AIoT with I4.0: the effect of Internet of Things and Artificial Intelligence technologies on the industry 4.0

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Abstract. The Internet of Things (IoT) extend the connectivity into billions of IoT devices around the world. Artificial Intelligence (AI) is the best solution to manage huge data flow and storage in IoT network. Nowadays, IoT is becoming more popular with the invention of high internet speed and many advanced sensors that can be integrated into a microcontroller. Internet of Things relies on Artificial Intelligence technology which gives the term of Artificial Intelligence of Things (AIoT).

AIoT is transformational and mutually beneficial for both technologies, as AI adds values to IoT through materials and software. This fusion impacts the revolution of industry 4.0 such as maintenance, production chains, optimization and logistics applied in industries to achieve increased productivity, profitability, efficiency, safety, and security.In this paper we will discuss the merge of Artificial Intelligence and Internet of Things, the soft-hard of AIoT and the impact of AIoT on the industry 4.0 applications.

Keywords: Internet of Things, Artificial Intelligence, Artificial Intelligence of Things, Industry 4.0.

1 Introduction

The internet of things (IoT) is defined as one of the new technologies used on the world, it is a global network of interconnected and intelligent objects to support humans in their daily activities with their capacity of calculation, communication, providing information and collecting them for decision making. Investment in the new technologies will be required to release full potential of IoT devices and the combination of Artificial Intelligence (AI) with the Internet of Things (IoT) has potential to reshape new opportunities in industry, business and economy operates [1].

This combination is called Artificial Intelligence of Things (AIoT). The combo of Internet of Things and smart systems makes AIoT powerful and important tool for many applications like Drones Manufacturing Traffic, Autonomous Vehicles and robot and smart retail [2].

The future of the industry is huge, while industry 3.0 focused only on the automation of a single machines and processes, industry 4.0 clearly refers to the fourth Industrial Revolution which assemble different technologies in real time and focuses on the digitalization of physical work and integration of new ecosystem as analyzing and communicating of data collected by the new technologies [3]. Industry 4.0 is a collection of ten different technologies one of them is the Industrial Internet of Things (IIoT).

According to business insider intelligence, there are more than 24 billion IoT devices installed in 2020, which is 4 devices for every human on the earth [4] and from their report, they project that there will be more than 41 billion IoT devices by 2027 [5] and it shows how demand of IoT is increasing year after year.

Many industrial companies are looking to implement new technologies on their production chains and looking to reinvent their companies into smart factory known as the future of digital production. For example, Siemens invested on a project called Mindsphere which is industrial IoT application service solution using AI for advanced analytics combined with IoT solution and cloud from connected products to optimize operations, control and protecting data for better quality products [6].

According to Mr. Klaus Helmrich, Siemens is focusing on reshaping processes with digitalization both of industrial enterprises and its production operations [7]. They are other enterprises success stories in smart factory like Amazon, Adidas, Whirlpool, and more other companies who started or who will start to implement new technologies on their production chains. The goal of this study is to define the term of Artificial Intelligence of Things, to study how AIoT soft-hard impacts on the Industrial applications and the benefits of implementing the AI and IoT technologies on the modern industry.

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2 Artificial Intelligence of Things

The Artificial Intelligence of Things is a merge of Artificial Intelligence (AI) innovations with the Internet of Things (IoT) solutions and communications to realize IoT operations, better human machine communication and improve information analytics [8]. The IoT is based on Three key emerging technologies, Figure 1 shows the technology keys of the Artificial Intelligence of Things:

- **Artificial Intelligence:** Programmable functions and systems that allow IoT devices to learn and process information like humans.

- **5G Network:** Fifth mobile generation network with high-speed data and near zero latency.

- **Big Data:** Huge data from many sources that are connected to internet.
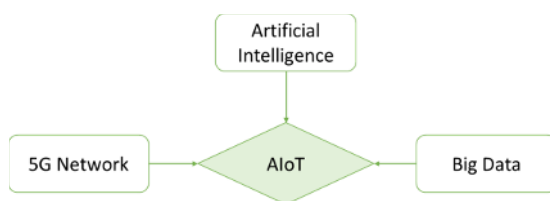
Fig. 1. the key emerging technologies of the Artificial Intelligence of Things

Although many applications of Artificial Intelligence of Things (AIoT) focus on implementing the use of computerized models to simulate human thought, AIoT impacts on those segments:

- **Smart industry:** Industries from manufacturing to mining rely on digital transformation to become more efficient and reduce human error. From real-time data analysis to supply chain sensors, smart devices help avoid costly mistakes in industry. In fact, Gartner also estimates that more than 80% of enterprise IoT projects will incorporate AI by 2022 [9].

