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Review: Development of Industry 4.0 and the Role of Industrial Internet of Things in Manufacturing Industry

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Abstract:*Industry 4.0 and Industrial Internet of Things are the two most advanced implementations used in some of the modern manufacturing industries. Development in Industry 4.0 and IIoT is the most popular area of interest of researchers and industries. Both the concepts are parallel, coincide and sometimes Industry 4.0 even considered to be the implementation of IIoT in automation and manufacturing industries. The current developments in Industry 4.0 have been brought significant improvements in efficiency, flexibility, communication, adaptability, customization, modularity and productivity of the industry. Authors are focusing on need of continuous developments in Industry 4.0 by implementation of various tools and applications under the roof of IIoT which is possible due to recent research in many branches. This advancement is today's need of the manufacturing industries and hence this paper covers the developments and status of Industry 4.0 by implementing the IIoT one path ahead of automation in manufacturing industries.*

Keywords: Industry 4.0, IIoT, Modularity, Productivity, Communication, etc.

I. INTRODUCTION

Industry 4.0 is the need of today's manufacturing industry and in academia as far as the goal of achieving maximum productivity with optimum resources and time is concerned. This term has been introduced by German engineers which was accepted and got importance by the German Government. It works as a tool of communication between physical and digital world of industry. The main objective of Industry 4.0 is the digitalization of the industry and to digitally access the industry from any place all over the world. More-over Industry 4.0 concept often considered as an Industrial Revolution, due to which the lives of many people of different work skills will be benefitted. The industry 4.0 concept has very close relevance with the Industrial Internet of Things model because the heart of both Industry 4.0 and IIoT concepts is the excellent feedback system between different industrial resources and workstations. IIoT is a phenomenon derived from the Internet of Things concept and its applications areas are constantly increasing. IIoT is trying to connect computers, controllers, actuators and sensors to the Internet, thus enabling information exchange between all components involved.

This information exchange can form the basis for building future intelligent services with high potential of increasing the current levels of efficiency and flexibility that can be found in industry today. Many developments are targeting the mentioned domains and the researches are branching and extending continuously with various concepts, sometimes without an actual chance of materializing the studies, because of the lack of sustainability within the industry. This problem raises from losing the actual connection to the current IIoT/Industry4.0 ideas, and to the development directions set by the majority or the key successful research movements and industrial representatives in the domain. To overcome these issues, an organized and well-structured perspective over the state-of-the-art is necessary. The current paper provides an overview of the main development directions from Industry 4.0 in the IIoT context and also briefly presents a literature review of the state of the art from each of those development directions.

This can be very useful and time saving for academia researchers interested in this area, providing an easier way to develop an overview picture of the domain. The authors have guided the current research after the following ideas: relevant research papers for the state of the art were identified by mainly focusing on conferences and journals with a high impact factor, the authors also favouring research papers with numerous citations. Several key words were used for searches, while the selecting and filtering process was based on both feasibility and sustainability of the researches. The research papers that were evaluated as either not sustainable or not having a significant impact by the authors were not used in the current paper. Also, the authors carefully considered the directions of interest in the industry, thus trying to narrow the gap between research and the real needs of the industry. The period of time considered of interest was between year 2016 and present, but a small number of relevant papers published before 2016 were also considered. The following section presents the most important concepts and characteristics of Industry 4.0. Section III introduces the Industrial Internet of Things with its most relevant concepts. In Section IV the main development directions of Industry 4.0 are presented, considering the Industrial Internet of Things context. Finally, Section V concludes this paper.

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II. LITERATUREREVIEW

`This section introduces the systematic literature review process that was conducted in order to determine the main characteristics of the different frameworks presented in various contexts in the literature. Herein, the main question this literature review intends to answer is: "What are the generic frameworks intended to guide Industry 4.0 implementation in companies for practitioners?".

Structure of the Review

The field of Industry 4.0 technology implementation is vast. While a large bibliography is dedicated to actual implementation of technologies (at various technology readiness levels, TRL), publications have recently appeared that introduce implementation frameworks for a more or less large range of industries. The issue that was faced in this review is the genericity of the keywords, which can be used in many different ways by authors. Therefore, in order to identify those publications, a systematic literature review (SLR) was performed. The chosen methodology is presentedin and consists of five steps:

1. Definition of the review scope: this step is used to define an appropriate perimeter of the scope and orientation of the review;
2. Conceptualization of the topic: this step intends to define the keywords that will be used in the next step, searching for articles;
3. Literature search: this step includes the choice of the source of information and the design of the queries in accordance with the previously defined topics;
4. Literature analysis and synthesis: this step shows the process of inclusion/exclusion of the results of the requests, and a categorization of the reasons that led to this result;
5. Research agenda: the last step consists in an analysis of the content of the included articles, showing the evidence retrieved from the review.

