Intent-Based Configuration of ICT Components for Industry 4.0 Applications

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Abstract. My doctoral research proposal is a cross-field project between Information Systems (IS) architecture and Distributed Systems Computing applied to Industry 4.0 (I4.0) applications. It combines the configuration of Information and Communication Technologies (ICT) (e.g., smart IoT devices) like I4.0 components with a business delivery orientation. The scientific problem of this Ph.D. project is the lack of interconnectivity and alignment of I4.0 ICT to the business strategy and business intents. The notion of intent is very crucial regarding business requirements, as it allows all devices and the equipment under consideration to be connected to business and other needs, the notion has already gained traction in many fields, for instance, Intent-Based Networking (IBN) allows the configuration of the physical and virtual network infrastructure depending on business strategies requirements. To our knowledge, the components of I4.0 applications have not leveraged this important concept yet. Therefore, our objective is to encompass both business strategy and digital technologies deployed to support the I4.0 vision using an intentional perspective, to facilitate the use and configuration of I4.0 components through the automation of administration, and, flexible on-demand reconfiguration.

Keywords: Industry 4.0, Information and Communication Technology, Intent-Based Approach.

1 Introduction

The new industrial revolution, ICT-backed automated and interconnected Industry 4.0, powered by the Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), and various sensors, provides interconnected manufacturing systems capable of communicating, analyzing, and driving further intelligent production in the physical world. I4.0 allows new opportunities for business development [1]. However, the successful adoption of these emerging technologies is not obvious, as it requires tools and skills to make the vision of I4.0 a reality.

To meet these challenges, organizations are rethinking their architecture to ensure that the enterprise will achieve the goals and intents defined and mitigate any threats from an adverse environment. Yet, there is a lack of alignment of I4.0 ICTs to business strategies and business intentions. In most cases, intents are neglected, whereas this is a type of data that can clarify the requirements of business strategies while taking into consideration the internal and external users of I4.0 applications. Therefore, my research goal is to, investigate, and conceptualize intents in the industrial area, to provide an intent-based approach to facilitate the use and configuration of available ICT components. Organizations would be able to adapt and stick, as quickly as possible, to changing business needs and to the requirements of digital transformation.

2 Problem Statement & Related Works

Our research problem is related to a variety of complex technological and organizational challenges. The situation requires an automated configuration as a facilitator for new ICT implementation, as well as the alignment to business intentions. We see that both the business intentions and digital technologies deployed by industries should be encompassed and supported by industrial organizations. We have identified three dimensions to solve this research issue: (i) state of the art of industrial intents and intent-based approaches, (ii) definition of the ICT components within the level of abstraction of our use cases, and (iii) contextual selection and configuration of ICT components using an intentional layer within an I4.0 application. We need to answer the following questions: (a) how are intents captured, translated, and applied regarding an I4.0 infrastructure? (b) Could an intentional layer link both business intents and ICT components of the I4.0 application? (c) How can an intent-based approach solve the ICT configuration issues regarding a given context?

2.1 Intents and Industrial Intention-Based Approaches

Software Networking intents or objectives were introduced first in 2015, in the context of Software Defined Network controllers, then in 2017, Gartner called it the "Next big thing" in networking to help organizations transition to digital [2]. The topic of intent is huge and can be deployed in various areas and many ways. Different dimensions can be considered to categorize or understand intents nature: by the considered role (e.g., Detection, processing, or implementation of intents), by concerns addressed with the defined purposes, by types of origin, intentions can directly be defined by humans or can be automatically generated, etc. Several previous works in different scientific fields have implemented the teleological (intent-based) perspective like Intent-Based Accounting [3], and Web Mining [4].

In the industrial area, intents can have different readings within the ICTs application and depending on the context. For instance, the intent of a business process may be translated as the fulfillment of its described task in the most efficient manner. In [5], intents are defined as business intents "when an intention is declared in a certain context it becomes a stated intent". Intents can be as simple as an atomic intent or as complex as an algorithm of intents that combines a set of sub-intents. In manufacturing applications, within ICT components, an intent is defined as the state that is intended to be achieved In collaborative assembly plans, they have defined two kinds of intents, Designer intent, which means the designer's knowledge about both the individual components as well as the entire assembly process (e.g. geometric information and spatial relationships to generate the assembly plan.) and the operator intents as the human objectives regarding the assembly processes [6].

