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PLANET 4

Practical Learning of Artificial Intelligence on the Edge for indusTry 4.0

PLANET4 TAXONOMY – TERMS DEFINITION

Statement of originality

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INDUSTRY 4.0 CHALLENGES AND NEEDS

1. **Process Optimization**: It is related to the macro need to improve the efficiency of the production processes. Generally, industrial processes can be optimized by improving equipment, workforce, and supply chain efficiency.
   1.1. **Equipment and Process Efficiency Improvement**: Concerns activities related to manufacturing ecosystem connectivity for alerting, running data analytics processes, and all maintenance processes that ensure continuous readiness and operation of industrial equipment without unplanned disruptions. It also concerns the need to shorten the processing time, efficiently allocate equipment and human resources, and make informed decisions about tasks, such as repairing or replacing failed industrial equipment, hiring, and scheduling maintenance. The efficiency optimization of production lines also involves initiatives for a) employing industrial units that work independently without human intervention; b) transforming older industrial systems and equipment to adapt to the modern era's requirements; and c) ensuring that all components are correctly designed, constructed, and installed to function following operational requirements.
      1.1.1. *Real-time Production and Process Monitoring:* It refers to manufacturers' need to monitor and supervise production and processes in real time. The goal is to ensure that production and processes run smoothly, efficiently, and quickly to identify and address any issues. Real-time monitoring can help manufacturers optimize their operations, improve quality control, and reduce downtime due to equipment malfunctions or failures.
      1.1.2. *Maintenance*: It refers to the need for regular upkeep and repair of industrial equipment to ensure proper functioning and reliability and to prevent unplanned downtime, which leads to costly repairs and replacements.
      1.1.3. *Production Planning and Scheduling*: The need to enable industries to optimize production by shortening processing time (e.g., generating the optimal sequence of operations needed to manufacture a workpiece, minimizing transportation time) and efficiently allocating equipment and human resources. It also concerns helping managers make informed decisions about repairing or replacing failed industrial equipment, hiring, and scheduling maintenance (e.g., measuring metrics maintenance time).

1.1.4. *Automation of Production Facilities*: It refers to the need to automate production processes and reduce human intervention. to reduce the risk of workplace accidents and injuries and to optimize their operations to meet the demands of modern industries..

1.1.5. *Legacy Systems Modernization and Retrofitting*: The process of transforming older production systems to adapt them to the requirements of automated manufacturing and the Industrial Internet of Things, allowing the collection of data from the production process (digitization of the production process) and the control of the operation of these devices.

1.1.6. *Commissioning Process*: The process of ensuring that all components of the production system are correctly designed, constructed, and installed and that they function according to operational requirements.

1.2. **Worker Safety Improvement and Accident Prevention**: Needs for preserving the safety of employees and, more generally, creating a safe workplace.

1.2.1. *PPE Improvement*: Refers to the improvement of equipment necessary to protect workers from workplace hazards and injuries.

1.2.2. *Worker Attention and Mental State Monitoring*: The need to monitor employees' mental state, behavior, and motion to optimize their performance, as well as the ergonomics of industrial tasks.

1.2.3. *Workers Navigation and Detection*: The need to monitor the location of employees supporting their navigation inside the plant (indicating the optimal route to the destination), monitor designated zones where employees should not be present for safety reasons, and count employees (e.g., emergency evacuation or preventing the spread of infectious diseases).

1.2.4. *Remote Operation*: The need for remote control to limit employees' physical exposure to crowded spaces and harsh environmental conditions (e.g.,harmful dust, collisions, cuts, crushing), injuries from industrial equipment, and electrical hazards.

1.3. **Supply Chain Improvement**: The need to improve and update the supply chain to cope with the increasing complexity and interconnectedness of modern manufacturing processes as well as the growing demand for real-time data and agility. This enables effective adaptation to dynamic market conditions and the optimization of operations.

1.3.1. *Vertical Integration*: Refers to the integration of business processes in an enterprise (the integration of material and information flow) in order to achieve better cooperation between production system elements and enterprise departments.

1.3.2. *Horizontal integration*: The need to connect business partners and customers to optimize the supply chain, enabling transparency, flexibility, and rapid response to problems and faults.

