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Interaction of Artificial Intelligence with Industry 4.0 Components in Manufacturing Sector

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ABSTRACT

Industry 4.0 is an intelligent system used as a flexible production line for almost all production processes of real-time information provided by Artificial intelligence (AI), Internet of Things (IoT) and other digital technologies. Artificial intelligence sharpens business intelligence, an important development for the global economy. The purpose of this paper is to show how industry 4.0 components interact with artificial intelligence and examine how industry 4.0 components affect artificial intelligence. For this purpose, a questionnaire containing industry 4.0 components has been developed and this survey has been applied to companies operating in the manufacturing sector. The obtained data were analyzed with the SPSS 22.0 statistics software and the results were presented. It has been determined that the Internet of objects, smart systems and technologies, the digital factory which are among the components of Industry 4.0, are closely related to artificial intelligence.

1 INTRODUCTION

Industrial revolutions have caused radical changes in the tools and production process used by people and can be mentioned as the periods in which new production methods and lifestyles are formed by transforming the communication tools and energy systems used. In the Fourth Industrial Revolution, which was the last of the industrial revolutions, the use of the internet became widespread and caused the explosion of the concept of Industry 4.0 [1].

One of the important developments brought by Industry 4.0 is artificial intelligence technology.

The main purpose of artificial intelligence is to make machines more autonomous and smart. Artificial Intelligence is a concept that aims to produce devices capable of reasoning, learning, communicating, perceiving, using past information, playing objectively and moving [2]. Artificial intelligence (AI) is generally defined as having the ability to perform tasks assigned to augmented mental phenomena such as reasoning, understanding, learning in previous experiences, which are carried out by a computer or a machine under the supervision of a computer [3].

While old habits and models are replaced by new generation futuristic approaches, we can easily state that artificial intelligence, machine learning and deep learning are the leading issues at this point. While machines become more "smarter" with machine learning and deep learning,

machines that interact with each other in this direction cause a wide range of changes, especially in the business world [4].

Main research question of this study is what kind of interaction between artificial intelligence and industry 4.0 components are there?

Firstly, we explained industry 4.0 and artificial intelligence. Then we defined their interaction. Later we evaluated statistically data collected by the survey. At the end we discussed the results.

2 INDUSTRY 4.0

In the first industrial revolution, production was based on water and steam power. In the second industrial revolution, electric power made mass production possible. In the third industrial revolution, automation of production was achieved thanks to developing electronic and communication technologies. Today, the fourth industrial revolution (industry 4.0) built on the third is on the agenda. However, although it was built on top of the third industrial revolution, the fourth industrial revolution is different from the previous one in three respects. These; their speed, scope and systemic effects. The pace of scientific progress today is higher than its past counterparts. Compared to previous industrial revolutions, the development of the fourth industrial revolution is increasing exponentially rather than linearly. Moreover, this revolution negatively affects almost the entire industrial sector. With this change in scope and depth, all production, management and administration systems will be transformed [5].

Although it is a top priority for many companies, research centers and universities, there is no generally accepted definition of the" Industry 4.0" term. The term of Industry 4.0 is widely used in almost every industry-related fair, conference or declaration for publicly funded projects in Germany, and It was firstly spoken at the Hanover Fair in 2011 and brought up many discussions with it. Since the German federal government declared Industry 4.0 as one of the most important initiatives of its high-tech strategy in 2011, a large number of academic publications, articles and conferences have been focused on [6].

Distinctive innovations brought about by this new era are listed as follows:

• Global interaction of storage systems and resources and machines,

• Development of unique smart products with location information,

• The implementation of smart factories that adapt to product characteristics and provide resource optimization,

• Realization of new business models (such as new services emerging with the use of Big Data),

• New social infrastructure in the workplace for employees, a work structure sensitive to individual differences,

• Better work / life balance,

• Responding to individual consumer requests,

• Intelligent software developed for instant engineering and instant response to problems [7].