2.2 ICT Configuration

ICT focuses on two critical aspects: assisting people in converting data into meaningful information and communicating that meaningful information to others. Therefore ICT can be defined as the fusion of methods and processes for the generation, storage, processing, transmission, and perception of information by humans or specialized devices. ICT systems, are based on the traditional components of data center infrastructure components (security, connectivity, power continuity) in addition to an overwhelming amount of internet-delivered content, software, hardware, and support services which include (according to [7]): (a) Internet, a digital communication infrastructure; (b) Data: raw facts and figures, information that is converted to meaningful insights; (c) Hardware components: Physical components that handle the information (creation, transmission, storage, management). (d) Software as a Service (SaaS): software applications over the internet and local client applications that assist with digital design, personal productivity, and process management. (e) Electronic materials facilitate the exchange of digital data. (f) Procedures: like services that support data assets management and customer experience management.

These ICT components are the key technologies underlying the I4.0 technological distributed, highly automated , and highly dynamic enablers, we can mention the most cited ones like IIoT, Big Data, AI, and Robotics, each has interdependencies and characteristics with I4.0.

One of the pressing issues in implementing I4.0 applications is to design uniform interoperability between all of these components. This challenge was globally reported by the World Economic Forum to implement I4.0, that, more than 300 platforms exist for IoT solutions, and four proposals about IoT architectures and reference models, where layers represent the interconnection between applications, services, and physical devices [8]. In the manufacturing industry, interoperability has emerged to become a core concept of I4.0; corresponding to this need, we want to extend the vision of IBN in a larger context. The IBN approach allows a specialized software layer to manage the network, it guarantees that network lifecycle management conforms to the stated objectives, even users could express their network requirements, and the software translates it into network configurations. The IBN systems have operational efficiencies by (a) translating the intents into policies, (b) automated implementation of these policies right after the approval of the network administrator, (c) continuous data analysis, for faults and performance, and (d) Assurance by real-time reporting.

For I4.0 standardization, we refer to the Reference Architectural Model for Industry 4.0 (RAMI 4.0), a service-oriented architecture developed by the German Electrical and Electronic Manufacturers' Association (ZVEI) to support I4.0 initiatives [9], it is used as a reference architecture model based on vertical integration, horizontal integration, and end-to-end engineering. RAMI 4.0 coordinates a three-dimension system, where crucial aspects of I4.0 are associated: (i) Layers, to simplify the IT perspective as a set of smaller manageable parts. (ii) Life Cycle & Value Stream, a layer based on the IEC 62890 standard, which represents the evolution of entities. (iii) Hierarchy Levels, an axis based on the IEC 6224, an international standard for enterprise control system integration. RAMI4.0 added three layers to respond to I4.0, ‘Field Device’ to introduce intelligence in systems, ‘Product’ and, ‘Connected World’ to add collaborative service networks to the factory.

RAMI 4.0 enables common assimilation of I4.0 standards and use cases, however, it does not clarify the details about implementation as needed, and there is no guidance regarding production in the manufacturing process, and communication between devices [10]. In addition, one of the dimensions of this model includes the business layer “intents,” still it is reduced to business processes. This lack of a powerful alignment metaphor is a weakness of the RAMI 4.0 proposal and the other existing approaches. Which involves less efficient distribution of resources, less adapted configuration, lower level of business goals achievement , and adaptation to the context.

3 Scientific Method, Expected Results & Plan for the Evaluation

Ongoing work: We are preparing a literature review of industrial intent-based approaches. To our knowledge, a taxonomy of industrial intents still didn’t appear in the literature. We use the SMS method to give an overview of a research area by setting categories and counting existing works, then creating classifications and schemes respecting the founded categories [11]. To synthesize the existing literature about intent-based approaches used in industry, we have decomposed our research questions into two main categories. The first category of research questions consists of finding evidences about definitions or existing types and categories of intents in ICTs. The second category involves the configuration and adoption of ICT components, through mining, presenting, transforming, or implementation. The research questions are: (a) how intentions are characterized in the literature of the technological and industrial domain? (b) How intentions and sub-intents are distributed over the building blocks of an industrial architecture? (c) Could a valid taxonomy of intents in the industrial area be defined? (d) What are the strengths and weaknesses of the intent-based approach?

