional-neural-networks-on-the-internet-fbb8b1ad5df8

Hart, P. E., Nilsson, N. J., & Raphael, B. (1968). A formal basis for the heuristic determination of minimum cost paths. IEEE transactions on Systems Science and Cybernetics, 4(2), 100-107.

Hartley, R. and A. Zisserman, Multiple View Geometry in Computer Vision. Kybernetes, 2008. 30(9/10): p. 1865 - 1872.

Havasi, C., Speer, R., & Alonso, J. (2007, September). ConceptNet 3: a flexible, multilingual semantic network for common sense knowledge. In Recent advances in natural language processing (pp. 27-29). Philadelphia, PA: John Benjamins.

He, B., & Bai, K. J. (2020). Digital twin-based sustainable intelligent manufacturing: a review. Advances in Manufacturing, 1-21.

Hennebert, Jean. Encyclopedia of Biometrics, Speaker Recognition Overview. https://www.researchgate.net/publication/242800410_Encyclopedia_of_Biometrics_Speaker_Recognition_Overview

Holzinger, A. (2018, August). From machine learning to explainable AI. In 2018 World Symposium on Digital Intelligence for Systems and Machines (DISA) (pp. 55-66). IEEE.

https://en.wikipedia.org

https://github.com/marcotav/natural-language-processing/blob/master/sentiment-analysis/README.md

https://samim.io/p/2019-12-15-abductive-reasoning/

https://www.affectiva.com/emotion-ai-overview

https://www.definitions.net/definition/explicit+knowledge

https://www.sciencedirect.com/topics/immunology-and-microbiology/interactive-voice-response-system

IEEE Conference on Computer Vision and Pattern Recognition 2014, "Rich feature hierarchies for accurate object detection and semantic segmentation".

Important Topics in Machine Learning You Need to Know. https://towardsdatascience.com/important-topics-in-machine-learning-you-need-to-know-21ad02cc6be5

Industry 4.0 and Cognitive Manufacturing. https://www.ibm.com/downloads/cas/M8J5BA6R

Introducing New Levels of Transparency with AI – Thought Leaders. https://www.unite.ai/introducing-new-levels-of-transparency-with-ai-thought-leaders

Jerry R. Hobbs, Mark Stickel, Douglas Appelt, and Paul Martin. Interpretation as abduction. Artificial Intelligence, 63:69–142, 1993.

Ji Genlin, Shuai Ke, Sun Zhiwei. Data mining technology and its application [J]. Journal of Nanjing Normal University (Natural Sciences Version). 2000, 23 (2): 25 – 27.

Jia, Y., Weiss, R. J., Biadsy, F., Macherey, W., Johnson, M., Chen, Z., & Wu, Y. (2019). Direct speech-to-speech translation with a sequence-to-sequence model. arXiv preprint arXiv:1904.06037.

Jiang Shuqiang, Min Weiqing, Wang Shuwei. Overview and Prospect of intelligent interactive image recognition technology [J]. Computer Research and Technology. 2016, 53 (1): 113 – 122.

Joint EU-China White Paper on IoT Identification, 2014, China Academy of Telecommunication Research (CATR) & Research Cluster on the Internet-of-Things (IERC), https://www.theinternetofthings.eu/john-soldatos-joint-eu-china-white-paper-iot-identification

Kamila, N. K. (Ed.). (2015). Handbook of research on emerging perspectives in intelligent pattern recognition, analysis, and image processing. IGI Global.

Kerly, A., P. Hall and S. Bull, Bringing chatbots into education: Towards natural language negotiation of open learner models. Knowledge-Based Systems, 2007. 20(2): p. 177-185.

Kolodner, Janet. Case-Based Reasoning. San Mateo: Morgan Kaufmann, 1993.

Korf, R. E. (1985). Depth-first iterative-deepening: An optimal admissible tree search. Artificial intelligence, 27(1), 97-109.

