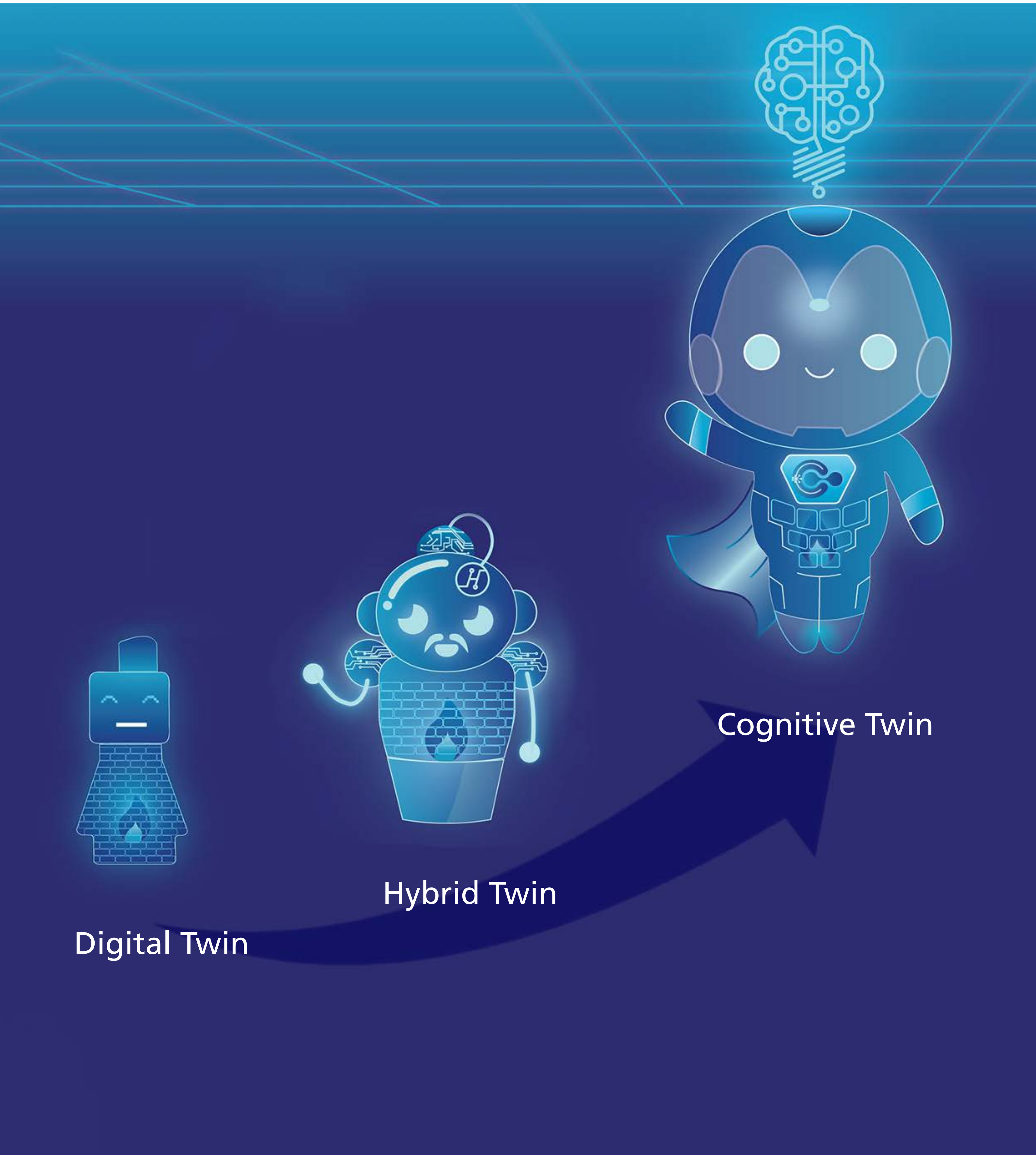
COGNITWIN



CONTENT

COGNITWIN Project Information

42 Months (1-September-2019 to 28-February-2023)

€ 8,653,170.00

14 Partners (6 Process Industries, 4 Technology Providers, 4 R&D Partners), 7 Countries

Leaflet | Map data © OpenStreetMap contributors, Credit: EC-GISCO, © EuroGeographics for the administrative boundaries

Image taken from: https://cordis.europa.eu/project/id/870130

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European Commission

Dear readers,

We are pleased to share with you the 1st COGNITWIN newsletter.

Our vision is to cognify the process industry. We want to enhance the potential of the process industry in Europe by creating and validating a new approach for cognitive digital twins affordable for all process industries. In this first issue, we highlight the key results we have achieved in the first year of the project.

To give a better overview of the status of the COGNITWIN project, the newsletter is split into three parts. The first part is about the technical aspects. We discuss the main research and technical challenges we have addressed, describe the novelty of the proposed approach and outline the next steps we plan to take.

In the second part we focus on the COGNITWIN use cases which cover the following SPIRE process industry sectors: (i) Non-Ferrous (Aluminium and Silicon); (ii) Steel and (iii) Engineering. For each use case, we describe a problem to be solved, the expected benefits, the results achieved so far, and the next steps.

The third part of the newsletter deals with the exploitation, dissemination and project management activities. We justify the chosen approach, discuss the organizational challenges we have faced, summarize the achievements and indicate our intentions for the next year.

To make the newsletter more attractive and to draw the attention of a wider audience, we include many pictures that show not only the real plants but also the conceptual architectures and the comic-based visualization of our approach.

After the first year of activity, we are now moving into a new phase in which results will be tangible, visible and measurable!

Enjoy the reading & contact us if you have questions or suggestions!

Best regards
The COGNITWIN project

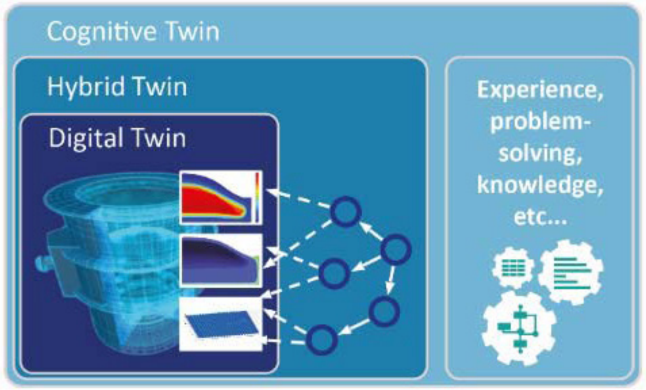
PART I: COGNITWIN TECHNICAL APPROACH

DIGITAL TWIN

The COGNITWIN project aims to develop several enabling technologies that collectively realize the vision of cognitive production plants. These technology blocks will be integrated in the so-called COGNITWIN toolbox.

To realise this vision, several steps have to be performed. We started by clarifying the concept of digital, hybrid and cognitive twins.

The dependencies between different types of digital twins are shown in figure below and reported in our paper "COGNITWIN – Hybrid and Cognitive Digital Twins for the Process Industry"[1].



COGNITWIN 3-layered approach to define "twins".