Industry 4.0's goals; to ensure collective customization of products produced by information technologies, to ensure automatic and flexible adaptation of the production chain, to monitor parts and products, to facilitate communication between parts, products and machines, to implement human-machine interaction (HMI) paradigms, to provide Internet-of-things-specific production optimization in smart factories, and offering new types of services and business models in terms of value [8].

Despite the growing complexity of the Industry 4.0 system, it also has potentials summarized below [9]:

• Increasing competition and flexibility arising from the dynamic nature of business processes (quality, time, risk, durability, price and environmentally friendly),

• Eliminating malfunctions in the demand chain,

• Optimizing decision making with real-time end-to-end visibility,

• Increased resource productivity (providing the highest output from a given volume of resources) and efficiency (using the least amount of resources possible to achieve a given output),

• Creating value opportunities (innovative services, new forms of employment, opportunities for SMEs and new enterprises to develop),

• Reducing energy and personal costs.

All these situations and the scope of Industry 4.0 are not just an evaluation that can be created within factories on the product and production. For example, the development of appropriate technologies in which the service sector will satisfy the consumer and meet the most important criteria such as speed / efficiency / efficiency of the service offered is also considered within this scope. Because the 4th Industrial Revolution includes everything that provides convenience as a result of adding intelligence to technology [10].

Industry 4.0 does not only consist of the communication of machines; is more extensive. It affects a variety of scientific fields, from genetics to computing technologies. The features that make this revolution different from the previous ones; It is the interconnection of the developments in technology by activating each other, acting in coordination and development of all areas under the influence of each other [11]. In this context, the concepts that should be known in order to understand Industry 4.0 and to carry out its implementation works in a coordinated manner are as follows:

1. Big data and analysis,

2. Augmented reality,

3.Three-dimensional (3D) printers,

4. Cloud computing system,

5. Cyber Security,

6. Internet of Things,

7. Cyber, Physical Systems,

8. Simulation,

9. Smart robots / Smart Factories

Explanation of some industry 4.0 components are presented in Table 1.

3 ARTIFICIAL INTELLIGENCE

Artificial intelligence has been defined in the scientific world as the ability of a computer or a computer-aided machine to perform tasks related to higher logical processes such as human-specific qualities, finding a solution, understanding, deducing a meaning, generalizing, and learning from past experiences [14].

Artificial intelligence studies model living systems that do their job perfectly and the human brain; In addition to giving products in different areas of daily life, it is also used for purposes such as prediction, classification, clustering. Techniques such as expert systems, genetic algorithms, fuzzy logic, artificial neural networks, machine learning are generally referred to as artificial intelligence technologies. In addition to these techniques, living things are also examined in order to imitate nature and similar smart methods are recommended. What is meant by artificial intelligence in general; It is

the modelling of the physiological and neurological structure of human intelligence, such as the nervous system and gene structure, and natural events, and transferring them to machines (computers and software). Artificial intelligence in a nutshell; They are computer systems that have intelligent behaviors of living beings that "think like a human, act like a human, think rationally and act rationally" and machine learning is accepted as the last stage of artificial intelligence in this sense [15].

Artificial intelligence technologies consist of expert systems, fuzzy logic, artificial neural networks, machine learning and genetic algorithms.