Krizhevsky, A.; Sutskever, I.; Hinton, G. E. (2012). "Imagenet classification with deep convolutional neural networks". Advances in Neural Information Processing Systems. 1: 1097–1105.

Lake, Brenden, et al. (2011) One shot learning of simple visual concepts. Proceedings of the Annual Meeting of the Cognitive Science Society. Vol. 33. No. 33.; Qiao, Siyuan, et al. (2017) Few-shot image recognition by predicting parameters from activations. CoRR, abs/1706.03466 1; Qianru Sun Yaoyao Liu Tat-Seng Chua Bernt Schiele (2019) Meta-Transfer Learning for Few-Shot Learning, arXiv:1812.02391

Learning-based scheduling of flexible manufacturing systems using case-based reasoning. P. Priore , D. de la Fuente & R. Pino.

LeCun, Yann; Bengio, Yoshua; Hinton, Geoffrey (2015). "Deep learning". Nature. 521 (7553): 436–444.

Lee K F. Automatic speech recognition: the development of the SPHINX system[M]. Springer Science & Business Media, 1988.

Li Wujun, Wang Chongjun, Zhang Wei, et al. Review of Face Recognition [J]. Pattern Recognition and Artificial Intelligence. 2006, 19 (1): 58 - 66.

Lin and et al, "Focal Loss for Dense Object Detection", ICCV 2017.

Liu Boyuan, Fan Wenhui, Xiao Tianyuan. Analysis of the status quo of DSS [J]. Journal of System Simulation. 2011, 23: 241 - 244.

Liu, B. (2012). Sentiment analysis and opinion mining. Synthesis lectures on human language technologies, 5(1), 1-167.

Manning C D, Manning C D, Schütze H. Foundations of statistical natural language processing[M]. MIT press, 1999.

Marc'Aurelio Ranzato, F. J. H., Boureau, Y. L., & LeCun, Y. (2007, June). Unsupervised learning of invariant feature hierarchies with applications to object recognition. In Proc. Computer Vision and Pattern Recognition Conference (CVPR'07). IEEE Press (Vol. 127).

Masters, R. S. (1992). Knowledge, knerves and know - how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. British journal of psychology, 83(3), 343-358.

McKinsey Global Institue, "The Age of Analytics: Competing in a Data-Driven World", https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/the-age-of-analytics-competing-in-a-data-driven-world#

McTear M F. Spoken dialogue technology: enabling the conversational user interface[J]. ACM Computing Surveys (CSUR), 2002, 34(1): 90-169. McTear M F. Spoken dialogue technology: toward the conversational user interface[M]. Springer Science & Business Media, 2004.

McTear M F. Spoken dialogue technology: toward the conversational user interface[M]. Springer Science & Business Media, 2004.

Melo, H. P. M., Franks, A., Moreira, A. A., Diermeier, D., Andrade Jr, J. S., & unes Amaral, L. A. (2013). A Solution to the Challenge of Optimization on''Golf-Course''-Like Fitness Landscapes. PloS one, 8(11), e78401.

Minsait, Advanced analytics for Industry 4.0, September 2018, https://www.minsait.com/sites/default/files/newsroom_documents/analitica_avanzada_para_la_industria_4_en.pdf

Murch, R. (2004). Autonomic computing. Ibm Press. [2] Kephart, J. O., & Walsh, W. E. (2004, June). An artificial intelligence perspective on autonomic computing policies. In Proceedings. Fifth IEEE International Workshop on Policies for Distributed Systems and Networks, 2004. POLICY 2004. (pp. 3-12). IEEE.

Nir, A. (2018). How LSTM networks solve the problem of vanishing gradients. https://medium.com/datadriveninvestor/how-do-lstm-networks-solve-the-problem-of-vanishing-gradients-a6784971a577

Object Memory Modeling. https://www.w3.org/2005/Incubator/omm/XGR-omm-20111026

Oduguwa, V., Tiwari, A., & Roy, R. (2005). Evolutionary computing in manufacturing industry: an overview of recent applications. Applied Soft Computing, 5(3), 281-299.