The next issue is how to represent a digital twin. The general idea of the digital twin concept is to have a digital representation of a physical system a (standardized) interface interface for digital interaction with the system. On a conceptual level, such digital twins are envisioned to provide a multitude of functionality, e.g., management of documents related to the system, provide visualization and 3D representation, access to (historical) data about the system, and methods to interact with the system, etc. An overview of the standards is reported in our journal paper "Digital Twin and Internet of Things-Current Standards Landscape"[3]. The table below provides an overview on the classification of the different standards analyzed. Although the standards were developed independently by different standards developing organization, they ended up with quite similar approaches/solutions to some aspects.

	AAS	DTDL	NGSI-LD	OData	STA	WoT
Resource Description						
Resource Term	Asset	Interface	Entity	Entity	Thing	Thing
Model Type(s)	Meta	Meta	Meta Cross-Domain	Meta	Cross-Domain	Meta
Resource Identification	IRI IRDI custom	DTMI	URI	URL custom	URL custom	URI
Type System (based on)	XSD	custom	JSON GeoJSON JSON-LD	custom	JSON SWE-standards	JSON JSON Schema
Resource Interlinking	X	X	X	X	-[a]	X
Semantic Annotation	X	O[b]	X	-	O[c]	X
Resource Elements						
Properties	X	X	X	X	X	X
Services	X	X	-	O[d]	O	X
Events	X	X	O[e]	-	O[e]	X
Serialization Format	JSON RDF XML OPC UA AutomationML	JSON RDF Avro Protobuf	JSON RDF	JSON XML	JSON	JSON RDF
Supported Kind of Data						
geo-spatial	-	-	X	X	X	-
temporal	-	-	X	X	X	-
historical	-	-	X	-	O[f]	-
Resource Discovery						
Protocols	-[a]	-	HTTP	HTTP	HTTP	HTTP[g] CoAP[g] DNS-SD[g]
Querying supported?	-[a]	-	X	X	X	O[g]
Query Language						
Query Language based on	-[a]	-	custom	custom	OData	SPARQL[a,g]
geo-spatial queries	-	-	X	X	X	-
historical queries	-	-	X	-	O[f]	-
Resource Access						
API: Define vs. Describe	define	-	define	define	define	describe
Protocols	HTTP MQTT OPC UA	-	HTTP	HTTP	HTTP MQTT	HTTP MQTT CoAP
Protocols extendible?	-	-	X	-	-	X

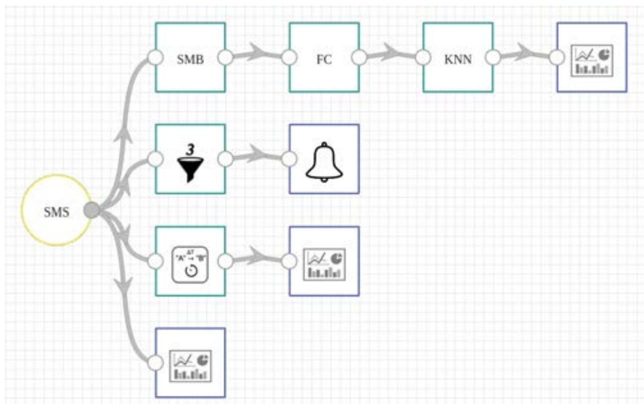
[a] extension under discussion
[b] only predefined definitions and only for telemetries, properties, and units
[c] only explicitly for observed properties and units, possible for everything else via custom properties
[d] only on service-level
[e] only property changes
[f] only for observations
[g] not part of standard, only in implementation(s)

Table: Comparison of the following internet of things and digital twin standards: AssetAdministrationShell (AAS), Digital Twin Definition Language (DTDL) v2.0, Next Generation Service Interfaces–Linked Data API (NGSI-LD API), Open Data Protocol (OData) v4.0, SensorThings API (STA) v1.0, and Web of Things (WoT)[2].

As digital twins are not intended to be used by end-users directly but rather by software systems, standardization of APIs is essential. Based on the analysis shown above, we decided to base our work on the Asset Administration Shells (AAS), mainly because there is support for the key protocols used in industry (e.g. OPC UA). The Joint working group Industrial Internet Consortium and Plattform Industrie 4.0 came to the same conclusion: the Asset Administration Shell could be used for the implementation of the digital twins for Industrie 4.0 as well as for use cases beyond manufacturing. This is reported in the white paper "Digital Twin and Asset Administration Shell Concepts and Application in the Industrial Internet and Industrie 4.0"[4] to which we also contributed.

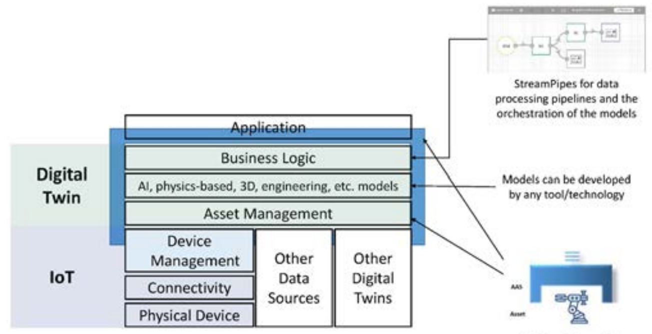
However, the **A**sset **A**dministration **S**hell model and APIs are not enough to realize the COGNITWIN vision. There is a need to run the models (e.g. data-driven and physics-based models), to "combine" different models, to integrate components developed by companies using different technologies, etc. Both the models and components are part of the COGNITWIN toolbox and should be reusable. In order to deal with this issue by minimizing the number of interfaces to be implemented and by ensuring reusability, we decided to use StreamPipes[5], an open source toolbox for the Industrial IoT.

An example pipeline created by using StreamPipes. Main purpose of developed pipeline is to create a path from sensory data to the neural network output, depicting state of the tool, through several pipeline elements. In addition, this pipeline triggers notification when value of particular property goes above certain threshold and shows results.



An example pipeline created by using StreamPipes.

The dependencies between all above mentioned entities are shown in figure below. COGNITWIN covers all building blocks for digital twins: whereas AASes will be used for the asset management and the standardized interfaces, the StreamPipes will provide an environment to host and orchestrate different models, components, services.