First Step: Definition of Review Scope

This first step is especially well suited for literature reviews on a large scope, where a horizontal search on a large range of topics is needed. It consists in defining the perimeter of the review and highlighting the main keywords. Here, the objective is rather oriented towards a vertical search, in order to identify the frameworks that are actually related to the work. The review scope here is directly connected to the previously defined problems. The objective is to detect the few articles that deal with a generic framework or methodology to implement Industry 4.0 technologies in companies from the whole set of articles dealing with only the implementation of one of those technologies.

Second Step: Conceptualization of Topic

The topic was decomposed into three necessary sub-topics: (i) the environment; (ii) the contribution; and (iii) the generalization. The environment is mainly built around the industry 4.0 paradigm; however, some authors might use the terms "smart factory", "intelligent manufacturing", or "smart manufacturing" to illustrate the same concept. The contribution is meant to address the implementation of new technologies, integration of those technologies in a manufacturing environment, or the transformation from a classical manufacturing system to an Industry 4.0-compliant one. These three terms were, therefore, addressed. The desired articles were meant to introduce a new framework or methodology, generalizing implementations. Therefore, those two terms were added to the topic.

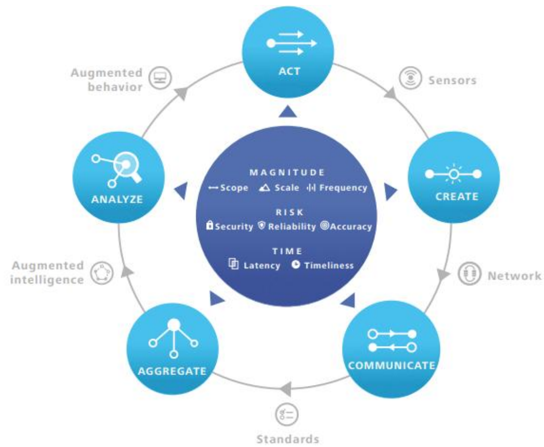
Third Step: Literature Search

In order to address a wide range of valuable contributions, the Scopus database was chosen. The topics mentioned above were searched in titles, abstracts, and keywords in the whole database, limiting the subject area to engineering, business, computer science, materials, energy, and the environment (which constitute the main pillars of Industry 4.0 technologies). Finally, only journal and proceeding papers in the English language were accepted in this search in order to consider only internationally recognized work

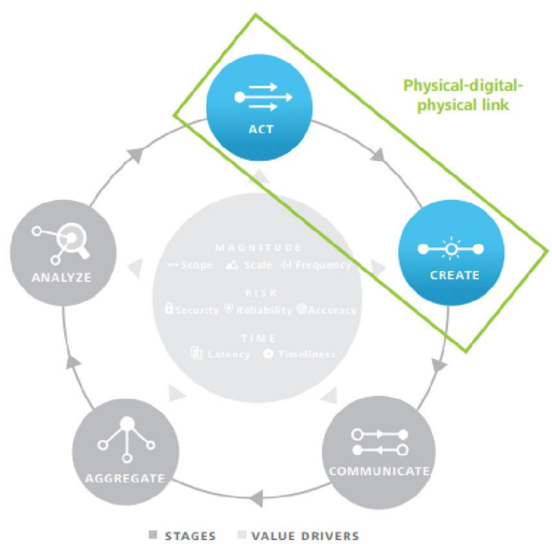
Fourth Step: Literature Analysis and Synthesis

The 1024 records obtained from Scopus were imported into Rayyan QCRI [29], a free online tool that can be used by researchers to assist in a systematic literature review. It allows to label each record with reasons to include or exclude articles from the final review. A first analysis, based on only the metadata of the records (title, abstract, keywords) was performed thanks to the filtering options in Rayyan. For records with ambiguous results, a manual check of the full text version was performed in order to guarantee accuracy of the analysis.

