SOON
Social Network of Machines

Project ID: *COFUND-CHIST-ERA-SOON*
Contract number: *101/ 17.04.2019*
Title (En): *Social Network of Machines*
Title (Ro): *Rețea Socială de Dispozitive Inteligente*
Acronym: *SOON*
"George Emil Palade" University of Medicine, Pharmacy, Sciences and Technology of Târgu Mureș (UMFST)
Contract duration: 17/04/2019 - 28/02/2022

Summary Report

1st Phase: Year 2019

Exploration, Identification and Requirements Analysis

1st Phase start date / Reporting date: 17.04.2019 / 02.12.2019

1. The Objectives of the First Phase: Year 2019

1.1. Context. Preliminary Aspects

Nowadays, new concepts based on discoveries and new technologies, are adopted, many of them are coming from the field of information and communication technology (ICT) and allow strengthen of the industrial production activities efficiency. The "Industry 4.0" represents the concept that brings under the same framework such approaches. The present project, proposed within the 2017 call "Big data and process modelling for smart industry (BDSI)", aims to investigate the impact that the use of autonomous social agents would have on the optimizing of the manufacturing processes within the concept of Industry 4.0.

From the project point of view, the social agents are considered cyber-physical entities capable of operating autonomously in order to optimize a wide range of industrial processes based on behavioural models inspired by the models of human social networks. The main idea is to introduce an intelligent component capable of ensuring a collaborative process at the equipment level, shop floor and even externally. The baseline pursued in the project is to create a framework specific to the Internet of Everything (IoE) that interconnects processes, data and human operators. This goal is possible if there can be established ways to interconnect these elements on the basis of an easily understood and applied paradigm.

In the first reporting phase of the project, the consortium, consisting of three European universities, a research institute of an academy of sciences and three companies that have a distinct industrial production profiles, was focused on creating the proposal implementation framework, aspect that are briefly presented in this summary report.

The implementation consortium is composed of the following entities:

- University of applied Sciences and Arts Western Switzerland (HES-SO);
- Slovak Academy of Sciences (SAV);
- University of Oviedo (UNIOVI);
- "George Emil Palade" University of Medicine, Pharmacy, Sciences and Technology of Târgu Mureș (UMFST);
- Tornos S.A., Switzerland, (Tornos), industrial partner;
- MAT-obaly s.r.o. Slovakia, (MAT), industrial partner;
- ArcelorMittal Innovación Investigación e Inversiones S.L. Spain, (AMI3), industrial partner.

List of acronyms and abbreviations

AI	Artificial Intelligence
CA	Consortium Agreement
ERP	Enterprise Resource Planning
HPC	High-Performance Computing
IIoT	Industrial Internet of Things
IoE	Internet of Everything
NGSI	Next Generation Service Interface
OEE	Overall Equipment Effectiveness
SBC	Single-Board Computer
MAS	Multiagent System
SoC	System-on-a-Chip

1.2. The Objectives for the Year 2019

The overall objective of this project is to investigate the impact of using intelligent autonomous social agents for the optimization of industrial production processes within Industry 4.0 from the perspective of maintaining in operation at the nominal process parameters and avoiding interruptions by applying appropriate measures of predictive maintenance. The proposed investigation aims mainly to anticipate/forecast and early detection of the faults, the identification of the nature of the failures, respectively their location.

The specific objectives to this reporting phase can be categorized into objectives whose full achievement is proposed in this stage and objectives that begin in this stage and are carried out over several stages.

The specific objective of the stage with the complete fulfil in the first stage:

- Identification of the particular industrial environment needs from the Industry 4.0 perspective;

The specific objectives of the stage with the continuation of the achievement in the following stage:

- Multiagent system architecture design initiation for predictive maintenance;
- Initiation the design of an ontology related to MAS;
- Definition of predictive maintenance scenarios initiation;
- Initiation the definition of the specifications of the integration framework of the MAS based predictive maintenance solution;
- Design of a platform for testing and evaluating IIoT/IoE solutions for predictive maintenance;
- Planning the dissemination strategy of the project.

1.3. Specific Activities of the Reporting Phase

During the reporting stage, starting from the implementation plan, the following main activities were initiated and/or carried out within the consortium:

Act 1.1. *Industrial requirements specification*.
The activity consisted of identifying, specifying and analyzing the industrial requirements starting from real industrial scenarios. With the support of industrial partners, actors and stakeholders, interdependencies, use cases and quantifiable objectives were identified. Those scenarios that are covering the different situations of failure within the industrial production systems were also identified and selected.