COGNITWIN approach based on AAS and StreamPipes. Icons used are made by Eucalyp - www.flaticon.com

[1] *Sailesh Abburu, Arne J. Berre, Michael Jacoby, Dumitru Roman, Ljiljana Stojanovic, Nenad Stojanovic: COGNITWIN - Hybrid and Cognitive Digital Twins for the Process Industry. ICE/ITMC 2020: 1-8*
[2] *Jacoby, M.; Usländer, T.: Digital Twin and Internet of Things–Current Standards Landscape. Appl. Sci. 2020, 10, 6519*
[3] *https://www.mdpi.com/2076-3417/10/18/6519*
[4] *https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/Digital-Twin-and-Asset-Administration-Shell-Concepts.html*
[4] *https://streampipes.apache.org/*

PART I: COGNITWIN TECHNICAL APPROACH

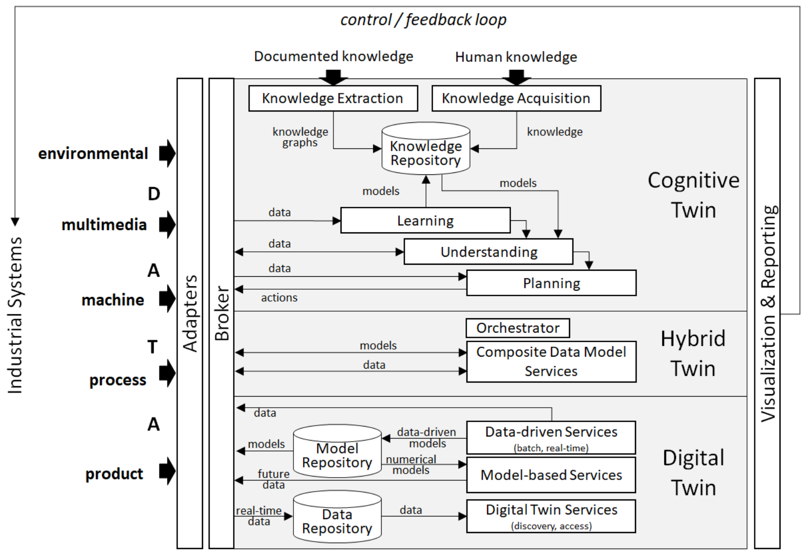
HYBRID TWIN

In the COGNITWIN industrial pilots several digital twins are under development. Both models developed from data and physical models, based on balances of mass and energy, including laws of chemistry and mechanics, are applied. The models may focus on the same or different aspects of the pilot plants.

We define a hybrid digital twin as an extension of digital twin in which the isolated digital twin models are intertwined to recognize, forecast and communicate less optimal (but predictable) behaviour of the physical counterpart well before such behaviour occurs. A hybrid digital twin integrates data from various sources (e.g., sensors, databases, simulations etc.) with the digital twin models, and applies AI analytics techniques to achieve higher predictive capabilities, while at the same time optimizing, monitoring and controlling the behaviour of the physical asset. A hybrid digital twin is typically materialized as a set of interconnected models, achieving symbiosis among the digital twin models.

The different models for each pilot will later be combined in suitable ways, such that they form hybrid digital twins. COGNITWIN explores the information from the literature, indicating that a hybrid modelling approach often yields better results than a purely data-driven or a purely first principles-based approach.

Examples of first order models tools we have are for instance models for heat transport and refractory erosion in a steel ladle, where the heat transport model is based on the solution to the energy equation $\frac{\partial \rho h}{\partial t} + \nabla(\rho \mathbf{U} h) = \nabla(\lambda \nabla T)$, where ρ is density, U is fluid velocity, h=h(T) is enthalpy, λ is thermal conductivity, and T is temperature. Boundary conditions are developed to represent the actual pilot case. The erosion is represented by N coupled ordinary differential equations (conservation equations), $\frac{\partial \theta_k}{\partial t} = \sum_{i=1}^{N} A_i \theta_i$,which need input from the thermal calculation. Similar approaches are being developed for other pilots.



Cognitive Twin capabilities

COGNITIVE TWIN

An important aspect of the COGNITWIN project is the cognition. During the 1st year of the project we reviewed the relevant definitions in the literature and documented the results of this analysis in our paper "cognitive digital twins for the Process Industry" accepted for the Twelfth International Conference on Advanced Cognitive Technologies and Applications (COGNITIVE 2020[1]). We defined the cognitive digital twins as an extension of digital twins with cognitive capabilities in the context of the process industry.

We define a cognitive digital twin as an extension of hybrid digital twin incorporating cognitive features that will enable sensing complex and unpredicted behaviour and reason about dynamic strategies for process optimization, leading to a system that continuously evolve its own digital structure as well as its behaviour. A cogntive digital twin is thus a hybrid, self-learning and proactive system that will optimize its own cognitive capabilities over time based on the data it will collect and experience it will gain. A cogntive digital twin will find new answers to emerging questions by combining expert knowledge with the power of hybrid digital twin. A cogntive digital twin will thus achieve synergy between the hybrid digital twin and the expert and problem-solving knowledge.

For realizing cognitive digital twins in the process industry, we work to devise the architectural building blocks that can serve as a foundation for cognitive systems. This is shown in figure "COGNITWIN approach extending digital twin with hybrid twin and cognitive twin capabilities".

The main role of cognition services is to support decision making and enable behavior understanding of a monitored system. An addressed fundamental challenge, subject to digital twin development, is related uncertainties such as lack of data and unavailability of physics-based models to represent the current system behavior.

Additional challenges to be addressed:

1) How can knowledge be formally represented to enable a digital twin to learn from experience and behave intelligently?

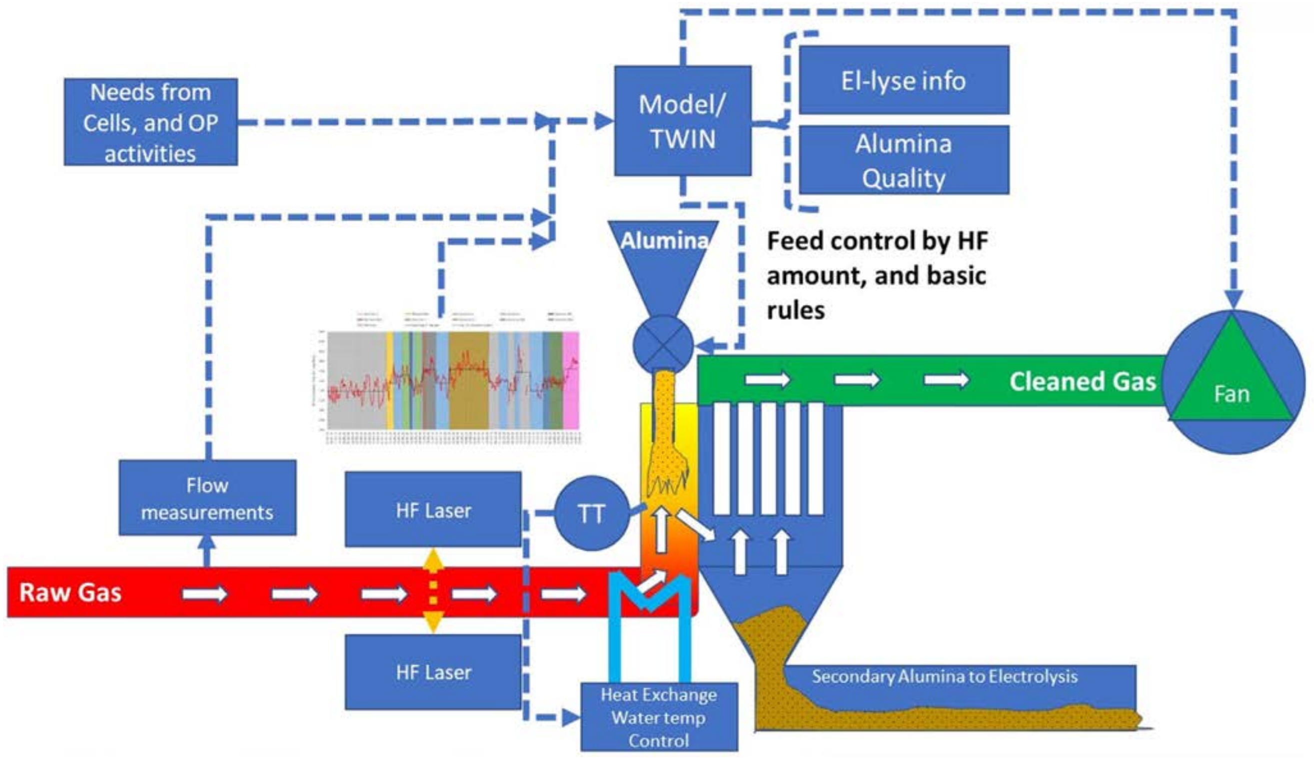
2) Knowledge acquisition – knowledge is not only spread in different documents (e.g., excel tables) and software systems (e.g., error reports in MES systems), but could be also implicit as it is based on personal experience that is even more difficult to express.

