AI Platform for Integrated Sustainable and Circular Manufacturing

3rd Press Release

Tech Pills: Know more about the first version of the Circular TwAIn Reference Architecture! | 31 October 2023

The Circular TwAIn Reference Architecture is based on an edge-to-cloud continuum approach and is designed to facilitate the development of circular applications to support *re-manufacturing, de-manufacturing*, and *recycling*, leveraging on three main pillars:

- Collaborative and Explainable AI

- Seamless Data Sharing in Dynamic Manufacturing Value Networks

- Digital Twins (for Products, Processes and Humans)

It is based on the main Reference Architectures in the industrial domain, i.e., RAMI4.0, IIRA, IDS-RAM4.0 and FIWARE for Industry, integrated and adapted to accommodate the end-users (Pilots) business needs.

The various components are grouped into:

Cloud Layer - Human and Applications:

- **Explanations:** XAI (eXplainable Artificial Intelligence) techniques have yielded insightful outcomes that allow humans to gain a deeper understanding of AI models and their behaviour within pipelines.

- **Assistance and Interaction: a** combination of outputs from AI models that have been enhanced with explainability methods.

- **Parametrisation, Labelling, Training:** an application that offers the possibility for the user to create datasets from raw and unstructured data by employing dedicated tools and algorithms for data pre-processing, cleansing, and transformation. In addition, the user can develop AI models and pipelines from scratch, configuring and tuning their settings and parameters according to their specific needs and use cases. Moreover, the platform enables users to provide feedback in the form of annotations,

labelling, or other techniques to improve the quality and accuracy of the models and pipelines during the training phase.

- **Other possible applications:** comprehensive support for a diverse range of requirements and applications, including Digital Twins and XAI-based applications, among others.
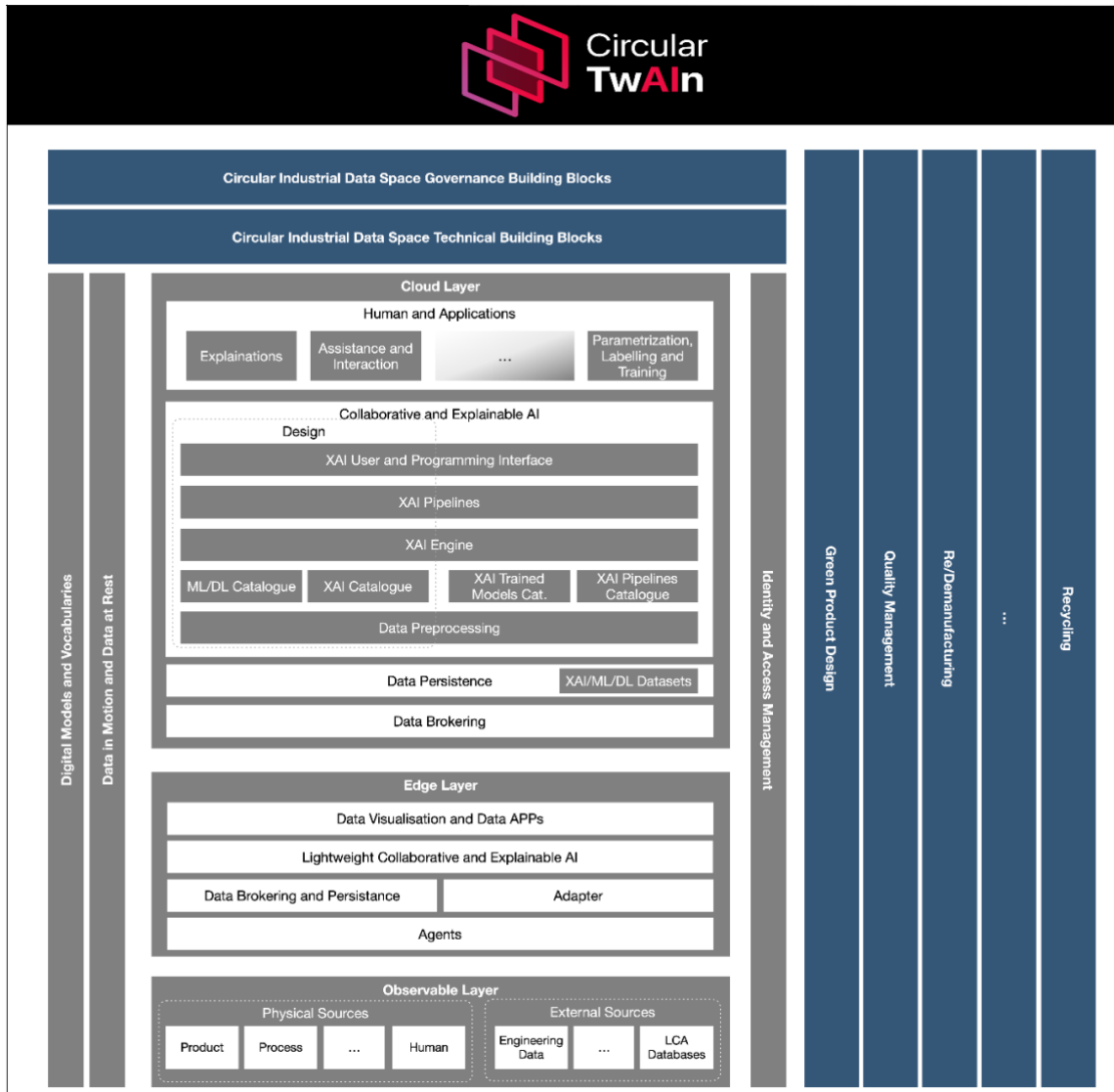