III. VALUE LOOP IMPLEMENTATION



Loop of Industry 4.0



Physical- Digital-Physical Link

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IV. DIFFERENTIAL ANALYSIS

Table 1: Physical- Digital-Physical Link

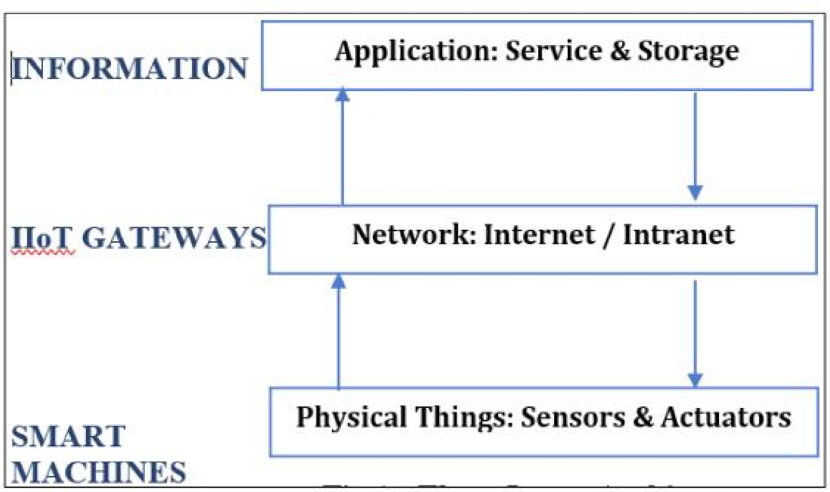
Product impact	Potential IT/OT applications
Physical ⟶ digital	• Sensors and controls • Wearables • Augmented reality
Digital	• Signal aggregation • Optimization and prediction • Visualization and POU delivery • Cognitive and high-performance computing
Digital ⟶ physical	• Additive manufacturing • Advanced materials • Autonomous robotics • Digital design and simulation

Table 2: Comparison on Internet of Things (IoT) and Industrial IoT (IIOT)

IOT	IIOT
IoT for Commercial Sector	IIoT for Industrial Sector
Human centred model	Machine centred Model
Volume of data is Medium	Volume of data is very High
Machine to Human communication.	Machine to Machine(M2M) communication.
Supports Infrastructure Less Mobile *Ad-hoc* connectivity	Structured Infrastructure based centralised connectivity is required.
Human and Things integrated Technology	Machine-to-Machine Integrated Digital Manufacturing and Operational Technology

V. THREE LAYER ARCHITECTURE

The structure of a IIoT architecture highlights scalability, modularity, and interoperability with various devices and platforms using different technologies.



A. Physical Things: Sensors & Actuators – Smart Machines

In the physical layer, some industry-specific devices like Sensors, Interpreters, Translators interfaces with ICS placed in the real-world environment. These devices enable the machines in industry environment as Smart Machines. Several heterogeneous physical things are deployed in the real-world environment like Sensors for monitoring environment, reading temperature, gauging pressure, proximity, location, smoke, humidity, chemical reaction, gas, and so on. Transient Data Stores, which stores the data temporarily to ensure durability during the system or network failure. Local Processors (data transformation, complex event processing, etc..) are also used to provide data to the application user end from the Physical things.

B. Network: Internet / Intranet – IIoTGateways

Network Channels act as a medium to connect and for data transfer between Physical Layer to the application end. The channel can be an Intranet if the smart environment has to be monitored within an industry closed monitoring system, known to be private IIoT channel. The smart environment can be built by connecting and monitoring the smart physical things at different locations of various industries on a production pipeline, there the channel supported through internet, known to be Public IIoT channel. The channels deploy different Network Protocols and API's for connectivity between machine to machine and machine to the application end. These channels interface with heterogeneous sensors and receive unstructured data, a sophisticated gateway is required, called to be IIoT Gateway. This gateway can be part of the middleware architecture – a cloud computing environment. Since the data would be huge, unstructured and with high velocity of retrieval, the IIoT can filter the captured data and send the structured data over the Internet to the service end.