During the second year of the project, the focus will be on realizing these challenges as building blocks of the proposed cognitive architecture.

[1] Abburu, Sailesh & Berre, Arne-Jørgen & Jacoby, Michael & Roman, Dumitru & Stojanovic, Ljiljana & Stojanovic, Nenad. (2020). Cognitive Digital Twins for the Process Industry." The Twelfth International Conference on Advanced Cognitive Technologies and Applications (COGNITIVE 2020)

PART II: COGNITWIN USE CASES

HYDRO PILOT



Schematic of plant and process flows for the Gas Treatment Centre (GTC). Raw gas extracted from the electrolysis cells is cleaned of fluorides by a filtration system and the fluorides are later cycled back into the electrolysis cells. Real-time information about the fluoride emissions process is measured by a new HF laser.

HYDRO, WHO ARE WE

Hydro is a fully integrated aluminium company with 35,000 employees in 40 countries on all continents, combining local expertise, worldwide reach and unmatched capabilities in R&D. In addition to production of primary aluminium, rolled and extruded products and recycling, Hydro also extracts bauxite, refines alumina and generates energy to be the only 360° company of the global aluminium industry. Hydro is present within all market segments for aluminium, with sales and trading activities throughout the value chain serving more than 30,000 customers. Based in Norway and rooted in more than a century of experience in renewable energy, technology and innovation, Hydro is committed to strengthening the viability of its customers and communities, shaping a sustainable future through innovative aluminium solutions.

The expectations for COGNITWIN and all other projects related to digitalisation are all aimed into improving process stability and efficiency. Specific in the Hydro pilot, we are aiming to link the fluoride recovery, i.e. the preparation of the raw material alumina for the electrolysis, to become interactive and as much as possible self-correcting.

When producing primary aluminium, a cryolite based electrolysis process is used. This process produces HF gas, and the F (fluoride) are to be recovered and returned to the process, both since it is harmful to the environment, but also a significant cost as raw material. The Hydro pilot in COGNITWIN has as target to synchronise the operation in the Gas Treatment Centre (GTC) with the connected Electrolysis process. Through this synchronisation the process conditions in the GTC will be optimised and directly linked to the various input parameters such as gas composition coming from the electrolysis, alumina qualities and ambient conditions. When considering the ambient conditions, the GTC can be operated such that the adsorption of HF (Hydrogen Fluoride) in alumina is maximised. Moreover, by adjusting addition of the adsorber (alumina) the HF can be distributed more evenly in the alumina, hence give better process stability when fed back to the electrolysis. Also, the project aims to control and adjust the main fans in the GTC in such a way that one does not use more energy than necessary.

STEPS

In order to carry out the Hydro pilot in COGNITWIN new and necessary sensors have to be installed. Once the sensors are installed, data from these will create a database collecting all the information needed. Based on the database an attempt to analytically model the process will carried out, and as more data and experience is gathered, the model should be continuously adjusted by using the collected data. By introducing continuously data driven adjustments the model will become more and more agile. Later when the model covers a wide array of data patterns, necessary human interventions will be recorded, and some machine learning will seek to give the system the cognitive function.

FIRST YEAR ACTIONS

During the first year of the project, the necessary level of digitalisation to meet the ambitions of the Hydro Pilot has been analysed and defined, followed up with installation of defined sensors. An analysis of the generated data, and model-based predictions of the measured process variable has started. Data are currently being harvested and will be the basis for data driven adjustment for the analytical models. Any new array of sensors and logic has challenges when introduced to a harsh environment such as the raw gas ducts in aluminium production, due to this a thorough de-bugging and stabilising effort has been carried out to ensure signal stability.

A summary of the technical accomplishments during the past year:

- Established data flow from weather stations monitoring ambient conditions
- Estimation of uncertain silo quantities by applying established algorithms to process data
- Identification of electrolysis cell operational variables that influence fluoride emissions
- Integrated weather data with multiple process data flows to generate novel model-based predictions that allow for the monitoring and future optimisation of HF emissions and fluoride recovery

PART II: COGNITWIN USE CASES

SIDENOR PILOT

Sidenor Aceros Especiales is a special steel producer with main customers in Automotive, machinery, railway and energy sectors. Sidenor's main steel product are round bars that will be lately cut, transformed, machined and finally converted into high responsibility pieces. Example of those pieces are: Crankshafts, Gears, Common rails, Leaf springs, Coil Springs, Bearings, Shafts, CVJ's, Steering racks, Steering pinions, Shock absorbers, Fasteners.

In the COGNITWIN project, SIDENOR pilot case deals with operations in steel ladles. In the steel plant, scrap steel is melted in an EAF (Electric Arc Furnace). The steel is then tapped into one or several ladles. The ladle serves first as an intermediate container for the tapped steel and is then transported to stations where melt refining and alloying is taking place. When each ladle has been through the required steps the metal is poured into a continuous casting steel tundish, which next supplies the steel to a casting machine.

Ladle refractory is a key factor in secondary metallurgy management for all steelworks despite particular differences due to process, installations or product conditions. It has clear economic implications but also affects quality, productivity and safety of the steelmaking installations and people involved. Ladle refractory wear problem is the combined effect of thermo-physical-chemical processes activated by working conditions. The understanding of the whole process requires splitting the different stages:

Tapping → Liquid Steel → Casting → Cooling → Burner Heating

The aim of this research work is to develop ML/AI models with cognitive capabilities that predict when the refractory lining in the ladle need to be replaced or repaired. The following steps are envisaged:

1 A digital twin (mathematical models) of the ladle will simulate the behaviour and degradation mechanism of the bricks.

2 By combining first-principles and physics-based models to predict the condition of the brick lining and help make better decisions on whether to replace/repair the lining

3 The cognitive twins on the other hand will include the human intelligence factor in the models to deal with the uncertainty inherent in the process

Briefly the goal is aimed to improve ladle refractory life-cycle management, optimizing its life and properly managing its end-of-life. The achievement of the objectives included in this work would lead to the following industrial benefits:

- Refractory material savings of about 10% of the total transformation cost in SBQ steels grades production (**cost reductions**).