Act 1.2. *Design of the social agents' architecture*.
The activity consisted of starting the multiagent system ontology and the architecture design taking into account the role and mapping of the agents (at the level of machine, shop floor, factory, company), the targeted performances, the capabilities, the state of the machines (the history of defects, the current state, etc.) and social capabilities.

Act 1.3. *Defining the maintenance scenarios*.
Starting of the predictive maintenance scenarios analysis and specification with the support of industrial partners to identify the most significant cases of failure, with emphasis on the prediction of the duration of interruptions due to failures and the detection of sensor failures.

Act 1.4. *Project management and dissemination*.
This activity consisted in carrying out the tasks needed to ensure the proper project management and dissemination activities. One step in order to ensure visibility was to create the web page of the project that belongs to the Romanian partner, respectively its content consisting in information specific to the current stage. A study was carried out regarding the elaboration and planning of the dissemination strategy throughout the course of the project.

Act 1.5. *Integration framework design*.
Starting the activity related to the task of requirements analysis and integration framework design that aimed to prepare the integration specifications in accordance with the predictive maintenance scenarios. The synthesized requirements depend to a significant extent on the scenarios implemented, the available machines and the increased variety of the available data. Among the fundamental features on which the solution will be based are the scalability and extensibility that proofs the independence of the proposed solution in relation with the order of size of the industrial platform.

2. Scientific and Technical Description

2.1. Preliminary aspects

In the framework of the SOON project, it is proposed to investigate a new innovative approach based on the technology of autonomous social agents to optimize industrial production processes based on the support provided by sensors, cyber-physical entities and human operators. All these elements are expected to function in an interconnected structure where they will act autonomously similarly like socio-professional entities that collaborate within a social network. Such an approach besides the data exchange also introduces

intelligent analysis algorithms that will characterize the proposal as a compliant solution with the concepts of Industry 4.0.

A novel aspect associated with the research undertaken is the interconnection of the mentioned entities in an IoE ecosystem based on a shared, comprehensible paradigm that solves the problem of efficient communication and cooperation.

From an architectural point of view, it is proposed to investigate the efficiency of a solution based on a holistic paradigm with intelligent agents entities associated to machines and human operators, who from the position of experts will provide knowledge, but at the same time will benefit from the results of processing in decision-making processes. This will be possible with the implementation of the planned algorithms for extracting data and features and deep learning algorithms respectively.

It is estimated that it will be necessary to process large amounts of heterogeneous data provided by a large variety of equipment classes and devices (sensors, automatic control systems, robots), but which will have to compete in real-time to solve complex predictive maintenance tasks.

It should be noted that in addition to the real-time measurements, the used data sources will also consist of historical records, available in the form of time series, some coming from ERP systems, which will represent the input of the algorithms used in the social network to implement predictive maintenance.

The developed concept will be based on the specifications from all the industrial partners involved in the project. It should be mentioned that they belong to different fields and profile of industrial activities that will ensure the generality of the solution. In addition to this aspect, the efficiency of the learning algorithms will be analyzed in the context of a cooperative multi-agent architecture from the perspective of the modeling and operation optimizing of the industrial processes.

The general concept of the proposed architecture, presented in Fig. 1., was designed in such a way that is able to ensure scalability, and its implementation allows the inclusion of entities such as physical machines and processes, devices, sensors and ICT infrastructure consisting of intelligent cloud processing systems, data concentrators or processing and analysis software.