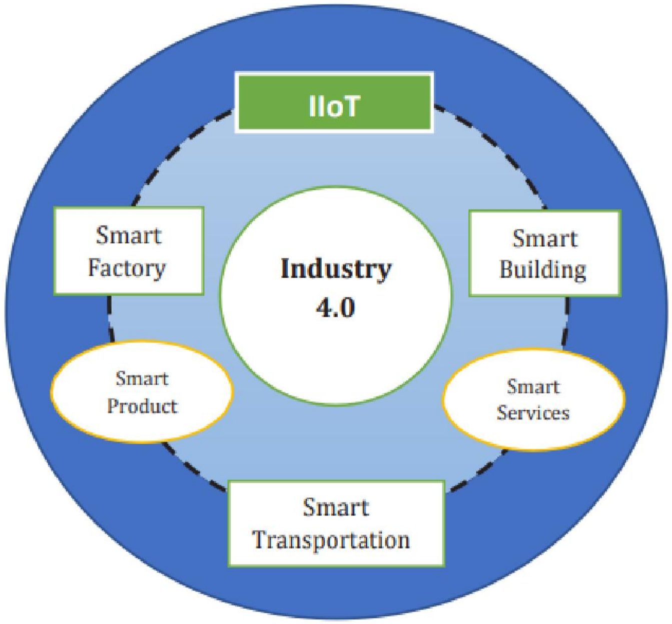
C. Application: Service & storage –Information

A collection of large amounts of context information from the Real-world IIoT environment to support different application domains are stored, processed and analysed in cloud computing environments. Some of the popular IoT based cloud environments like Thingworx[13], Xively[14], CISCO IoT cloud, AWS IoT Platform, etc.. supports for IIoT application development. Cantaloupesys supports remote stock tracking service in vending machines, HiKoB collects real-time measurements for the analysis parameters such as temperature gradients within the road, current outdoor temperatures, moisture, dew and frost points from sensors deployed in roads and provides traffic management, real-time information on traffic conditions, and services for freight and logistics. It is also evident that IoT based cloud platforms are allowed to build their own ecosystems with third party extension support for development and distribution through app store. The most user-end service support is extended through the Mobile Applications which allows users to interact and take or perform actuation tasks from any location at any point of the product development cycle in the industry environment, Mobile-based applications are also support the location-awareness service, i.e., service support based on the geo-graphic location specifically on Smart Enterprises – Transportation and Logistics, Energy and power production, Safety & Smart Infrastructure support. Wearable devices with gesture-based interactions also plays a significance role in IIoT applications also.

VI. RESULT and DISCUSSION

4.0 for an objective to attain a high level of productivity with effective operational and maintenance track. Digital optimization of production, Automation with industry environment adaption, Intelligent Data communication for remote action and effective and ease of Human-Machine interaction (HMI) are the major features of industry 4.0. Industry 4.0 makes a disruptive change in the traditional supply chain process and business models by integrating the IoT enabled services in the industry environment to build a smart industry ecosystem, for achieving the objective of the Industry 4.0 below figure shows the integrated IIoT applications for Industry 4.0, builds a smart productive environment, where different types and forms of massive amount of data is generated by the integration of sensor devices and communication technology for smart services and product development in manufacturing sectors.

Smart manufacturing is equipping machines with sensors, actuators, microchips and automatic recognition & detection in support with the computervision-based system. Agile software engineering technique is transferred to the manufacturing domain describing an agile factory prototype. The developed smart product requires a smart logistics support for transportation by tracking the location and predicting the delivery-time with automated routing applications by sensing the roadway parameters like temperature, mist, humidity etc. Smart Building combines the Internet, Telecommunication networks, short distance networks (like Bluetooth, NFC etc..), Broadband networks and Sensor networks to build a smart living environment that ensures the quality of day-to-day life, connected with technology, safety & security of living place with recognition, detection and prediction systems and effective energy consumption with atmosphere sensed adaptive electric or electronic devices.



VII. CONCLUSION

The current work presented the main characteristics and notions involved into both Industry 4.0 and Industrial Internet of Things concepts, also highlighting the similarities between the two concepts. Both paradigms are currently representing very active fields of research and development, in the same time managing to draw significant attention from the industry as well. The high interest into those concepts is generated by the major improvement potential in the manufacturing and automation industries, which promises to positively impact the lives of many people. In order to provide a useful research overview of the industry 4.0 development directions in the Industrial Internet of Things context, the paper identified five primary research and development directions in this area. For each of the identified development direction a short literature review containing the state of the art in the domain has been presented, alongside different challenges and obstacles that are currently rising concerns.

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