Ojokoh, B. A., & Kayode, O. (2012). A feature-opinion extraction approach to opinion mining. Journal of web engineering, 11(1), 51.

Osmar R. Zaïane: “Principles of Knowledge Discovery in Databases - Chapter 8: Data Clustering”.

Ou Yangzhi, Xiao Xu. Application of Machine Vision in Intelligent Manufacturing [J]. Big Data Age. 2018, 12: 9 – 12.

Picard, Rosalind W. (1997). Affective computing. Cambridge, Massachusetts: MIT Press.

Quinn, A. J., & Bederson, B. B. (2011, May). Human computation: a survey and taxonomy of a growing field. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 1403-1412). ACM.

R.K. Mobley. "An Introduction to Predictive Maintenance - A Volume in Plant Engineering (2nd Editin)", Butterworth-Heinemann, 2002.

Radford, A., Metz, L., & Chintala, S. (2015). Unsupervised representation learning with deep convolutional generative adversarial networks. arXiv preprint arXiv:1511.06434.

Rajat Raina, Andrew Y. Ng, and Christopher D. Manning. Robust textual inference via learning and abductive reasoning. In Proceedings of AAAI 2005, pages 1099–1105, 2005.

Ramchandran, A., & Sangaiah, A. K. (2018). Unsupervised Anomaly Detection for High Dimensional Data—an Exploratory Analysis. In Computational Intelligence for Multimedia Big Data on the Cloud with Engineering Applications (pp. 233-251). Academic Press.

Ren and et al, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks", CVPR 2016.

S.Ventura, C.Romero, A.Abraham.Intelligent data analysis.Journal of Computer and System Sciences; Volume 80, Issue 1, February 2014, Pages 1-2.

Sandini, G., Mohan, V., Sciutti, A., & Morasso, P. (2018). Social Cognition for Human-Robot Symbiosis—Challenges and Building Blocks. Frontiers in neurorobotics, 12, 34.

Sanveer Osahan: No Code Machine Learning Solutions with AWS. Infogain 2019.

SAS. "Predictive Analytics: Revolutionizing Business DecisionMaking", 2014, https://www.sas.com/content/dam/SAS/en_us/doc/whitepaper2/tdwi-predictive-analytics-107459.pdf#Find%20out%20more%20about%20predictive%20analytics

Schalk G, Brunner P, Gerhardt LA, et al. Brain-computer interfaces (BCIs):detection instead of classification. J Neurosci Methods. 2008.Jan 15:167(1):51-62.

Schmidhuber, Jürgen (2015). "Deep Learning". Scholarpedia. 10 (11): 1527–54. CiteSeerX 10.1.1.76.1541

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. Neuroreport, 14(8), 1107-1110.

Semantic Classification of Product Reviews", 2003. https://www.kushaldave.com/p451-dave.pdf

Sepp Hochreiter; Jürgen Schmidhuber (1997). "Long short-term memory". Neural Computation. 9 (8): 1735–1780. doi:10.1162/neco.1997.9.8.1735. PMID 9377276.

Serruya M D, Hatsopoulos N G, Paninskil, Fellows M R, et al.Brain2machine interface: Instant neural control of a movement signal[ J ]. Nature, 2002, 416:14 l-142.

SHUM, H., H.E. Xiao-Dong and L.I. Di, From Eliza to XiaoIce: challenges and opportunities with social chatbots. Frontiers of Information Technology & Electronic Engineering, 2018. 19(1): p. 10-26.

Siemens AG, "Semantic Web of Things for Industry 4.0", 2017. http://ceur-ws.org/Vol-1875/paper3.pdf

Silva P R , Andre D R , Paulo L , et al. IDARTS – Towards intelligent data analysis and real-time supervision for industry 4.0[J]. Computers in Industry, 2018, 101:138-146.