- More reliable ladle management (greater reproducibility and predictability), for better prediction will lead to a better adaptation capability to production stops and will also help **plant productivity** and to save costs.

In the 1st year of the project, the following issues have been addressed:

- Initial industrial starting point for ladles information has been assessed.

- Relevant process data and type of available measurement of the ladle profiles were also established.
- Definition of the data requirements has been started.

- First process parameters data set has been provided to the technological partners.

- Analysis of the suitability of sensors for measuring ladle steel shell temperature is missing at the end.

In the future, the hybrid twin that is in process of development will be enhanced further, and a cognitive twin supporting the proactive self-learning will be developed.

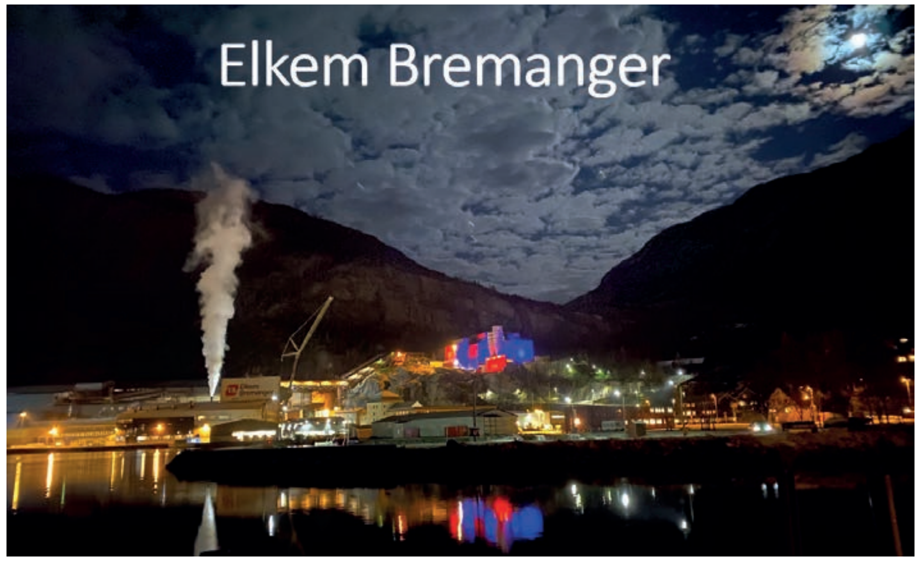
ELKEM PILOT

Elkem produces a variety of ferroalloys for chemical, automotive and electronic industry. The typical production route is shown schematically in Elkem-Pilot. The carbothermic reduction of quartz takes place inside a large submerged-arc furnace. Dust particles in the off-gases from the process are filtered and sold as a separate product, microsilica, while heat is recovered from the hot off-gases and used for steam production. Liquid ferrosilicon is drained from the furnace at regular time intervals for further processing.

In the COGNITWIN project, the focus is on the liquid metal refining/alloying/casting process (aka post taphole process). In order to fully utilize surplus heat of the liquid ferrosilicon as well as adapting to compositional variances of the tapped metal from the furnace, it is imperative to know the process status at any time – i.e. composition and temperature of the liquid metal. By developing a mathematical model (digital twin) for the mass and energy balance of the total system (relevant equipment + molten metal), we can predict the outcome of process actions and determine the optimal process route given the current state and final conditions. With time, such an approach will enable optimal use of the process surplus heat, for example by re-melting of scrap material to accurately control the final temperature. In addition, it is expected that the variation in the final composition of the melt will show less variance – i.e. increasing the chemical product quality.

Currently the project is focusing on developing and implementing the digital twin version of the on-line mass/energy-balance model. During the fall of 2020, the model will have access to real-time process data and the first version of this digital twin will be tested. Simultaneously, new high-temperature sensors are being installed that will give additional process information to the model. This installation work is expected to commence by the end of the year.

After completion of the model and installation of additional sensors, a prolonged testing period will be initiated in order to verify and optimize the digital twin model. Part of the test work will be benchmarking the new model against existing process decision support. Further efforts in the project are aimed at ultimately arriving at a cognitive twin model for the post tap-hole processing of liquid ferrosilicon.



SUMITOMO PILOT

Photo: Lahti Energia

Fast evolving energy market sets challenges to combustion-based power plants by demanding efficiency and flexibility in terms of fuel and load range. A specific challenge for today's thermal energy production is the variation in fuel quality, which contributes largely to fouling and corrosion phenomena in the critical structures of the boiler like superheater tubes. Sumitomo SHI FW (SFW) pilot case deals with developing novel digital services for energy boilers. The pilot will concentrate on an energy conversion process called Circulating Fluidized Bed (CFB).

The innovation of the pilot is to gather more exact fuel-related information by novel measurement technologies and indirect virtual sensors, and combine that information with other process data from the power plant. Eventually this will enable us to forecast the effect of changes in fuel quality on the process, which will enable earlier detection of process disturbances and prevention of availability problems. This kind of digital twin, with some cognitive abilities, will help the operator of the power plant to optimize the boiler controls so that the foreseen changes in fuel properties will be better handled, boiler emissions and operation economy will be optimal, and the downtime of the boiler will be reduced. In the future, the tools developed in COGNITWIN can be integrated into the SFW's offering of digital services to successfully manage plant operational changes and support plant prescriptive maintenance.

During the first project year we have concentrated on defining the existing level of digitalization in the pilot environment. In addition, the construction of digital twin model has been started, the most promising measurement technologies have been mapped, and the design work for the digital infrastructure of the pilot has been started. Future work will continue by setting up the digital environment for being able to demonstrate the pilot, implementation of new fuel monitoring approaches, and the development of all required models and cognitive elements for the digital twin.

SAARSTAHL PILOT

The Saarstahl AG - with its locations in Völklingen, Burbach and Neunkirchen along with Roheisengesellschaft Saar in Dillingen (Saarstahl and Dillinger Hütte each with 50%) - is a German steel manufacturing company with a global presence on the steel production market. Saarstahl AG specializes in the production of wire rod, hot rolled bars and semi-finished products of various sophisticated grades. These products are important preliminary products for the automotive industry and its suppliers, general mechanical engineering, oil and gas industry, the mining industry and other steel processing branches.

The objective of the SAG use case in the COGNITWIN project is to track individual billets in the rolling mill train and thus to be able to associate sensor and other data collected throughout the rolling process to the corresponding billet.

Combining the data from the rolling mill associated to the billet with data collected beforehand at the steel mill will allow SAG to extend the digital twin of the billet to span the entire production process and enable the twin to become a cognitive twin in the end. The digital resp. cognitive twin in return can then be used e.g. to optimize production processes and apply advanced AI-powered analytics, also helping to reduce the carbon footprint.

A heated billet passing through a rolling stand.