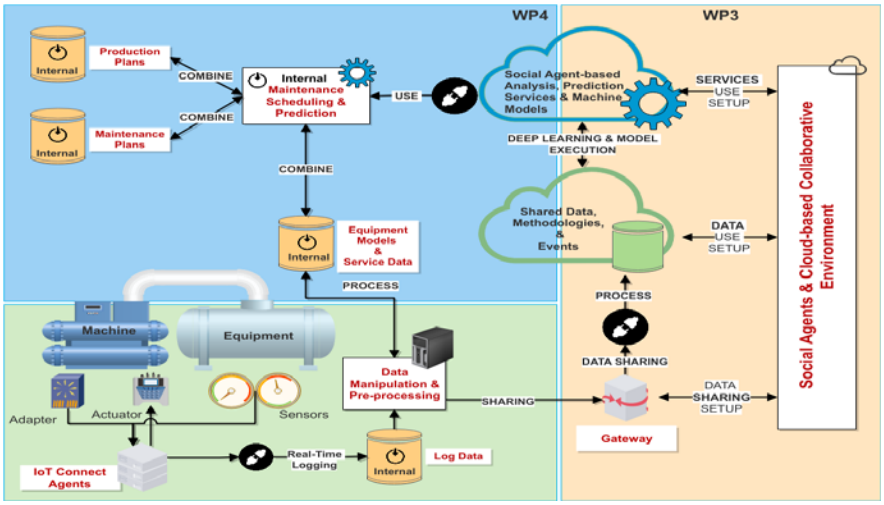

Figure 1. General Architecture of the proposed solution

2.2. Industrial Requirements: Identification and Analysis

A main objective of the first phase of the project implementation was to establish the context, needs and possibilities for adopting and implementing solutions to improve production processes by using various advanced techniques, including predictive maintenance, intelligent maintenance, etc.

In this process were involved all industrial partners coming from a large variety range of industries with particular production processes such as: metallurgical industry, machine tool construction, plastics sorting and recycling industry.

Industrial Requirements

In order to investigate and develop the optimization solutions based on predictive maintenance were identified the main expectations of the industrial beneficiaries and the scenarios that could lead to them. These scenarios are described in the "Document of industrial requirements" are:

- *Requirements specification and analysis from the perspective of predictive maintenance;*
- *Requirements specification and analysis from the perspective of intelligent maintenance;*
- *Requirements specification and analysis from the perspective of improving the quality of production;*
- *Requirements specification and analysis from the perspective of sensor failure detection;*
- *Requirements specification and analysis from the perspective of improving the organization of a production unit;*
- *Requirements specification and analysis from systems learning perspective.*

2.3. Experimental Testbed Development

In order to analyze the prototypes related to the solutions developed within the project, a comprehensive study of the specialized state-of-the-art literature on the support technologies that can be used was carried out, for providing the efficiency analysis.

Considering the industrial specifications and requirements, as an open-source solution that allows the integration of an intelligent solution based on IIoT sensors and devices, the FIWARE platform was chosen [1]. The FIWARE platform was developed as part of a large European project called FI-WARE: Future Internet Core Platform and used in numerous implementations in different fields [6, 7], including agriculture, industry, smart cities, etc. FIWARE is built around several components that provide various functionalities.

An important goal of the project is the aggregation of data from sensors and devices. The first step of the support evaluation solution was performed by experimental testing considering the FIWARE components dedicated to this aspect. Thus, the test platform was configured around a NoSQL database implemented with the MongoDB solution [8] and the Orion Context Broker component [9].

FIWARE Orion Context Broker is an implementation of the generic (generic enabler) Publish/Subscribe Context Broker, having as an access point a NGSI interface. Using this interface, the source and data beneficiary applications can perform a number of standard operations such as:

- The contextual information retrieval. The Orion Context Broker handles up-to-date context information for applications so that requests are solved based on those

information. Contextual information contain details regarding entities (for example, a machinery) and certain attributes (for example, locating and storing features for the car);
- Updating the context information, consisting in the effective updating of the entity attributes (for example, updating the functioning state of the machine from the nominal parameters to the defective mode);
- Registration of the context supplier application (for example, for the fan speed sensor in the cooling tower).

From the experimental point of view, it was analyzed the possibility of real-time data acquisition provided by industrial sensors while considering industrial processing time constraints.

The purpose of the performed experimental investigations was to acquire information that will allow the support for decisions regarding the specifications identification and the implementation parameters of the sensors integration solution and the context components of the social network for the provision and data access. The obtained experimental results constitute the source of a scientific article that will be prepared. They also will offer support in the decision-making process regarding the adoption of the appropriate solution for the module of pre-processing and manipulation of the data from the distributed sources.

3. Brief report on mobilities

Even though the project was in the initial phase, participation in the seminars and conferences were taken into account. At the same time, a major working visit was also considered.

Bucharest, 3-4 April 2019

The first action correlated with the starting project activity was the participation to the "CHIST-ERA Projects Seminar 2019", Bucharest, 3-4 April 2019.

Bucharest, 5 April 2019

The CHIST-ERA seminar was followed by the first meeting in the framework of the project. This event represented the project implementation kick-off meeting, bringing together all the members of the project consortium.