Table 1 Components of Industry 4.0

Components	Explanation	Reference
Big Data	This relates to the technologies that capture, archive, analyze, and disseminate large quantities of data derived from the products, processes, machines, and people interconnected in a company, as well as the environment around it	[12]
IoT	This corresponds to a set of devices and intelligent sensors that facilitate communication between people, products, and machines.	[12]
Virtual Reality	This involves a series of devices that enriches (or lessens) human sensory perception through the access to virtual environments; this is accompanied by sensory elements, such as sound, smell, or touch. These elements can be added to mobile devices (smartphones, tablets, or PCs) or other sensors to augment vision (augmented-reality glasses), sound (earphones), or touch (gloves) to provide multimedia information	[12]
Smart Systems Technologies	Smart Systems is a new generation of computing systems and information architecture that when combined with artificial intelligence, machine learning and Internet of Things technologies are breaking away from today's information, computing and telecom (ICT) paradigms to enable intelligent real-world physical systems to be integrated onto networks and the data from machines, sensors, video streams, maps, people, news-feeds and more to become an integral part of all information systems.	[13]
Additive Manufacturing 3D Printers	This additive production process allows for complex products by creating layers of materials, including such different types of materials as plastics, ceramics, metals, and resins, thus eliminating the need to assemble the material. A significant example is 3-D printing	[12]
Digital_factory_logistics	This refers to the creation of interconnected and modular systems that guarantee automated industrial plans. These technologies include automatic material-moving systems and advanced robotics, the latter of which are now on the market as "cobots" (collaborative robots) or automated guided vehicles or unmanned aerial vehicles	[12]
Cyber Security	This includes security measures designed to protect the flow of information over interconnected corporate systems	[12]

3 RELATIONSHIP BETWEEN INDUSTRY 4.0 AND ARTIFICIAL INTELLIGENCE

The Manufacturing Industry spends millions at high speed on research. The era is the age of having a more productive life together with "intelligent robots". Top topics that are stated to be beneficial for today and the future -such as Artificial Intelligence, Industry 4.0, IoT (Internet of Things)-are all created with algorithms [16].

Although the most interesting aspect of Industry 4.0, such as the fact that the machines in the factory inform each other, the intelligent machines, the self-reporting of who and when the products are produced, the factory can work even in the dark, although all of the situations are not clearly stated, Factories are in the position of "factory equipped with Artificial Intelligence"[16] as seen Figure 1.

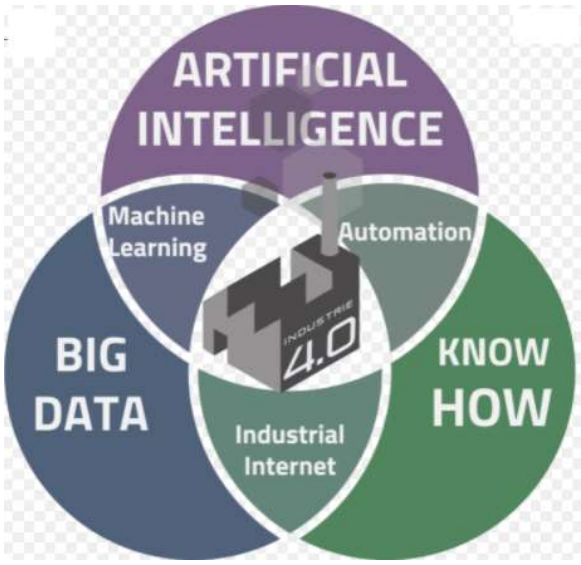

Figure 1: Artificial Intelligence and Industry 4.0 [24]

The Internet of Things (IoT) is that electrical devices, structures are in an interaction system environment with each other. The software, together with its sensor and network connectivity features, enables objects to receive information from each other and exchange information. It has the capability to enable the Internet of Things (IoT) to be controlled and send alerts to the computer in case of damage to the network infrastructures. The efficiency of the interconnection of systems and the interactions between Machine and Machine (M2M) are increased [17].

There is a reciprocal relationship between big data and artificial intelligence: artificial intelligence depends heavily on the big data for success, and it also helps organizations unlock the potential in data stores in previously useless or impossible ways [33]. Like Big Data, AI is about increasing volumes, velocities and variety of data. Under situations of large volumes of data, AI allows delegation of difficult pattern recognition, learning, and other tasks to computer-based approaches [19]

Smart Systems is a new generation of computing systems and information architecture that when combined with artificial intelligence, machine learning and Internet of Things technologies are breaking away from today's information, computing and telecom (ICT) paradigms to enable intelligent real-world physical systems to be integrated onto networks and the data from machines, sensors, video streams, maps, people, news-feeds and more to become an integral part of all information systems [13].