Figure 1: CT Reference Architecture

Cloud Layer - Collaborative and Explainable AI

- **XAI User and Programming Interface:** offers a comprehensive set of tools for both data/results/explanation dashboarding and XAI programming interfaces.

- **XAI Pipelines:** the fundamental building blocks of Collaborative and Explainable AI, they are the core "assets" that arise from the integration of reusable AI and XAI components.

- **XAI Engine:** a set of sophisticated tools that enable the design and execution of XAI pipelines and models. It provides access to all relevant catalogues, acting as an experimental and design platform for the operational production of XAI for the DTs. Additionally, it orchestrates data flow between the input and the different AI/XAI

modules of the pipeline before collecting and rendering the results in an easily accessible format.

- **ML/DL Catalogue:** a catalogue populated with state-of-the-art machine learning and deep learning algorithms.

- **XAI Catalogue:** a comprehensive catalogue of cutting-edge eXplainable Artificial Intelligence (XAI) techniques. These XAI techniques provide users with advanced and effective methods of explaining their AI models.

- **XAI Trained Models Catalogue:** a comprehensive list of domain-specific AI models that have been trained, explained, and assessed for their reliability and effectiveness, which can be used as a basis for building XAI pipelines.

- **XAI Pipelines Catalogue:** a list of XAI applications (pipelines) that have been specifically developed for a particular domain. Each application comes with an explanation technique that enhances the transparency and interpretability of the model's decision-making process.

- **Data Pre-processing:** a set of advanced tools and modules for data pre-processing that enable the creation of high-quality datasets from raw data. These datasets are then made ready to be ingested by the XAI Engine or to simply apply pre-processing techniques to incoming data.

- **XAI/ML/DL Datasets:** a comprehensive list of specific datasets that have been built from raw data and persisted on the Data persistence layer, ensuring that they are readily available to be fed into AI models and XAI pipelines.

- **Data Persistence:** collection of historical raw data from different sources (databases, data warehouses, data lakes).

- **Data Brokering:** enables the seamless and uninterrupted flow of data from various real-time sources, such as IoT sensors. It provides the necessary infrastructure to collect, store, and process these data streams in a timely and efficient manner, ensuring that they are readily available for consumption by downstream AI and XAI modules.

Edge Layer

- **Data Visualisation and Data Apps: a** set of consumer edge applications, referring to software applications that are deployed on edge devices, to provide services related to data visualisation, device management, monitoring, control, and other similar functions.

- **Lightweight Collaborative and Explainable AI:** a lightweight version of the Collaborative and Explainable AI component that can be deployed on the cloud and optimised for edge devices with limited computing power.

- **Data brokering and persistence:** serves as a manager and persistent storage for the entire lifecycle of contextual information. It enables seamless and efficient management of contextual data from its creation to its storage and retrieval, ensuring its availability and reliability throughout the data's lifecycle.

- **Adapter:** this component facilitates any necessary protocol transformations required for the transportation of data and commands.