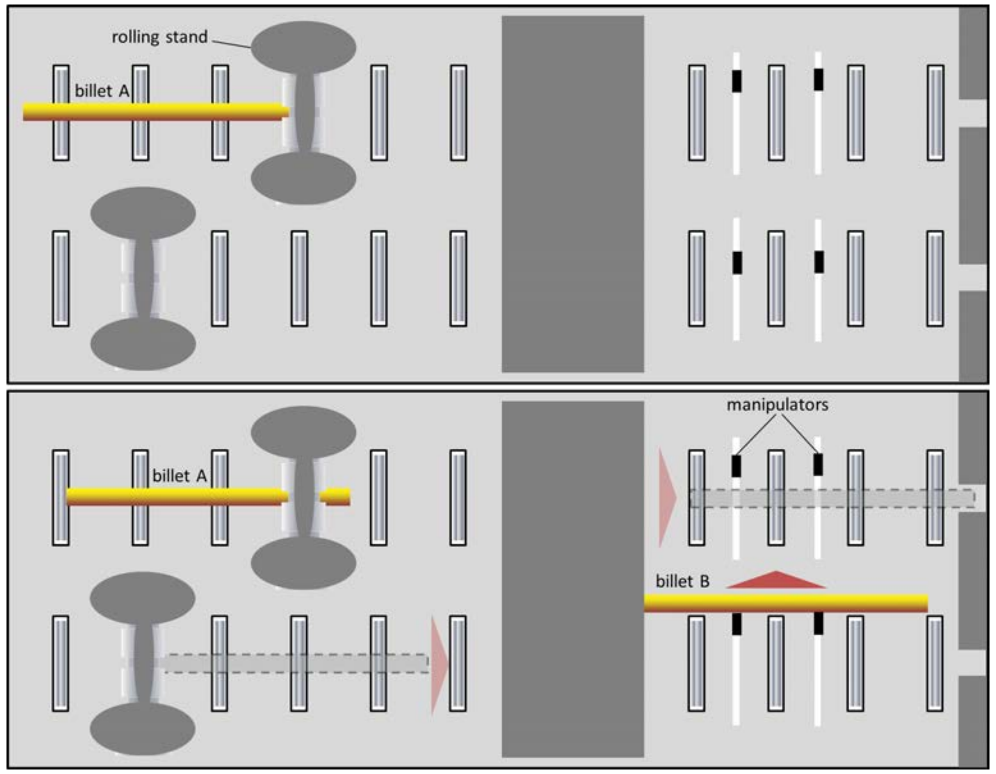
In one of Saarstahl's rolling mills, the mill train is not continuous. This means that rolled bars can overtake one another at certain points. The aim is to implement a computer vision tracking system to keep track of individual bars throughout the mill train:

1. A billet enters the mill train and passes through the rolling stand. In this situation, the billet ID is not in question as no other billets are present in this part of the rolling mill

2. Now two billets A and B are present in the mill train. As they do not necessarily pass through this section of the mill train sequentially, a tracking system is needed to associate the correct ID to both billets throughout the process.

In the first year of COGNITWIN project, the focus has been on establishing and providing the requisites for the tracking system, in particular installing the required cameras, generating a 3D-Modell of the section of the rolling mill where the tracking system is to be implemented, and using the 3D-Modell to render training data for the Deep Learning based Computer Vision tracking system.

Future work will involve defining a suitable Deep Learning architecture for the tracking system, integrating the trained model into existing infrastructure and developing hybrid and cognitive elements for the Digital Twin.



NOKSEL PILOT

Noksel's İskenderun Plant with annual 200.000 Tons production capacity at Hatay region in Turky.

Established in 1987, NOKSEL serves domestic and international markets by manufacturing spiral welded steel pipes for petroleum, gas, water, and piling industries. With headquarters in Ankara, Turkey and production facilities in Turkey and Spain, Noksel has been consistently in the top 500 Turkish Big Export companies in Turkey by export volume.

In steel pipe sector, operations run on 24/7 basis. Due to the multi-step and interdependent nature of the production process, a single malfunction in one of the work stations can bring the whole production process to a halt. Thus, the cost of machines breakdown is very high. Under COGNITWIN project scope; Noksel which is also one the pilot of the project, together with its technological partner Teknopar has initiated digital twin project to develop a Cognitive Twin (CT) for the production process of Spiral Welded steel Pipes (SWP). Briefly the goal is to make use of developed models and analyse multiple sensors' data streams in real time and enable predictive maintenance in order to reduce downtimes by digital twins. The main targets to be achieved are:

- 10% reduction in energy consumption, and
- 10% reduction in shifted average duration of downtimes.

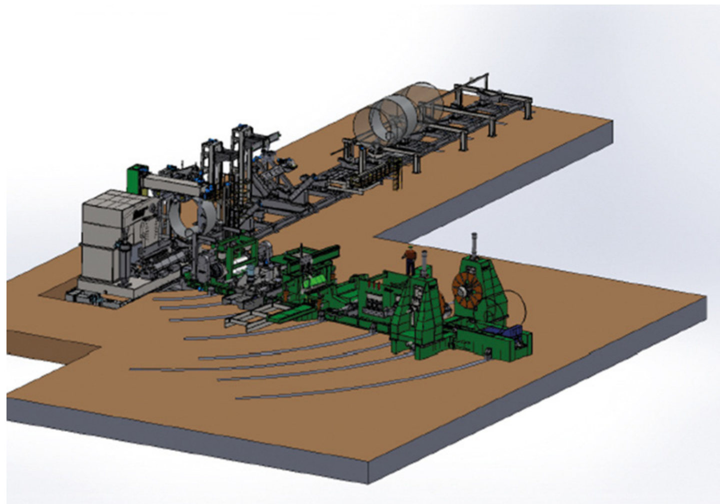
A digital twin on Noksel's production process of Spiral Welded Steel Pipes (SWP) will collect, integrate and analyse multiple sensors' data streams in real-time, and enable predictive maintenance by a smart condition monitoring system.

The digital twin models will be a virtual copy of the steel pipe manufacturing process of the SWP Machinery shown in below Noksel Pilot by creating a new networked layer joining the physical production line and the virtual models where intelligent objects interact with each other.

Cognitive twin system will be built up on digital twin with aiming to autonomously begin to detect changes in the process and will know how to respond in real-time to the constantly changing scenario with minimal human intervention. The first iteration of digital twin and cognitive twin systems will be a hybrid twin where human input will be required to take action based on the feedback of the cognitive twin system. The cognitive twin will have cognitive capabilities by using operational real-time data to enable understanding, self-learning, reasoning and making decisions.

In the 1st year of the project, we conducted a thorough analysis of the real-world data, the digital twin system's architectural design and implementation has been realized. The sensors have been deployed at the manufacturing site; real data from the deployed sensors has started to be collected. The 3D pictures of the machine parts were drawn. The models needed for the process and data driven digital twin are being developed in MATLAB. The GUI of the system applications and some of these interfaces have been implemented. Retrieved from PLC using OPC UA, sensors data have been sent from MQTT to an event processing platform in JSON format. The data have been stored in database for storage and processing.. Instant data received by the event processing platform has been transmitted to a Python based server, where the attribute extraction has been conducted. PCA analysis, hyperparameter tuning and feature engineering have been performed using the available data. To detect anomalies, ten different Machine Learning algorithms have been used. Prediction results have been produced using data from three different Machine Learning libraries. To compare the machine learning models used for predictive analysis an MLL application has been developed. AI algorithms and the toolbox needed to generate predictive maintenance for the system and its components are in development phase.