1.3.3. *On-Demand Custom Manufacturing*: A response to changing market demands and customer preferences for more customization and personalization of products. It refers to manufacturing products only when the customer orders, reducing overall resource wastage. (Related to Production on Demand, Also known as Manufacturing on Demand (MoD), Cloud Manufacturing or Demand-driven Manufacturing (DdM)).

1.3.4. *Warehouse and Inventory Management*: Refers to the improvement of warehouses through a systematic approach to sourcing, storing, selling (e.g., preparation of orders), replenishing, and tracking inventory, such as raw materials (components), maintenance materials (e.g., spare parts, lubricants), and finished goods (products). In addition, today's industrial warehouses need the highest level of product security (e.g., information leaks, false labelling, inadequate food hygiene management, malicious acts by staff or acts of corporate terrorism).

1.3.5. *Material Flow Control*: The organization, control, coordination, and optimization of materials to improve efficiency, reduce waste, and enhance productivity in the movement of goods within a logistics node or company.

1.3.6. *Supply Chain Transparency*: Refers to the requirement for clear and open visibility (i.e., real-time information regarding potential bottlenecks, disruptions, etc.), traceability (i.e., tracking and tracing the origins, movements, and transformations of goods and components), and information sharing (i.e., transparent communication and exchange of data among supply chain partners) throughout the entire supply chain process.

1.3.7. *Demand Forecasting*: Refers to the need to estimate and predict the future demand for a product or service. It involves using historical data, market trends, and other relevant factors to project the number of goods that customers are likely to purchase within a given timeframe, thus supporting better decisions such as the quantity of raw material to be ordered and whether new supply chains are needed or a reduction in the number of suppliers.

1.4. **Mass Customization**: The need to produce personalized products that meet the needs of specific customers at lower costs while still involving mass production volumes.

1.5. **Quality Assurance**: Preventing the production of non-compliant or defective products to ensure that products meet or exceed industry standards and customer expectations.

1.6. **Sustainable Industrial Practices**: The need for efficient and responsible use of resources in manufacturing to reduce waste and minimize negative impacts on the environment.

1.7. **Employee Training and Task Support**: It refers to providing employees with adequate training and support to perform their industrial duties efficiently and effectively. It aims to improve the training of employees and assist them in industrial tasks, including manual assembly, inspection and maintenance activities, and order picking.

1.8. **Knowledge management**: The manufacturing companies' needs on the acquisition, organization, and automatic retrieval of information from different content resources, such as technical documentation, videos, images, schematics, audio, web pages and much more, in the different phases of installation, servicing, break/fix, and parts knowledge.

2. **Product Innovation**: It relates to companies' need to build a new generation of products in response to market dynamics, customer feedback, technological advancements, competitive pressures, regulatory changes, and internal assessments. Product Innovation actions include the necessity to innovate capabilities and processes for product servitization, improve usability, develop smart products, optimize costs by reducing components, and enhance after-sales services.

2.1. **Product Servitization**: The necessity to innovate a company's capabilities and processes to enhance the creation of mutual value by transitioning from selling products to offering product–service systems that cater to a broader spectrum of customer requirements.

2.2. **Usability Improvement**: The need to improve the user experience and facilitate the completion of tasks with effectiveness, efficiency, and satisfaction while using the manufactured product.

2.3. **Smart Products**: It refers to the need for disruptive initiatives aimed at building a new generation of digital, connected, intelligent, and responsive products.

2.4. **Components Reduction and Cost Optimization**: The need to optimize the product bill of materials (BOM), thereby reducing product and production management costs.

2.5. **After-Sales Service**: The need to improve all services that bind the customer to the production company after selling the product (e.g., complaint management, warranty, field technical assistance responsible for installation, check-ups, out-of-warranty repairs and product disposal, usage monitoring, user analytics and profiling, automatic consumables reorder).