Moutier, Switzerland, 3 September 2019

One of the central events during the reporting period was the annual meeting organized by HES-SO and Tornos which led to a working meeting and a round table at Moutier, on the Tornos industrial platform.

Neuchâtel, Switzerland, 4 September 2019

The meeting from Neuchâtel took place at HES-SO and was dedicated to discuss aspects concerning the project management and implementation.

Târgu Mureș, 3-4 October 2019

In order to ensure the highest level of knowledge transfer related to the latest achievements in the project areas, the UMFST team members were involved in the events associated with the International Conference on Interdisciplinarity in Engineering (Inter-Eng

2019) with the main theme "Industry 4.0 developing a new generation of intelligent production-based factories on the digitization of manufacturing processes ".

4. Infrastructure: Testing and validation Industry 4.0 platform support solutions

During this reporting period, a pilot platform for testing and evaluating IIoT/IoE solutions for predictive maintenance was designed. Based on the 2019 planned budget for this purpose, processing equipment, communications and field devices (SBC and SoC) were purchased. The test solution consists of an HPC unit, workstations, a high speed switch communication network with management, and ten SBC systems connected via PoE as data concentrator systems from sensors via SoC solutions.

Description:

The testing and validating platform for Industry 4.0 based support solutions is intended to create in the laboratory an isolated or an interconnected environment that models ITC infrastructures used in the industrial environment as a support for monitoring, controlling and optimizing production processes. The platform will be used to calibrate, test and validate some advanced intelligent technologies and algorithms developed for analyzing large collections of data obtained from sensors, simulators of real industrial systems and ERP systems.

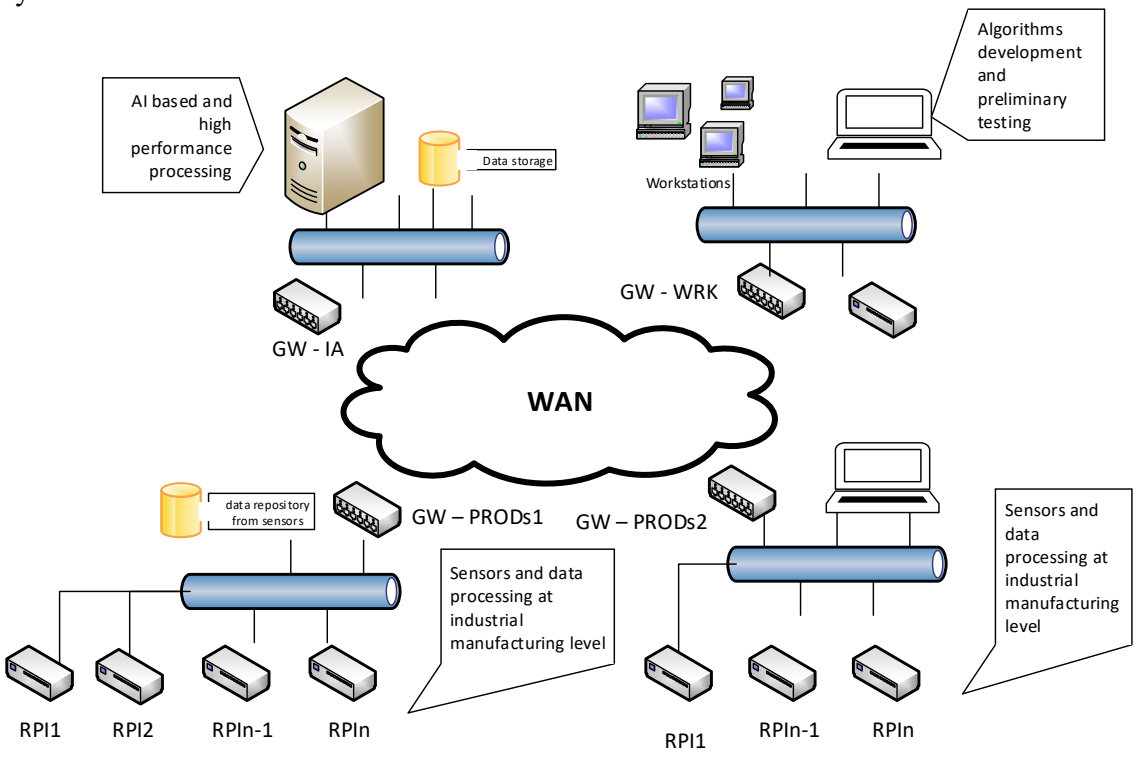

Figure 2. The architecture of the lab experimental and validation testbed.

