Big Data on Machine to Machine Integration's Requirement Analysis Within Industry 4.0

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Abstract. One of the foundations for Industry 4.0 is the integration of various industrial elements (i.e. sensors, machines, and services) so that these devices can decide in a relatively autonomous way the level of integration which will be adopted. Thus, it is important to understand how the communication Machine to Machine is effectively realized and how these data can be explored and used to enhance the manufacturing process. The exchange of information between machines in the industrial process represents a potential to acquire and analyze a mass of data characterized as "big data", which can be perceived as an opportunity to discuss the paradigms of the industrial systems. Therefore, the purpose of this research is to identify the requirements for the Machine to Machine communication and the use of this data/information for more complexes analyzes using big data and analytics techniques. The KAOS methodology was utilized to model these requirements.

Keywords: Industry 4.0, requirements engineering, KAOS modeling, big data, Machine to Machine, interoperability.

1 Introduction

Industry 4.0 (I4.0), or fourth industrial revolution, is an expression that was displayed in 2011 at the Hannover fair and started in April 2013 with the project "Plattform Industrie 4.0" [1]. Basically, Industry 4.0 uses technologies such as RFID (Radio Frequency IDentificator), to identify and track all of its elements or assets, such as machines, tools, and products. These identifiers [2]. Ploner [3] describes how the title "Industry 4.0" indicates an industrial revolution marked by the connection of three main technologies: Internet of Things (IoT), Cyber-Physical Systems (CPS), hings (IoT) and Information and Communication Technology (ICT).

Computational elements are used to control or monitor cyber-physical systems. In these systems, the physical and software elements are interconnected and also act closely integrated with the Internet and its users. Organization assets can be defined as a CPS with their physical and virtual functionalities, and the communication between the functionalities of these assets is carried out by IoT and ICT. From these functionalities, Machine to Machine (M2M) communication also can be achieved through IoT, which must satisfy all the needs of I4.0, relating the efficiency and monitoring criteria of these machines. Through Big Data analytical techniques, it is possible to understand how the machines work and how their performance can be optimized.

The Machine to Machine communication is accomplished by integrating any machine to any machine that shares a common data exchange service. For this, sensors, actuators, and identifiers are coupled on these machines, thus representing communication through the IoT [4].

For the development of this communication and the data analysis, it arises the need to develop criteria for its implementation. The first stage of this process begins with the analysis of requirements, responsible for specifying objectives and possible obstacles. In order to obtain a cohesive requirement analysis, three points must be considered [4]:

- The viewpoint of various stakeholders and development engineers should be analyzed in order to have no subsequent problems with wrong or incomplete requirements [5];
- Establishment of methods for requirements management and validation;
- Creation of organized processes that lead to a specification with a natural language.

In this context, the focus of work is the modeling of requirements in both communications between machines and big data systems.

A hypothesis raised by the authors is that modeling the requirements described by initiatives associated with the I4.0 like the RAMI 4.0 (Reference Architectural Model for Industry 4.0) [6] using the KAOS (Keep All Objectives Satisfied) [7] methodology can assist in developing systems that effectively reflect the needs of the industry.

2 Relationship to Industrial and Service Systems

As described [4], requirements analysis remains the first step of any type of project. It has the responsibility of defining goals and predicting hindrances and therefore assisting on creating a resilient system.

It is necessary that the requirements for a system are accurately identified, enabling its development to be effectively oriented to fulfill the necessities of the involved stakeholders (the individuals committed with the benefits of the company's business) associated with the I4.0 context.

In recent years, efforts to establish models and standards for the structure of the Industry 4.0 were made. Some of them decompose the properties of a productive system in layers, from the physical assets, at the bottom, to the business model and regulatory conditions, at the top. According to [6], the most advanced of these structures is the German initiative “RAMI 4.0”.

Within this context, previous works [4][8] characterize the objectives, requirements, and challenges from the viewpoints of stakeholders associated with the Industry 4.0 context. Using the layers described in RAMI 4.0 as a base, [4] presents the modeling of the interaction between machines and [8] alludes to the data analysis functionalities and information capacities needed.

This work relates to industrial and service systems, providing a take the first step towards the development of systems capable of dealing with the heterogeneity of the entities in the Industry 4.0. Another valuable contribution of this research is to propose the discussion of the current efforts surrounding Industry 4.0 from the angle of the requirements engineering, orienting the productive system development towards the solving of the existing problems.

3 Literature Review

The foundation concepts utilized in the present work are displayed in this section. A comprehensive review of the concepts of Machine to Machine, Big Data, and the KAOS methodology can be found in previous works [4] [8].

3.1 RAMI 4.0

A reference architecture is a document that represents the structures and integrations recommended to form a solution. It incorporates industry-accepted practices and therefore answers the most common questions that arise during the development of solutions and technologies [2][9].