4.0 ENABLING TECHNOLOGIES

1. **Big Data**: It refers to enormous data sets that are complicated for typical data-processing application software to handle.
   - 1.1. **Big Data Frameworks**: Toolsets that provide cost-effective solutions to the challenges of Big Data processing, such as extracting insights, incorporating metadata, and assisting in business decision-making.
   - 1.2. **Data Sources/Ingestion**: The process of transferring data from multiple sources to data storage, where it can be accessed, used, and analyzed.
     - 1.2.1. *Streaming and Messaging*: Big data technique that focuses on the real-time analysis of continuous data streams.
     - 1.2.2. *Orchestration and Pipelines*: The automation of end-to-end data pipelines, from data extraction to data loading
     - 1.2.3. *Query/Data Flow*: Software that sits on top of a database or server and runs queries against that data or server's data to offer answers to users or applications.
   - 1.3. **Data Storage**: Methods and technologies for capturing and retaining data.
     - 1.3.1. *Databases*: An organized set of structured data which kept electronically in a computer system. A database management system is usually in charge of a database (DBMS).
     - 1.3.2. *Data Warehouses*: A digital storage system for connecting and harmonizing massive amounts of data from various sources. Its goal is to feed business intelligence (BI), reporting, and analytics and fulfil regulatory needs so that businesses may turn data into insight and make intelligent, data-driven decisions.
   - 1.4. **Data Analytics**: This allows businesses to examine all of their data (real-time, historical, unstructured, structured, qualitative) to find patterns and develop insights that can guide and automate decisions in some circumstances.
     - 1.4.1. *Unified Data Analytics Engines*: Multi-language engines that can be used to perform data engineering, data science, and machine learning tasks on a single node or cluster.
     - 1.4.2. *Unified stream-processing and batch-processing frameworks*: A computing framework for querying continuous data streams and performing tasks such as real-time analytics, complex event processing, and streaming analytics in a short timeframe.
     - 1.4.3. *Business Intelligence (BI) Tools*: Software utilized to create significant enterprise insights, make reports intelligently and simplify the business decision-making processes.

1.4.4. *Data Visualization Tools and Platforms*: Tools that offer an intuitive way to recognize trends, outliers, and patterns in data through graphical representation of information and data

1.4.5. *Logging & Monitoring*: A software solution that collects, sorts, and stores log data and event logs from different sources in a single central location.

1.4.6. *Spreadsheet Applications*: Applications for calculating, organizing, analyzing and storing tabular data.

1.4.7. *Data Mining*: Tools for inspecting, cleaning, transforming, and modelling information to find meaningful information, and proposing conclusions.

1.4.8. *Process Mining*: A mixture of data mining and process management approaches that analyze event data using advanced algorithms, machine learning, and statistical methodologies to throw light on business operations such as bottlenecks, capacity constraints, etc.

2. **AI**: Methods for building computerized systems that can reason, learn, and act intelligently.

2.1. **Machine learning**: A subset of artificial intelligence and computer science that focuses on identifying significant insights through algorithms trained to learn from historical data, identify patterns, make classifications-predictions, and make logical decisions with little to no human intervention.

2.1.1. *Supervised Learning*: The machine learning task of identifying a function that maps an input to an output using training data (i.e., input-output pairs).

2.1.2. *Unsupervised Learning*: ML algorithms for analyzing and clustering unlabeled datasets by discovering underlying patterns or data groupings. They are used for exploratory data analysis, cross-selling strategies, consumer segmentation, image recognition, and other applications.

2.1.3. *Deep Learning*: A branch of machine learning in which a neural network with three or more layers attempts to replicate the behavior of the human brain, allowing it to "learn" from enormous amounts of data.

2.1.4. *Transfer Learning*: The application of a previously learned model to a new problem. In transfer learning, a machine uses prior knowledge to improve generalization about another.

2.1.5. *Reinforcement Learning*: A training method that rewards desired behaviors while penalizing undesirable ones. A reinforcement learning agent, in general, can detect and comprehend its surroundings, act, and learn via trial and error.

2.1.6. *Deep Reinforcement Learning*: The machine learning discipline that blends reinforcement learning (RL) with deep learning.

2.1.7. *Semi-supervised Learning*: Semi-supervised learning is an ML approach that combines a small quantity of labelled data with a large amount of unlabeled data during training. It falls in between unsupervised and supervised learning.