In the future, the hybrid twin that is in process of development will be enhanced further, and a cognitive twin supporting the proactive self-learning will be developed.



Schematic layout of SWP Machinery.

IMPACT AND EXPLOITATION

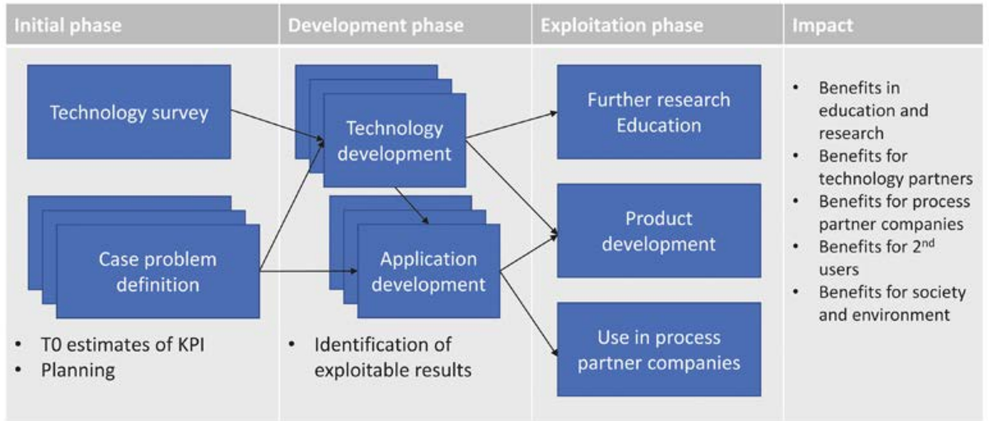


Illustration of the relation between pilot-driven development, generic technology development, exploitation of results and estimation of impact.

The scope of the work package "Impact and Exploitation" is to maximize the impact generated by the project;

- In different communities and on different aspects
- In improved operations
- Reduced emissions
- Improved energy efficiency
- Creating business opportunities and new jobs
- Improved education, and other socio-economic benefits.

An important part of the expected impact will come inside the process industry partner corporations - those of the project partners that provide pilot case studies. The following illustrates a phase model describing how innovation, exploitation and impact is closely related to technology and application development.

During the initial project phase, each of the process industry partners have provided a pilot case, described their respective cases, and for the purpose of estimating the impact of the project, they have:

- Provided a number of Key Performance Indicators (KPIs)
- Devised how to measure or quantify those
- Determined baseline values of the KPIs – based on historical data up to the time of project start-up.

COGNITWIN Deliverable 6.1. summarizes this work. It also contains objectives for improvements in some of the KPIs.

COGNITWIN is now well into the development phase. Moving forward, possible exploitable results will be identified by keeping an overview of technology innovations. The expected impact of the project is under review. In the next few months, the first version of the Initial Exploitation Plan: Process Industry Impact report and Initial Business Plan will be finalised and released.

KEY RESULTS OF THE DISSEMINATION, COMMUNICATION AND STANDARDIZATION ACTIVITIES

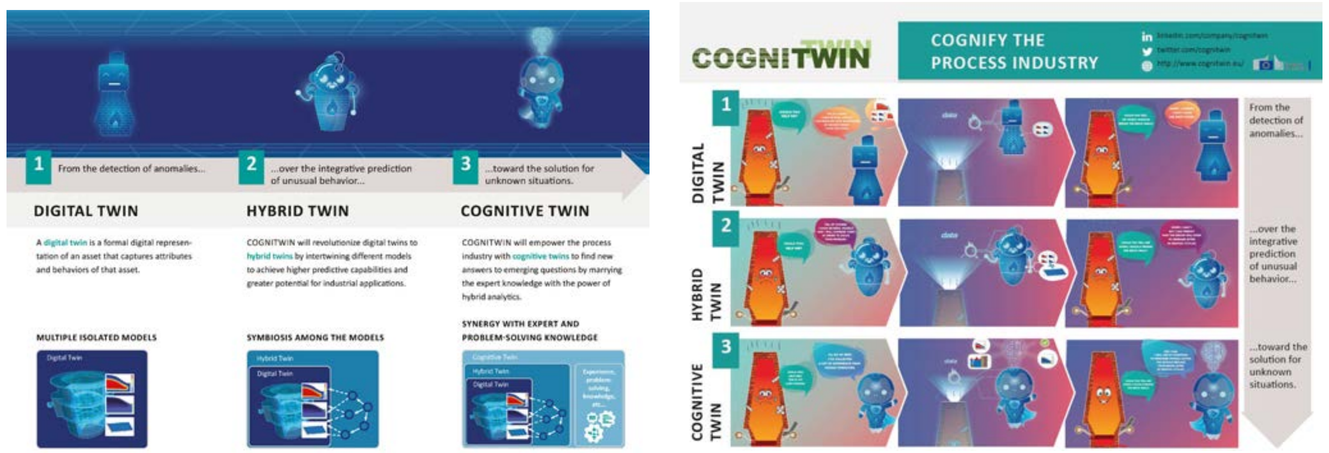
The overall goal of COGNITWIN's dissemination, communication and standardization activities is to ensure that the COGNITWIN results will have a maximum impact and that the consortium reaches its ultimate objective through communication activities. All activities have been a strategically planned process, which started at the beginning of the project and will continue throughout its entire lifetime.

To inform the general public about the project, the project website (http://www.cognitwin.eu/) was launched in November 2019. It is the main tool for dissemination during the project duration and beyond and will be maintained during at least two years after the project completion. The content (e.g. news, events, reports, publications, etc.) has been regularly updated.

The next step was to explain the general public what the project is about. To quickly attract as wider audience as possible and to improve the possibilities for COGNITWIN to influence public policy, we decide to start with comics. The visual representation of different types of twins indicates their intelligence. Whereas the digital twin has the same form as its physical counterpart, the hybrid twin is more human-like and has certain intelligence. The level of intelligence by the cognitive twin is significantly increased and it has some strong and elevated capabilities. This visual representation should help readers to understand the COGNITWIN aspects which are less obvious when reading the same information. This visual representation was used in two flyers that were created during the 1st project year. Whereas one flyer explains the concept of the digital, hybrid and cognitive twin from a technical point of view, the other flyer explains the project vision without going into technical/research details.

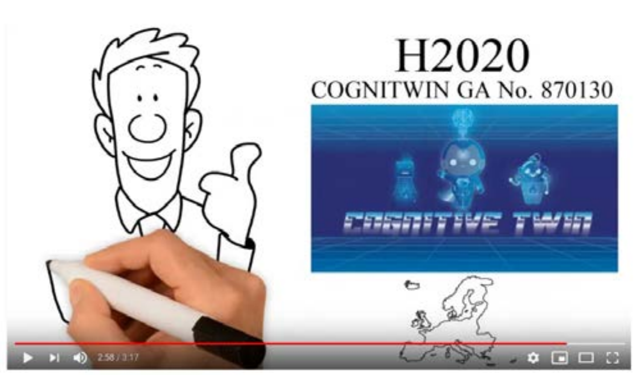
Cognitwin website.