Current results: We have chosen three scientific databases, Dimensions, Web of Science, and Scopus, because they are large multidisciplinary databases covering published material in the sciences, and they provide citation analysis of authors and subject areas. We have used criteria to find relevant papers for our project. Inclusion criteria are the following: research string ((industry 4.0/smart industry/smart factory OR manufacturing OR production OR IOT) AND (intent-based/oriented OR intention-based/oriented OR goal-based/oriented OR objective-based/oriented)), published year (between 2010 in 2022), subject categories (AI and Image Processing, Computer Software, Distributed Computing, IS, Manufacturing Engineering), search clause (title and abstract). The applied criteria are given in Fig. 1

Followed by the exclusion criteria, where an explicit description of approaches based on intents, should be observed in the title or abstract; or at least respond to one of the research questions. We ended with 80 articles divided into several subdomains of I4.0. The actual schema of relevant papers is still larger, and the concepts are much wider than expected, (could be found on the given link: https://bit.ly/3bXHjeW).

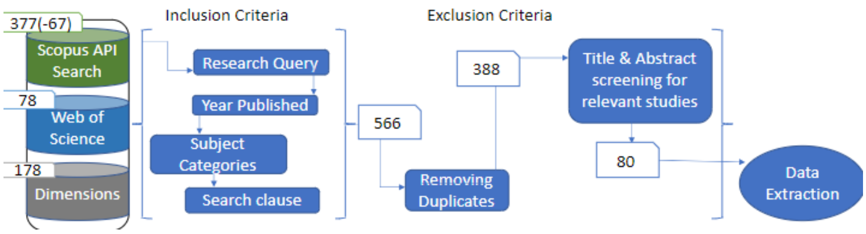

Fig. 1. Inclusion and exclusion criteria applied.

Plan for future work: The taxonomy of intent-based approaches from the 1st phase, would help us organize the literature review, and compare the various industrial intents. Thus extract and build an intent ontology, for our industrial intent-based approach (3rd phase). During the 2nd phase, we need to work on the standardization of industrial ICT components within a given level of abstraction, thereby, drawing the protocols and tools needed for their configuration; Moving to the analysis of the CIM approach and IBN architecture in the 3rd phase, we will adapt each selected intent, in relation with its appropriate context, to the use of the ICT component, in this way we can prepare the configuration of the components of the I4.0 applications through the link with the business strategy (These phases are summed up in Fig. 2).

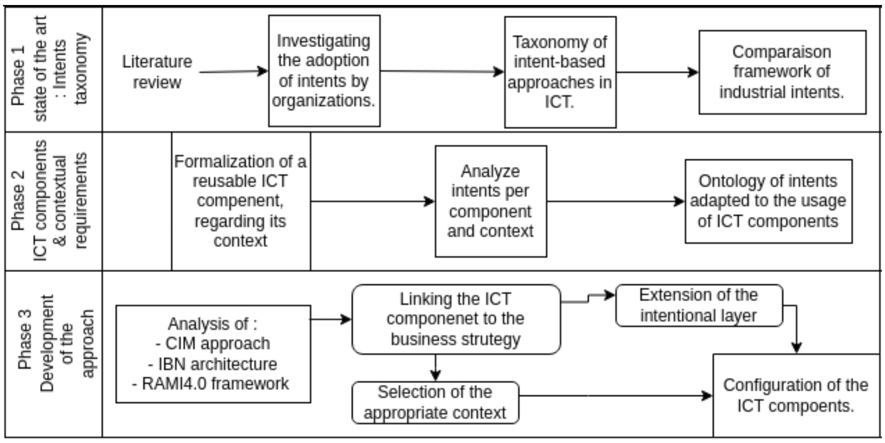

Fig. 2. Research Phases.

As a use case for our project, we conducted meetings with the French national electricity board (EDF). The IS structure of EDF is built on the Computer Integrated Manufacturing (CIM) architecture, it is an architecture that enables industrial enterprises to integrate information and business processes. The next step for us is to find common concepts between CIM and IBN architecture and to study the position of the intentional layer. Then, we propose to apply Situational Method Engineering (SME) inspired methods. SMEs allow building methods adapted to a concrete real use case where reusable method components depend on context factors [12]. Another possible objective for us, obviously an important track, is a direct contribution to the Development Repository for the open Asset Administration Shell (openAAS) project, which works and searches for demonstrable and verifiable reference solutions to strengthen the distribution of I4.0 components (Further information could be found on: https://www.basys40.de).

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