Additive manufacturing (AM) has emerged as a disruptive digital manufacturing technology. However, its wide adoption in the industry is still hampered by high entry barriers for additive manufacturing (DfAM), limited material library, various machining defects, and inconsistent product quality. In recent years, machine learning (ML) which is one of the methods of artificial intelligence has attracted increasing attention in AM for its unprecedented performance in data tasks such as classification, regression, and clustering [20]

Digital Factories are proving to be highly effective. A critical, large-scale application of AI is the creation we call the "Digital Factory". Sometimes referred to as the "Smart Automation Factory", this innovative approach allows organizations to bring together all the business and technology resources they need in a single framework. It connects user experience designers, customer service specialists, marketing specialists and internal processes managers with tech professionals skilled in AI, data science and IT integration [21].

Next-generation cybersecurity products increasingly include Artificial Intelligence (AI) and Machine Learning (ML) technologies. By training AI software on large data sets such as cybersecurity, network, and even physical information, cyber security solutions providers aim to detect and prevent abnormal behavior. Cybersecurity solutions using artificial intelligence and machine learning can drastically reduce the time required for threat detection and incident response, and can often alert IT staff of abnormal behavior in real time [22].

Based on the above explanations, we proposed following hypothesis

Hypothesis 1: Components of Industry 4.0 affect artificial intelligence.

Research model of the study is presented in Figure 2.

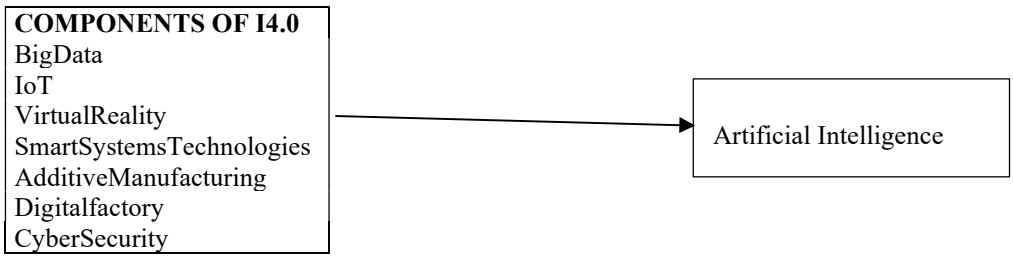

Figure 2: Research Model

4 METHODOLOGY

Research was conducted on manufacturing industry. For research aim, a questionnaire was developed and applied to 121 managers working in the companies. Some characteristics of respondents are presented in Table 2. Then correlation analysis and regression analysis are used to analyze the data.

Table 2 Demographic characteristics of respondents

Gender	*Number*	*Percent (%)*
Male	112	78,87
Female	30	21,13
	142	100
Experience		
0-1 year	2	1,41
1-3 year	27	19,01
3-5 years	22	15,49
5-10 years	55	38,73
More than 10 years	36	25,35
	142	100
Graduation Degree		
Bachelor's degree	99	69,72
Master degree	41	28,87
PHd Degree	2	1,41
	142	100
Working position		
Asistant Expert	18	12,68
Expert	53	37,32
Senior Expert	14	9,86
Project Leader	38	26,76
Vice manager	19	13,38
	142	100

5 RESULTS

Table 3 provides means, standard deviations and correlations of the constructs and the main control variables. The correlation matrix provides initial support for the hypothesis that artificial intelligence is strongly related components of industry 4.0. As seen in Table 3, all components of industry 4.0 involved in this study are positively and significantly correlated with artificial intelligence.

Table 3 Correlations between items

		1	2	3	4	5	6	7	8	9
1	Artificial Intelligence	1,000	,654	,726	,594	,608	,608	,631	,470	,542
2	BigData		1,000	,770	,573	,618	,618	,708	,397	,526
3	IoT			1,000	,706	,564	,564	,710	,357	,516
4	VirtualReality				1,000	,521	,521	,613	,452	,579
5	Cloud					1,000	,720	,716	,303	,492
6	SmartSystemsTechnologies						1,000	,716	,303	,492
7	Additive Manufacturing							1,000	,415	,604
8	Digital_factory								1,000	,512
9	Cyber Security									1,000

All correlations are statistically significant at 0.001 significance level.