Simom, L. (2019). Basic Implementation of TensorFlow: Classification of Titanic survival. https://medium.com/@simonli_18826/basic-implementation-of-tensorflow-classification-of-titanic-survival-60a9fbcc7a35

Singh, Sonit, Natural Language Processing for Information Extraction, https://arxiv.org/pdf/1807.02383.pdf

Singhal, Amit (May 16, 2012). "Introducing the Knowledge Graph: Things, Not Strings". Google Official Blog. Retrieved September 6, 2014.

Stockman and C. George, Computer vision. 2001.

Sutikno, T., Facta, M., & Markadeh, G. A. (2013). Progress in artificial intelligence techniques: from brain to emotion. TELKOMNIKA (Telecommunication Computing Electronics and Control), 9(2), 201-202.

Tao J., Tan T. (2005) Affective Computing: A Review. In: Tao J., Tan T., Picard R.W. (eds) Affective Computing and Intelligent Interaction. ACII 2005. Lecture Notes in Computer Science, vol 3784. Springer, Berlin, Heidelberg.

Terziyan, V., Golovianko, M., & Gryshko, S. (2018). Industry 4.0 Intelligence under Attack : From Cognitive Hack to Data Poisoning. In K. Dimitrov (Ed.), Cyber Defence in Industry 4.0 Systems and Related Logistics and IT Infrastructures (pp. 110-125). NATO Science for Peace and Security Series D: Information and Communication Security, 51. IOS Press. doi:10.3233/978-1-61499- 888-4-110

The Definitive Guide to AIOps https://docs.broadcom.com/doc/the-definitive-guide-to-aiops

Thrun S, Wolfram Burgard, Dieter Fox. Probabilistic Robotics[M]// Probabilistic robotics /. 2006.

Tim Berners Lee and et al, "The Semantic Web", 2000.

Tim Berners Lee, "Linked Data - Design Issues", 2006.

Torrey, L., & Shavlik, J. (2010). Transfer learning. In Handbook of research on machine learning applications and trends: algorithms, methods, and techniques (pp. 242-264). IGI Global.

Tsung-Yi Lin, "Feature Pyramid Networks for Object Detection", 2017 Revised, Facebook AI Research and Cornell University.

Tunney, P., 2008, "The Latent Relation Mapping Engine: Algorithm and Experiments," Journal of Artificial Intelligence Research, 33: 615–55.

Understanding Explainable AI. https://www.forbes.com/sites/cognitiveworld/2019/07/23/understanding-explainable-ai

Understanding RNN and LSTM. https://towardsdatascience.com/understanding-rnn-and-lstm-f7cdf6dfc14e

Van Lent, M., Fisher, W., & Mancuso, M. (2004, July). An explainable artificial intelligence system for small-unit tactical behavior. In Proceedings of the national conference on artificial intelligence (pp. 900-907). Menlo Park, CA; Cambridge, MA; London; AAAI Press; MIT Press; 1999.

Von Ahn, L. (2008, April). Human computation. In Proceedings of the 2008 IEEE 24th International Conference on Data Engineering (pp. 1-2). IEEE Computer Society.

Wang Fang. Brief analysis of human-computer interaction system in intelligent manufacturing process [J]. Automation Expo. 2016,11: 78 – 91.

Wang Kejun, Hou Benbo. Review of Gait Recognition [J]. Chinese Journal of Image and Graphics. 2007, 12 (7): 1152 - 1160.

Wang Lijia. Research on Robot Target Tracking Algorithms Based on Multi-feature Fusion [D]. Ph.D. Dissertation of Beijing University of Technology. 2017: 1 – 2.

Wang, Jinjiang & Ma, Yulin & Zhang, Laibin & Gao, Robert & Wu, Dazhong. (2018). Deep Learning for Smart Manufacturing: Methods and Applications. Journal of Manufacturing Systems. 48. 144-156.