2.1.8. *Federated Learning*: A machine learning approach in which a machine learning algorithm is trained across several decentralized edge devices or servers containing local data samples (usually not complete datasets).

2.2. **Computer Vision**: A branch of artificial intelligence that allows computers and systems to extract useful information from digital images, videos, and other visual inputs.

2.3. **Natural Language Processing, Natural Language Generation**: A subfield of AI that aids computers in understanding, interpreting, and manipulating human language. Sentiment analysis, topic detection, language detection, key phrase extraction, and document categorization are all tasks that it is utilized for.

2.4. **Intelligent Agents and Multiagent Systems**: A system comprising of multiple intelligent agents interacting with each other. An intelligent agent is an autonomous entity (software, person, etc.) that monitors its environment and acts under objectives.

2.5. **Soft Computing**: A set of methodologies designed to achieve robustness and low-cost solutions by exploiting their tolerance for imprecision, uncertainty, and partial truth.

2.5.1. *Fuzzy Set Theory*: It performs numerical computations using linguistic labels defined by membership functions, and it provides a systematic calculus to cope with ambiguous information linguistically. In addition, a collection of fuzzy if-then rules is a critical component of a fuzzy system that may accurately model human expertise in a given application.

2.5.2. *Neurocomputing*: Methods for simulating intelligent behavior by modelling the human brain as a continuous-time non-linear dynamic system in a connectionist architecture. Such an architecture consists of weights between a massive set of interconnected neurons (or processing units).

2.5.3. *Optimization Techniques*: Techniques that are performed iteratively by comparing different solutions until an optimum or satisfying solution that maximizes or minimizes an objective function is identified.

2.5.4. *Probabilistic Reasoning (PR)*: A way of representing knowledge in which the concept of probability is used to show knowledge uncertainty.

3. **Cloud Computing**: The offering of computing services over the Internet ("the cloud"), including servers, storage, databases, networking, software, analytics, and intelligence, to provide rapid innovation, more flexible resources, and economies of scale.

3.1. **Infrastructure as a Service (IaaS)**: A pay-as-you-go cloud computing service that provides necessary computation, storage, and networking capabilities on demand.

3.1.1. *Cloud Data Storage & Computing*: Highly scalable data storage and computing infrastructure that can be rapidly provisioned and de-provisioned on-demand.

3.2. **Platform as a Service (PaaS)**: A cloud computing approach in which cloud vendors give users a platform for app development.

3.2.1. *Device Management*: Refers to the registering, monitoring, and updating of nodes in large-scale distributed environments.

3.2.2. *Operating System*: A form of an operating system that controls the operation, execution, and procedures of virtual machines, virtual servers, virtual infrastructure, and the back-end hardware and software resources in cloud computing and virtualization environments.

3.3. **Software as a Service (SaaS)**: It enables users to connect to cloud-based programs and use them over the Internet.

3.3.1. *Media streaming software platform*: Allows audio or video material streamed over the Internet.

3.3.2. *Website Building*: A cloud-based development platform that helps in building websites.

3.3.3. *IoT Analytics Software*: It enables industries to examine and interpret sensor data from connected devices through the internet.

3.4. **Infrastructure as Code (IaC)**: A software-based IT practice that codifies and manages underlying IT infrastructure.

3.4.1. *Provisioning tools*: Tools for building, managing, updating, and deleting infrastructure resources like virtual machines, containers, networking, etc.

3.5. **Container Technology (Container as a Service)**: Virtualization of running environments to run agnostic-architecture applications and services in isolated user spaces.

3.5.1. *Containerization Platform*: Tool for OS-based virtualization, which creates multiple virtual units in the user space, known as Containers encapsulating an application as a single executable package of software that contains all of the necessary configuration files, libraries, and dependencies for it to run.

3.5.2. *Container orchestration*: This allows you to create application services that span numerous containers, schedule containers across a cluster, scale them and monitor their health over time.

3.6. **Serverless programming**: Programming paradigm where the developers are abstracted from the underlying infrastructure.

3.7. **Edge computing**: Computation approach that limits the amount of data to be transferred within a distributed system by concentrating the maximum number of computation tasks close to where data were generated (i.e., in the edge nodes).