The use of reference architectures is important for orienting the technological development towards the needs and requirements of the stakeholders of a production process, ensuring that the solutions developed are focused on solving existing problems.

The German Electrical and Electronic Manufacturers Association (ZVEI) established the RAMI 4.0 (Reference Architectural Model for Industry 4.0) as a standard design for I4.0 [6]. The RAMI 4.0 was conceived from current standards of the productive sector aiming to group different specifications on a single three-dimensional model (Figure 1) to match the integration, both vertical, horizontal, and of distinct stages within the engineering process [2].

With these three dimensions, all significant features of I4.0 can be outlined, allowing the elements like the machines to be classified according to the model. The concepts of high flexibility proposed by I4.0 can be represented and implemented using RAMI 4.0, enabling a step-by-step departure from the current industry to the Industry 4.0 [10].

Each dimension can be summarized as:

- The dimension "**Layers**" is used to represent asset characteristics, making it possible for them to be fully mapped virtually.
- The dimension "**Life Cycle and Value Stream**" is used to visualize and normalize the relationships of Industry 4.0 components along their life cycle.

The dimension "**Hierarchical Levels**" describes the integration of business control systems. It was based on the ISA-95 standard, which defines the interface between the control functions and the other functions of the enterprise [2].

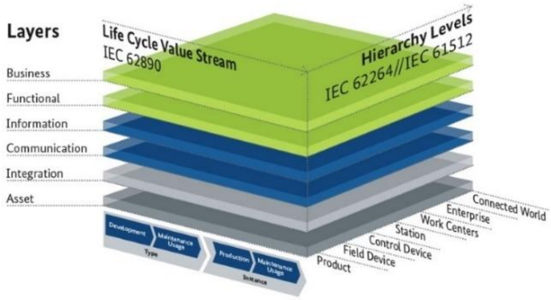

Fig 1. RAMI 4.0 [6].

According to [2], the dimension *Layers* is divided into six levels to illustrate the breakdown of machines and physical entities, mapping those elements to their respective virtual representations, this virtual represented entity can also be referred as Industry 4.0 Component.

Using these levels, an overview to data mapping, functional descriptions, communication protocols, hardware and assets, and business processes can be represented. Each level and its interrelationships can be described as [6]:

- **Business**: Contains the rules that the system must follow as legal and regulatory conditions, mapping the business model of the system and orchestrating the services of the functional level;
- **Functional**: Contains a formal description of all the functionalities of a system and it is the stage responsible for their horizontal integration;
- **Information**: Contains the necessary data source for the control of assets, ensuring that the data of an asset is treated and made available. In this layer Big Data analysis is performed according to the specific application;
- **Communication**: Guarantees that all the data directed to the above layer have a uniform format, allowing the access of information;
- **Integration:** It is the virtual mapping of the real system. Here, the information on the physical assets is provided by the sensors as RFID (Radio-Frequency IDentification) and the Human Machine Interface (HMI);
- **Asset:** Represents physical components such as machines, actuators, parts, documents, and people.

This "Layer" dimension on RAMI 4.0 represents the main change on the way to view and understand a physical asset. Here the asset is seen as a CPS and the IoT is the tool that enables the connection among the physical asset and its digital counterpart on the Integration Layer.

3.2 KAOS Methodology

The KAOS methodology is a "goal-oriented requirements engineering approach" elaborated at the Universities of Oregon and Louvain. The benefit of KAOS over other methods is its ability to align goals to its requirements, improving the odds of the modeling adding value to the business [8] [11].

The KAOS modeling uses a graph with:

- **Goals**: Central Work Objective (white parallelograms);
- **SoftGoal:** Secondary objectives to achieve the central objective (gray parallelograms);
- **Requirements**: Establish the requirements for achieving the Goals (bold white parallelograms);
- **Operation**: Act that shows the procedures for obtaining the result (ellipses);
- **Actors**: Responsible for system action (hexagons);
- **Event**: Effect of the operation and demonstrated requirements (pentagons).

Figure 2 represents an example of how the requirements modeling are divided in this paper:

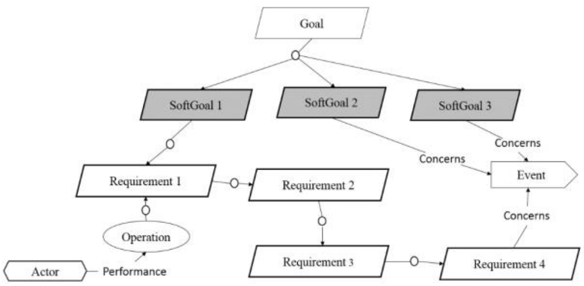

Fig 2. Example of modeling.

4 Requirements Modeling

In this section, the objectives, operations, entities, and actors are demonstrated and discussed.