Wang, X., Han, Y., Wang, C., Zhao, Q., Chen, X., & Chen, M. (2018). In-edge ai: Intelligentizing mobile edge computing, caching and communication by federated learning. arXiv preprint arXiv:1809.07857.

Waseem Ghrayeb: The Role of Automated Machine Learning in the Smart Factory, Presenso, 2017. https://www.presenso.com/single-post/2017/03/28/the-role-of-automated-machine-learning-in-the-smart-factory/

Watson, Ian. Applying Case-Based Reasoning: Techniques for Enterprise Systems. San Francisco: Morgan Kaufmann, 1997.

Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. Journal of Neuroscience, 18(1), 411-418.

What are Linked Data and Linked Open Data?. https://www.ontotext.com/knowledgehub/fundamentals/linked-data-linked-open-da

What Is a Chatbot?. https://www.oracle.com/bh/solutions/chatbots/what-is-a-chatbot

What is Machine Learning?. https://medium.com/towards-artificial-intelligence/what-is-machine-learning-ml-b58162f97ec7

Wolfgang Wahlster, etc., "SemProM - Foundations of Semantic Product Memories for the Internet of Things", 2013.

Wolfgang Wahlster, "The Semantic Product Memory: An Interactive Black Box for Smart Objects", 2010.

Wolpaw JR, Birbaumer N, Mcfarland DJ. Brain-computer interfaces for communication and control. Clin Neurophysiol 2002;113(6):767-791.

Wu, Y., et al., A Sequential Matching Framework for Multi-turn Response Selection in Retrieval-based Chatbots. 2017.

Xu Caiyun. Review of image recognition technology [J]. Computer Knowledge and Technology. 2013, 10: 2446 – 2447.

Xu Na. Design and Implementation of Decision Support System for Manufacturing Enterprises Based on Data Warehouse [D]. Master's Degree Thesis of Engineering, Tianjin University. 2015: 1 - 4.

Xu Ning. Application of Data Mining Technology Based on Big Data in Industrial Informatization [J]. Modern Industrial Economy and Informatisation. 2017, 22: 50 – 54.

Xu Tingting. Research on Some Problems in Language Recognition [D]. Master's Degree Thesis, Beijing University of Posts and Telecommunications, 2011: 1 – 5.

Xu Yican, Liu Jibin. Current situation and prospects of machine translation [J]. Overseas English. 2017: 117 - 148.

Yannakakis, M. (1981). Edge-deletion problems. SIAM Journal on Computing, 10(2), 297-309.

Yu D, Deng L. AUTOMATIC SPEECH RECOGNITION[M]. Springer London Limited, 2016.

Yuan, G. , Yao-Yi, X. I. , Bi-Cheng, L. I. , & Jing, Y. . (2016). Argument extraction algorithm based on convolution tree kernel. Journal of Chinese Computer Systems.

Zhang Yunde. Research and Application of Gesture Recognition Technology [D]. Master's Degree Thesis of Anhui University. 2013, 2 - 3.

Zhang, G., Huang, Y., Zhong, L., Ou, S., Zhang, Y., & Li, Z. (2015). An ensemble learning based framework for traditional Chinese medicine data analysis with ICD-10 labels. The Scientific World Journal, 2015.

Zheng Bingxuan. Artificial intelligence technology and its application in the iron and steel industry, lecture 2: Knowledge acquisition and knowledge representation technology [J]. Metallurgical automation. 1994, 18 (1): 42 – 46.

Zhou, S. K., Rueckert, D., & Fichtinger, G. (Eds.). (2019). Handbook of medical image computing and computer assisted intervention. Academic Press.

Zhu, X. Semi-Supervised Learning. in International Joint Conference on Ijcai. 2011.

Ziemke, T. (2001, September). Are robots embodied. In First international workshop on epigenetic robotics Modeling Cognitive Development in Robotic Systems (Vol. 85, pp. 701-746).