3.8. **Fog Computing**: Computation approach that takes advantage of the individual computing capabilities of each of the nodes within a distributed system and spans the computing tasks over them.

4. **IoT and IoE**: IoT is an interconnection of various smart devices that interact with each other and with the external environment via the internet. In contrast, Internet of Everything (IoE) extends IoT and emphasizes machine-to-machine communication and describes a more complex system that includes people and their processes.

4.1. **IIoT (Industrial IoT)**: The capacity to apply the Internet of Things technology to the industry environment, connecting online objects, machines, printers and other tools inside a factory.

4.1.1. *Industrial communication protocols*: Real-time communications protocols, developed to interconnect the various systems, interfaces, and equipment that comprise a manufacturing system.

4.1.2. *Industrial Gateways and Data Acquisition Devices*: The link between the manufacturing system and the cloud which is usually the initial system-level device in the IIoT communication chain.

4.1.3. *Software Data Adapters*: It is an additional IEC61131-3 function block that is run straight as part of the control code on the PLC. During the operation of the industrial system, it reads PLC data and sends it to the superordinate intranet using an IIoT protocol.

4.2. **Physical Devices and Controllers**: Hardware-based physical objects with sensing and communication capabilities.

4.2.1. *Embedded Computing*: A computer with limited and dedicated resources to control the physical operations of a machine.

4.2.2. *Sensors (hardware)*: Devices capable of providing raw data for various process parameters with high precision and accuracy.

4.3. **Signal Processing**: A field dealing with manipulating and analysing analog and digital (sampled and quantized) signals.

4.4. **Connectivity**: Methods by which you interconnect your data processing module to devices and sensors.

4.4.1. *Radio Communication Technologies*: The use of radio waves for signaling and communication.

4.4.2. *Optical Communication Technologies*: Optical fiber transmission of data. The original electronic signals are converted into light pulses using laser or light-emitting diode light sources.

4.4.3. *IoT Messaging Protocols*: Protocols for transmitting device telemetry (or messages) from IoT devices to an IoT Messaging Hub (or Broker).

4.4.4. *Application Programming Interfaces and Programming Tools*: A software interface that allows two applications to communicate with one another.

4.5. **IoE (Internet of Everything)**: A notion that expands on the Internet of Things' (IoT) emphasis on machine-to-machine (M2M) communications to define a more extensive system that includes people and processes.

5. **Digital Twins**: The virtualization of a physical object or process to analyze and simulate the industry process.

5.1. **CAD software**: Software that facilitates the development, modification, and optimization of the design process by allowing users to build designs in either 2D or 3D to visualize construction.

5.2. **Finite Element Analysis (FEA) software**: A computational method for forecasting how a product will react to forces, vibrations, heat, fluid flow, and other physical effects in the actual world.

5.3. **Simulation software**: This allows engineers to evaluate, optimize, and compare product or system designs by modeling real-life events in a computer-generated environment.

5.4. **DTs management and orchestration framework**: A system for interacting with and managing the status of digital twins by creating a link between physical IoT devices and their digital twins.

5.5. **Digital twin data modelling**: It uses the object-oriented paradigm to store engineering information and enables modelling of physical and logical plant components as data objects encapsulating various characteristics.

5.6. **Virtual Process Controllers (VPC)**: It is the framework that receives input values from industrial cyber-physical systems, runs one or more Virtual Process Control Functions (VPFs), handles the transfer of output values to them, and can be compared to a virtualized PLC.

6. **Industrial Robotics**: Robots and machines used in manufacturing companies to automate an industry process.

6.1. **(Offline) Programming and Simulation**: Simulation and offline programming allow you to explore numerous situations of a robot work cell before setting it up. In addition,

offline programming can be used to program robots outside the manufacturing environment, thus, avoiding production downtime.

6.2. **Middleware**: A set of software tools for managing the complexity and heterogeneity of distributed systems. It's a software layer that sits atop the operating system but below the application program and provides a standard programming paradigm for distributed systems.