4.1 GOALS

With the purpose of understanding the problem, it is first necessary to design the objectives. In this paper, the central goal is to implement Machine to Machine integration by monitoring the performance of products and machines with Big Data analysis. Thus, some points must be considered:

- The proper use of IoT for communication;
- Interoperability between the machines;
- Integrate M2M within CPS steps, using RAMI 4.0.
- In the Big Data analysis, it must be verified whether the decision-making speed for the manufacturing process is satisfactory; if the amount of data transmitted is

enough; if there is a possibility of working with various types of data; if there is reliable information; and if the analysis can improve production [8].

4.2 Interaction Between Tiers of "Layers" Dimension

Machine to Machine integration and Big Data analysis happens on RAMI 4.0 "Layers" dimension. The operation begins when physical assets are initially represented as virtual assets. This step in RAMI 4.0 is called integration.

After the virtualization of the assets, the standardization of the data occurs in the Communication level, in order to guarantee that they are standardized before passing them to other levels.

The level of Information is next. At this level, machines can be evaluated to improve production performance. Big Data analytical methods can be employed to direct the production to the machine with the best performance for the required procedure.

The last level considered is the Functional one. It is at this level that commands are directed to the selected machine. At the end of the process, the machine receives the information and executes the required command. In this level, in fact, that occurs the interaction between the machines (M2M), supported by Big Data techniques. The requirements model is exemplified in Fig. 3.

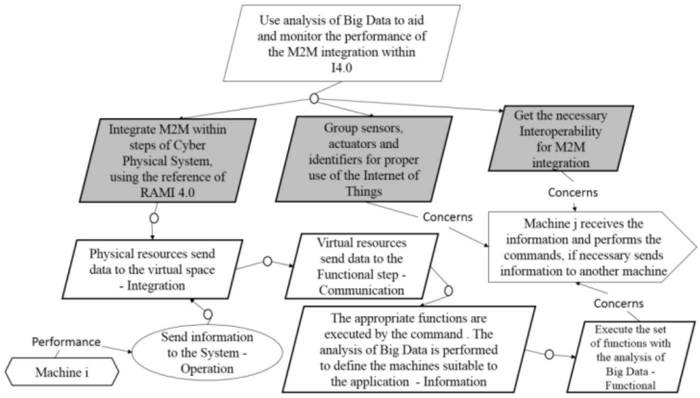

Fig 3. Goals on the Machine to Machine integration and Big Data analysis.

4.3 Discussion about the Model

It is considered in the model, the steps of asset, integration, communication, information and functional. Machine to Machine communication starts at the asset, goes through the integration, collects information, and performs the function. Big Data occurs in the Information step, where the data are studied for the highest performance of the process.

It is noted in [12] that the communication between elements can occur not only within a single company but also throughout a "partner network". In the context of risk assessment, the model presented in this work can be improved by considering the concepts presented in [13] for risks involving "virtual enterprises" (i.e. a temporary entity created through a collaborative network of enterprises for the fulfillment of a goal).

Another important point to note is that there is no level of "Business" in the model. The legal and regulatory conditions and the orchestration of the level of functional services are represented in the level of "Business". The model represents each company with its operating rules guided by its level of "Business". In addition, each company has specifics functions, communication structures, databases, physical and virtual resources. Each company has its "partner network" who can communicate with each other, if necessary, and share a database or even Machine to Machine communication if there is interoperability.

4.4 Model Checking

For validation, it is necessary to know if all the requirements are correctly defined in the model. This problem can be solved with interactive questions directed to the stakeholders that aim to show if all the requirements have been fulfilled according to the viewpoint of each stakeholder. Some of these questions are verified in the papers [7] and [14]. The key issues addressed in [7] and [14] that are relevant to the present paper can be summarized in:

- Does the model need to further detail the system requirements?
- Would you like to check out the model's critical properties?
- Is it necessary to determine the scope of the system?
- Does the model need to consider non-functional system requirements that are difficult to quantify?

5 Final Remarks

The requirements analysis is an essential step required to understand the global and initial aspects of a project. The adoption of the methodology to model these requirements depends on the intricacy of the system to be included.

With the KAOS methodology, the requirements of the big data analysis on the M2M integration are accurately recognized, supporting its development to be adequately oriented to answer the needs of the interested stakeholders associated within the Industry 4.0 context. Validation of the requirements can be further performed with the statement of the aforementioned questions to be answered by the stakeholders and end users involved in a specific business model within the Industry 4.0 context. In this case, further details will be added to the model by incorporating characteristics sought by a specific application or system.

An interactive process must be carried out if any point not previously considered is identified on the model when answering the questions. A new solution is then proposed with a further corrected interpretation of requirements. The cycle must be carried out until the model is completely defined without issues.

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