References

[1] Ramparany, F.; Marquez, F.G.; Soriano, J.; Elsaleh, T.: Handling smart environment devices, data and services at the semantic level with the FI-WARE core platform, 2014 IEEE International Conference in Big Data, IEEE Press, 2014, pp. 14-20.

[2] Iantovics, L.B.; Kovacs, L.; Rotar, C.: MeasApplInt - a novel intelligence metric for choosing the computing systems able to solve real-life problems with a high intelligence, *Applied Intelligence*, 49(10), 2019, 3491-3511. (Publication in the framework of the project.)
[3] Iantovics, L.B.; Kountchev, R.; Crișan, G.C.: ExtrIntDetect-A New Universal Method for the Identification of Intelligent Cooperative Multiagent Systems with Extreme Intelligence, *Symmetry*, 11(9), 2019, 1123. (Publication in the framework of the project.)
[4] Iantovics, L.B.; Rotar, C.; Morar, F.: Survey on establishing the optimal number of factors in exploratory factor analysis applied to data mining, *Wiley Interdisciplinary Reviews-Data Mining and Knowledge Discovery*, 9(2), 2019, e1294. (Publication in the framework of the project.)
[5] Iantovics, L. B.; Gligor, A.; Niazi, M. A.; Biro, A.I.; Szilagyi, S.M.; Tokody, D.: Review of Recent Trends in Measuring the Computing Systems Intelligence. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, 9(2), 2018, 77-94.
[6]Martinez, A.; Estrada, H.; Ramírez, F.; Gonzalez, M.: A New Software Library for Mobile Sensing Using FIWARE Technologies. In: Batyrshin, I., Martínez-Villaseñor, M., Ponce, E.H. (Eds.) Advances in Computational Intelligence. Mexican International Conference on Artificial Intelligence (MICAI 2018). Lecture Notes in Computer Science, Vol 11289. Springer, Cham, 2018, pp 253-263.
[7] Rodriguez, M.A.; Cuenca, L.; Ortiz, A.: FIWARE Open Source Standard Platform in Smart Farming - A Review. In: Camarinha-Matos, L., Afsarmanesh, H., Rezgui, Y. (Eds.) Collaborative Networks of Cognitive Systems. Working Conference on Virtual Enterprises (PRO-VE 2018). IFIP Advances in Information and Communication Technology, vol 534, Springer, Cham, 2018, pp 581-589.
[8] Christudas, B.: Install, Configure, and Run MongoDB. In: Practical Microservices Architectural Patterns. Apress, Berkeley, CA, 2019, pp 813-825.
[9] da Cruz, M.A.A., Rodrigues, J.J.P.C., Lorenz, P.; Solic, P., Al-Muhtadi, J., Albuquerqueg, V.H.C.: A proposal for bridging application layer protocols to HTTP on IIoT solutions, *Future Generation Computer Systems*, 97, 2019, 145-152.
[10] Gligor A., et al.: Power Demand Forecast for Optimization of the Distribution Costs, Proc. of 13th Intl. Conf. on Interdisciplinarity in Engineering, 3-4 oct. 2019 (in press) (Publication in the framework of the project.)
[11] Nakajima, S., Introduction to TPM: Total Productive Maintenance, Cambridge, MA, Productivity Press, 1988.
[12] Cios, K.J.; Swiniarski, R.W.; Pedrycz, W.; Kurgan, L.: Data mining: A knowledge discovery approach. Boston, MA, US: Springer, (2007).
[13] Choi, Y.; Taylor, J.; Tibshirani, R.: Selecting the number of principal components: Estimation of the true rank of a noisy matrix. Annals of Statistics, 45(6), 2017, 2590-2617.
[14] Preacher, K.J.; Zhang, G.; Kim, C.; Mels, G.: Choosing the optimal number of factors in exploratory factor analysis: A model selection perspective. *Multivariate Behavioral Research*, 48, 2013, 28-56.
[15] Besold, T.; Hernandez-Orallo, J.; Schmid, U.: Can Machine Intelligence be Measured in the Same Way as Human intelligence? Künstliche Intelligenz, 29(3), 2015, 291-297.
[16] Nicolas, S.; Andrieu, B.; Croizet, J.-C.; Sanitioso, R.B.; Burman, J.T.: Sick? Or slow? On the origins of intelligence as a psychological object. Intelligence, 41(5), 2013, 699-711.