To investigate the effects of independent variables (components of industry 4.0) on dependent variable (Artificial Intelligence), multiple linear regression was conducted. Results are shown in Table 4, Table 5 and Table 6.

Table 4 presents that 61.2 % variety of Artificial Intelligence is explained by industry 4.0 components (Cyber Security, Digital Factory, Additive Manufacturing, Smart Systems Technologies, Virtual Reality, IoT, Big Data)

Table 4 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,803[a]	,644	,612	,765

a. Predictors: (Constant), CyberSecurity, DigitalFactory, AdditiveManufacturing SmartSystemsTechnologies, VirtualReality, IoT, BigData
b. Dependent Variable: ArtificialIntelligence

Table 5 presents Anova results to evaluate validity of the regression model. F value is equal to 19,932 and it is statistically meaningful at significant level of 0,000 ($p<0,001$). This means that our regression model is valid.

Table 5 Anova Results of the Model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	116,670	10	11,667	19,932	,000[b]
	Residual	64,388	110	,585		
	Total	181,058	120			

a. Dependent Variable: ArtificialIntelligence
b. Predictors: (Constant), CyberSecurity, DigitalFactory, AdditiveManufacturing, SmartSystemsTechnologies, VirtualReality, IoT, BigData

Table 6 presents regression analysis results. Our model is expressed as following;

$$Y = -0,293 + 0,010\,X1 + 0,446\,X2 - 0,003\,X3 + 0,063\,X4 + 0,08\,X5 + 0,177\,X6 + 0,048\,X7$$

As seen in Table 6, IoT, Smart System Technologies and Digital factory are positively and significantly related with artificial intelligence. There is a positive and significant effect of IoT on Artificial Intelligence. IoT is the most affecting factor for artificial intelligence is IoT because β= 0,456, t=4,184, p<0,05. Second most affecting factor for artificial intelligence is Smart System Technologies because β= 0,255, t=2,828, p<0,05. Third affecting factor is Digital Factory with values of β= 0,171, t=2,360, p<0,05. Cyber Security, Additive Manufacturing, Virtual Reality are not related with Artificial Intelligence.

Table 6 Regression Analysis Results

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
Model	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-,293	,251		-1,167	,246		
BigData (X1)	,010	,116	,010	,088	,930	,259	3,865
IoT (X2)	,446	,107	,456	4,184	,000	,272	3,675
VirtualReality (X3)	-,003	,089	-,003	-,034	,973	,384	2,605
SmartSystemsTechnologies (X4)	,263	,092	,255	2,858	,005	,406	2,462
AdditiveManufacturing (X5)	,008	,114	,008	,072	,943	,286	3,500
Digitalfactory (X6)	,177	,075	,171	2,360	,020	,615	1,626
CyberSecurity (X7)	,048	,085	,048	,567	,572	,456	2,194

a. Dependent Variable: ArtificialIntelligence

To establish the quality of the regression models, the extent of multicollinearity was analysed in the models. Variance inflation factor values as well as tolerance values in the model and for all independent variables clearly demonstrate that there is no multicollinearity between the independent variables. Specifically, in no case does the variance inflation factor exceed 5 or 10, nor is the tolerance lower than 0.2 or 0.1 [23].

6 CONCLUSIONS

In this study effects of Industry 4.0 components on Artificial Intelligence. We determined seven components of Industry 4.0. These are Cyber Security, Digital Factory, Additive Manufacturing, Smart Systems Technologies, Virtual Reality, IoT, Big Data. While three of them influence Artificial Intelligence positively and significantly (Digital Factory, Smart Systems Technologies, IoT), four of them do not have any significant influences on Artificial Intelligence (Cyber Security, Additive Manufacturing, Virtual Reality, Big Data). But all six components are positively correlated with Artificial Intelligence.

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