- **Agents:** This component acts as an interface between the observable layer, which includes standard and/or custom devices, external systems, etc., and the upper layers of the system. It is responsible for integrating and connecting these different components to ensure smooth communication and interaction between them.

Observable Layer

In this layer, it is possible to locate external data sources. They can be differentiated in *physical data sources* and *external data sources.*

- **Physical data sources (Products, Processes, Human, Others)**

- **External data sources (Engineering Data, LCA Databases)**

Horizontals

- **Circular Industrial Data Space Governance Building Blocks:** a set of components essential for enabling the circular economy. The governance building blocks provide a framework for managing data in a standardised and secure manner, ensuring compliance with regulatory requirements, and enabling collaboration between different parties. This framework includes components such as data sharing agreements, data ownership, access control, and privacy management, all of which are critical for building trust and promoting the exchange of data in a circular economy context. Overall, these blocks can be considered as a key enabler for industry to transition towards a more sustainable and circular way of operating.

- **Circular Industrial Data Space Technical Building Blocks:** a comprehensive set of technical components that support an agile, secure, and fluid flow of data and information among various parties and domains. These components can be implemented and deployed in various ways, based on different runtime frameworks, while performing a diverse set of roles within the data space. These roles include serving as fundamental building blocks that ensure data interoperability and exchange between components, such as *Agents*, *Data Brokers*, and *Connectors*. Additionally, other components support the creation of data value, like the *XAI Catalog*, while some ensure data sovereignty and trust, like the *Identity and Access Management* component. Lastly, the system provides all necessary components for connecting additional systems to the data space, like the Adapters. Within the set of technical building blocks, there are also various components dedicated to data processing, data preprocessing, and data visualisation, including the *XAI Engine*.

Verticals

- **Digital models and vocabularies:** standardised data models and ontologies that enable seamless data exchange and interoperability between various components and applications. Common digital models and vocabulary development and adoption are fundamental for promoting cross-border data exchange and digital services integration across diverse sectors. This element offers a common understanding of data, allowing for the implementation of automated processes, minimising errors, and boosting efficiency.

- **Data in motion and data at rest** it refers to the entire spectrum of data that flows through the architecture, which encompasses data that is either at rest or in motion. Data at rest refers to information that can be accessed by any component within the architecture. Conversely, data in motion pertains to information that is being continuously gathered from various sources, processed, and utilised in real-time, providing input to the pre-processing and processing components. By effectively handling both data at rest and in motion, this component ensures a comprehensive and dynamic approach to data management, enhancing the efficiency and effectiveness of the entire architecture.

- **Identity and Access Management:** vertical that all entities and components, including individuals, organisations, machines, and other actors, are equipped with recognised identities that can be authenticated and verified, with additional information provided as needed for authorisation mechanisms to enable effective access and usage control.

- **Circular Economy Applications (Green Design, Quality Management, Re/De-manufacturing, Recycling):** circular economy applications are the primary focus for the entire architecture, where the convergence of business objectives and technological capabilities is realised. The implementations cover a wide range of processes, starting from the initial phases of the product lifecycle, aided by AI generative design to minimise environmental impact, to optimising processes and products, managing quality, and enabling human-robot interaction for de-manufacturing and re-manufacturing to reduce wastes, among other areas.

The Project in a Nutshell

Circular TwAIn will research, develop, validate, and exploit a novel AI platform for circular manufacturing value chains, which will support the development of interoperable circular twins for end-to-end sustainability.

Based on the use of trustworthy AI techniques, the project will enable human-centric sustainable manufacturing, fostering the transition towards Industry 5.0 as well as the integration and combination of different data from various sources, with the intent to exploit the advantages of seamless data sharing within trusted and effective manufacturing data spaces, over the entire product life cycle considering sustainability aspects.

Circularity and end-to-end sustainability through trusted AI technologies will be promoted in 3 industrial use cases, both in the discrete manufacturing and the process industry.

- De- and Re-Manufacturing Li-Ion Battery Packs in e-mobility by COBAT, RAEEMAN and POLIMI
- De- and Re-Manufacturing Consumer WEEE by RECYCLIA, REVERTIA and AIMEN
- Energy Optimisation in Petrol-Chemical Production Plants by SOCAR and TEKNOPAR

Partners

The Consortium consists of 21 Partners across 11 European countries. An experienced and multidisciplinary group that will contribute the most towards achieving the project objectives.

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