PART III: EXPLOITATION, DISSEMINATION AND PROJECT MANAGEMENT



COGNITWIN flyers.

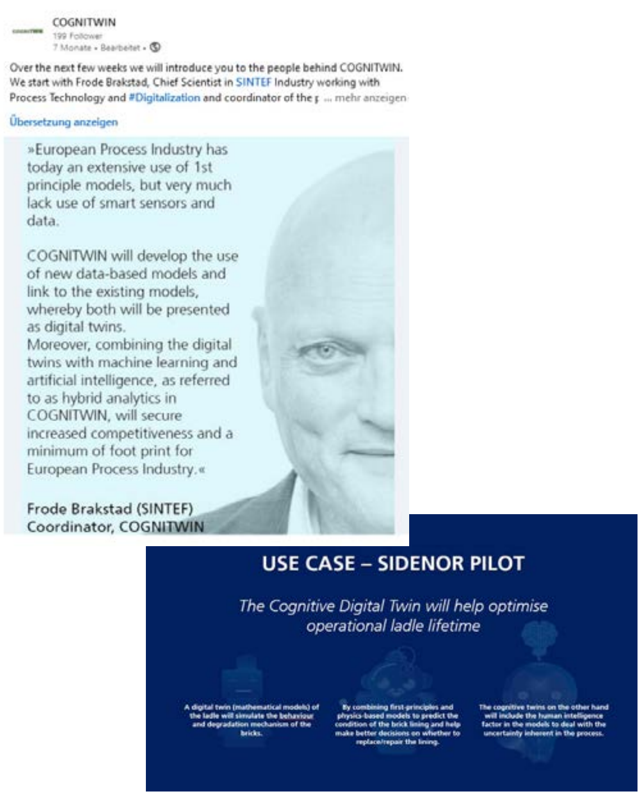
The same visual metaphor is used for the project video (https://www.youtube.com/watch?v=xuUsopTUWjA&featu-re=emb_logo) that presents the project profile and general concept.



COGNITWIN video.

Regarding the social media activities, the LinkedIn and Twitter social networks have been used as a marketing tool in order not only to promote results of the project but also to encourage a wider discussion on digital twins. The social media campaigns started in March 2020, after the first project results were available." In addition to posting about the project news, we created two special campaigns. The first is about the role of the project members and their expectations of COGNITWIN. The second is about the meaning of digital, hybrid and cognitive twins in the pilots.

In the first year of the project, dissemination activities focused on a scientific audience, using publications and conferences. The following papers were published:



COGNITWIN in social media.

1. Jacoby, M.; Slander, T.: Digital Twin and Internet of Things–Current Standards Landscape. Appl. Sci. 2020, 10, 6519. Link: https://www.mdpi.com/2076-3417/10/18/6519

2. S. Abburu, A. J. Berre, M. Jacoby, D. Roman, L. Stojanovic and N. Stojanovic: „COGNITWIN – Hybrid and Cognitive Digital Twins for the Process Industry," *2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC),* Cardiff, United Kingdom, 2020, pp. 1-8, doi: 10.1109/ICE/ITMC49519.2020.9198403.

3. S. Abburu, A. J. Berre, M. Jacoby, D. Roman, L. Stojanovic and N. Stojanovic: "Cognitive Digital Twins for the Process Industry," „The Twelfth International Conference on Advanced Cognitive Technologies and Applications" (COGNITIVE 2020)

With regard to the presentations, we gave an invited talk on "Cognitive Digital Twins: Challenges and opportunities for semantic technologies" at International Workshop on Semantic

Special issue organized by COGNITWIN.

Digital Twins (SeDiT 2020), co-located with the 16th European Semantic Web Conference (ESWC 2020). In addition, a presentation on „Intelligent Steel Tube Production Facility on Cognitive Digital Twins: A Case Study on Digitization of SWP" was given at the 3rd ESTEP Workshop, Impact and Opportunities of Artificial Intelligence in the Steel Industry.

Next, the COGNITWIN partners Dr. Ljiljana Stojanovic and Dr. Arne Berre are the guest editors of a special issue about Cognitive Digital Twins[1]. The special issue intends to explore new directions in the field of digital twins in combination with cognitive computing and to clarify the underlying reasons and benefits.

Finally, we worked on organizing a webinar series for the process industry, including a presentation on digital twins for the process industry.

COGNITWIN webinar on digital twins.

In addition to communicating and disseminating the results of the project to relevant stakeholders, we have also followed various standardization activities that will help COGNITWIN leave a long-lasting impact on the European industrial sectors. For example, we contributed to the joint whitepaper on the Industrial Internet Consortium (IIC) and Plattform Industrie 4.0 on the technical aspects of the digital twin. The focus was on exploring whether the Asset Administration Shell can support digital twins in manufacturing and use cases beyond.

[1] https://www.mdpi.com/journal/information/special_issues/digital_manufacturing_industries

CONSORTIUM

COGNITWIN partner participants at the Kick-off meeting in Molde (Norway).

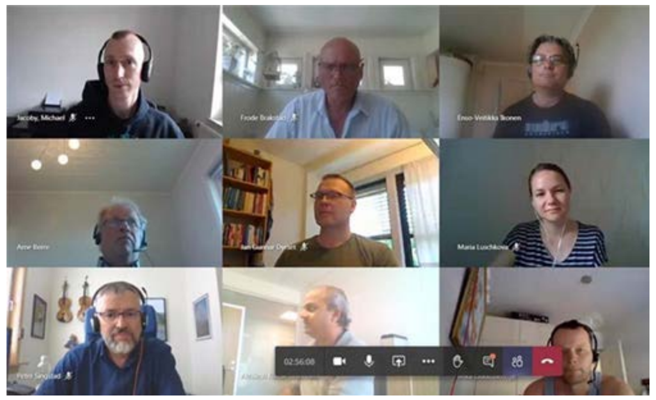
The COGNITWIN project started 1st September 2019 with a physical meeting with all the partners in Molde (Norway), and was originally planned to end 31st August 2022. Due to the COVID -19 pandemic situation, the employees in three of the six pilot plants had restricted access to the plants during the spring and summer 2020. Thus, the consortium made a consensus to request a 6-months project extension with extended delivery dates for future deliverables and milestones. European commission has now granted a 6-month project extension.

The project has also decided to replace M12 project meeting from physical to on-line mode. The meeting was held online via Microsoft Teams on 16th and 17th June, with almost 42 people joined the meeting.

In pre-COVID situation, it was planned that the consortium will have a tour of SUMITOMO's industrial facilities during the M12 meeting. In the changed situation, SUMITOMO had made an excellent online presentation on its company profile and processes.

Although all the Work Packages have reported significant progress regardless of the challenges of COVID-19 situation, we hope to soon be back in a more normal situation where:

- Our project work will be carried out smoothly without any further changes due to the pandemic situation
- We will be able to again meet physically with on-site industrial tours


A screenshot from COGNITWIN M12 project meeting on Microsoft Teams.

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