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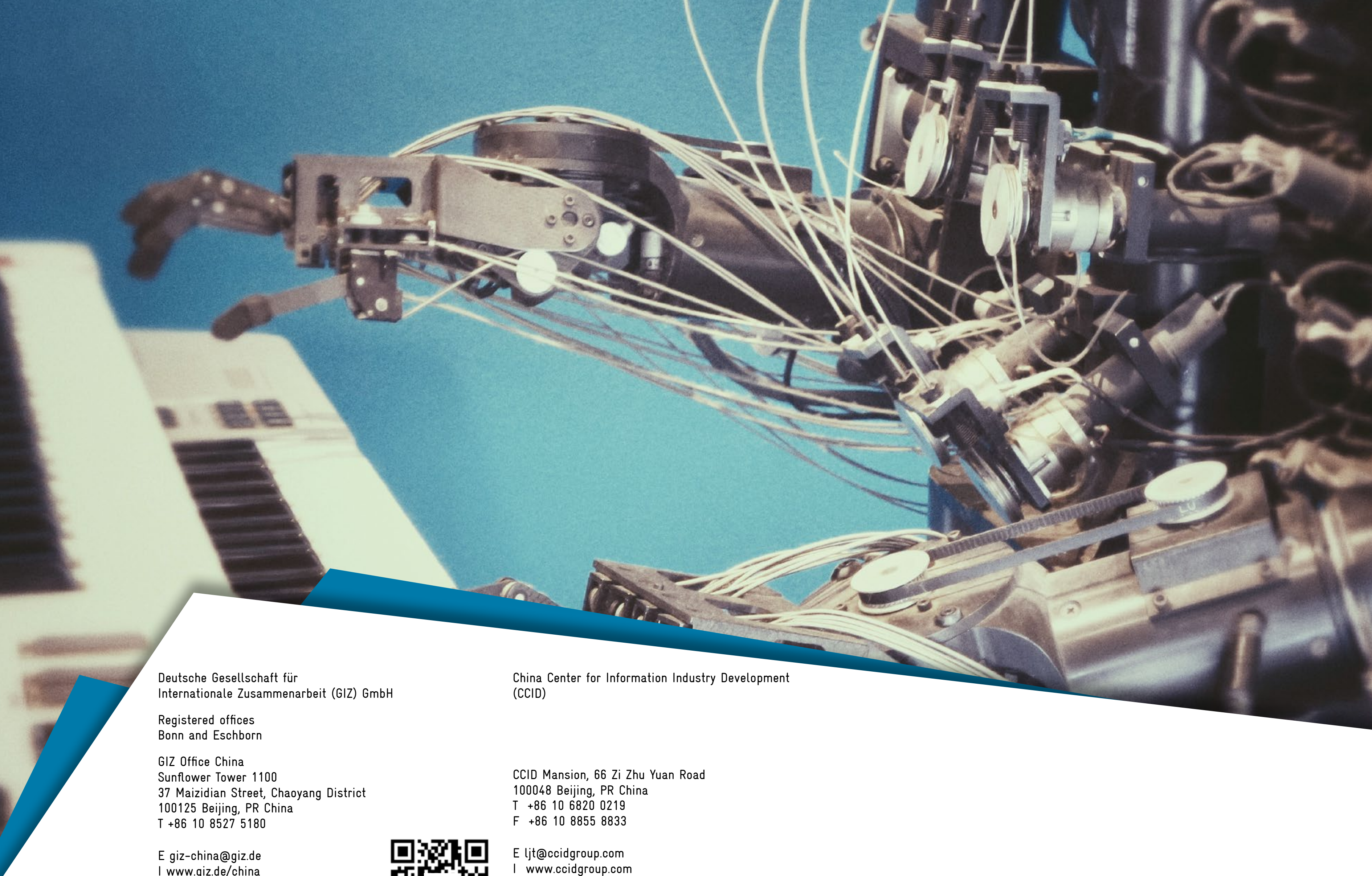

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