7. **Augmented Reality (AR) and Virtual Reality (VR)**: Technologies that work with the simulation and augmentation of the real environment.
   7.1. **VR**: A completely immersive experience that replaces a real-life environment with a simulated one.
      7.1.1. *VR glasses*: A headset with a display screen, stereo sound, sensors, and appropriate controls that provides a 3D immersive and interactive audiovisual experience.
   7.2. **AR**: Augments your surroundings by adding digital elements to a live view, often using a smartphone's camera.
      7.2.1. *AR glasses*: Wearable computer-capable glasses that overlay computer-generated information (usually 3D visuals and information such as animations and films) on the user's real-world sceneries to provide extra information.
      7.2.2. *AR Software Development Kits*: This allows developers to create digital things that merge into the real world, offering features like 3D object tracking, image recognition, visual SLAM (simultaneous localization and mapping), multi-tracking, etc.
   7.3. **AR and VR Software development, Platforms and Technologies**: Tools for creating innovative AR & VR content

8. **Additive manufacturing**: The technique of constructing an object one layer - by - layer.
   8.1. **3D Printers**: A computer-aided manufacturing (CAM) device that produces three-dimensional objects.
   8.2. **3D Printing Technologies**: Manufacturing technologies which differ in terms of material selection, surface polish, durability, as well as manufacturing speed and cost.

9. **Cybersecurity Technologies**: The use of technologies to defend against cyber-attacks on systems, networks, programs, devices, and data.
   9.1. **Security Virtualization**: Software-based security solutions designed to operate in a virtualized IT environment.

9.1.1. *Virtual Machine Monitor (VMM)*: It is a software program that enables the management, governance, and development of VM (Virtual Machines) and the functioning of the virtualized environment.

9.2. **Data Protection**: The process of protecting crucial data from corruption, compromise, or loss.

9.2.1. *Secure Communication Protocols*: Protocols for communication that ensure confidentiality, authentication, and content integrity.

9.2.2. *Key Management System (KMS)*: It relates to the administration of cryptographic keys in a cryptosystem comprising key production, exchange, storage, use, crypto-shredding (destruction), and replacement, the design of cryptography protocols, key servers, user procedures, and other relevant protocols.

9.2.3. *Public Key Infrastructure (PKI)*: It manages the issuing of digital certificates to secure end-to-end communications and protect sensitive data.

9.2.4. *Encryption*: The technique of mathematically encoding information (i.e., hiding its true meaning) so that it can only be read or decrypted by those who have the right key or cipher.

9.2.5. *Tokenization*: Tokenization is replacing sensitive data with a non-sensitive substitute known as a token, a randomized data string with no essential or exploitable value or meaning. Therefore, it does not give any method to interpret the token and reveal the original data.

9.2.6. *Blockchain*: Blockchain is described as a decentralized data ledger that is securely shared and allows a chosen set of individuals to share data. Transactional data from numerous sources may be easily collected, integrated, and shared via blockchain cloud services. Data is divided into shared blocks linked together using cryptographic hashes as unique IDs.

9.3. **Identity and Access Management**: It handles digital identities and user access to data, systems, and resources inside an enterprise to decrease identity-related access risks.

9.3.1. *Protocols*: Protocols for communication or cryptographic protocols that are specially developed for the exchange of authentication data between two entities.

9.3.2. *User Management*: It describes the collection of administrative functions that include user administration, password management, role/group management, user/group provisioning, and identity creation, propagation, and maintenance of user identity and rights.

9.3.3. *Authentication*: The phase at which the Identity Provider confirms that the user matches the identity.

9.3.4. *Authorization*: The point at which the user is granted appropriate Service Provider access.

9.4. **Security Operations**: Functions inside an organization that continually monitor and enhance the company's security posture while preventing, detecting, analyzing, and responding to cybersecurity issues.

9.4.1. *Change Management*: It includes requesting, approving, verifying, and recording system modifications.

9.4.2. *Threat Detection and Analysis*: It analyzes the whole security ecosystem to detect any malicious behavior that might compromise the network. If a threat is found, mitigating actions are taken to neutralize it before it can exploit any existing vulnerabilities effectively.

9.5. **Foundational Security**: The basic controls that ensure the security of an organization's information systems.

9.5.1. *Network*: The basic controls that ensure the security of the network.

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