- **Smart City:** Smart technology with sensors, lights and meters that are used to collect data to help improve drive economic growth and quality of life.

- **Autonomous Cars:** monitor driving conditions relying on video camera and sensors.

- **Wearables:** continuously monitor and prepare user preferences and habits. This has not only led to applications in the health technology sector, but it also works well for sports and fitness. According to leading technology research firm Gartner, the global wearable device market is expected to generate over $87 billion in revenue by 2023 [10].

3 Material and Methods

To carry out this study, in this section, we will identify the soft-hard which means the hardwares and softwares that Artificial Intelligence of Things uses for the industry 4.0 applications.
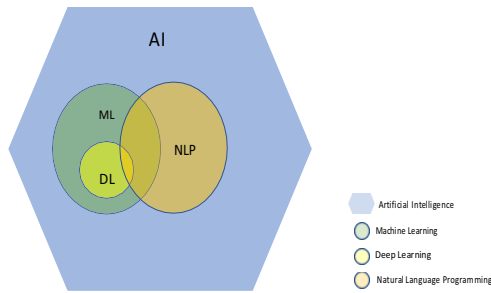
3.1 AIoT Hardwares

With the presence of AIoT in industry 4.0, AI chips are improving rapidly. Embedded hardware AI chips have witnessed rapid development, and multiple options are available to support the development and deployment of AI models. Examples include **NVIDIA's** latest graphics processing units (GPUs), which were introduced in March 2021 and are suitable for AI use cases, such as recommender systems and computer vision systems [14]. The use of AI hardware is to reduce model calculation and pushing forward the capabilities of IoT devices to easily execute AI, Deep Learning, and Machine Learning models [15]. There are also some IoT Devices that are used for AIoT such as Mxchip Devkit of Microsoft Azure that use language C and Raspberry Pi that uses Python as programming language, there is also a method that can make those two devices working together with Azure IoT hub services. Another hardware which is used also for AIoT technologies, it is FPGA an integrated circuit designed to be configured by consumer after being manufactured for using text-based operations to create hardware interactions.

3.2 AIoT Softwares

In the software AIoT part, Artificial Intelligence of Things uses various platforms and technologies that uses AI and IoT:

- **Machine Learning:** Embedded machine learning on-device transforms AIoT devices into smart, intelligent systems that can process data independently. The technical advances in different fields make it possible to apply AI technology efficiently. Popular examples are on-device ML model versions TensorFlow Lite or Lightweight OpenPose [16].

- **Deep Learning:** Deep learning is a class of machine learning that trains a system by using many layers of a neural network to extract progressively higher-level features and insights from complex input data. Deep learning works with very large, diverse, and complex input data and enables systems to learn iteratively, improving the outcome with each step [16].

- **Natural language processing (NLP):** it is a branch of AI that interacts between human and systems.

Fig. 2. The interrelation of Artificial Intelligence, Machine Learning, Deep Learning and Natural Language Programming

With the Artificial Intelligence of Things, IoT hardware can communicate with AI software. For example, Tensorflow is a tool of artificial intelligence exactly on Deep Learning part that support new programming languages, usually tensorflow is used for graphs with python /C++ and this needs a processor CPU or GPU, and those processors are IoT devices with the use of tensorflow and processors it facilitates the communication between human & machines.

3.3 AIoT Edge Computing

Edge computing is the merge of Artificial Intelligence and IoT materials, instead of data being transferred on cloud on a server, some algorithms such as AI algorithms to run on edge device or multiple edge devices and this powerful edge devices analyze low amount of data but on various devices at the same time. AIoT edge computing method is characterized by:

- **Real time operations:** there is transmission of large amount of data that cloud server can't make it in real time due to delay of data transmission since it works with network bandwidth.

- **Energy consumption:** data centers consume much energy power, and it doesn't meet requirement for optimization of energy consumption in industry.

- **Data privacy:** using AIoT soft-hard with edge computing improve on securing data instead of uploading or downloading it from a cloud which is shared with centralized environment.

AIoT Edge Computing meet the critical needs of IT industry in application intelligence, real time operations, optimization of energy and data.

4 Results and Discussion

Table 1 shows the impact of Artificial Intelligence of Things on different industries related to industry 4.0 applications in value between 1 to 5.

Table 1. Impact of AIoT on different industries [17]

Industry	Average	Value
Smart Manufacturing	4.1	4.6
Logistics Optimisation	3.9	3.9
Pharma Healthcare	4	2
IT Industry	4.5	4.7
Financial services	3.7	3.9

And this due to the demand of IoT devices, with results of demand of IoT devices an estimation of 10 years between 2018 and 2027. The figure 3 shows an estimation of total devices connected using Artificial Intelligence and Internet of Things technologies.
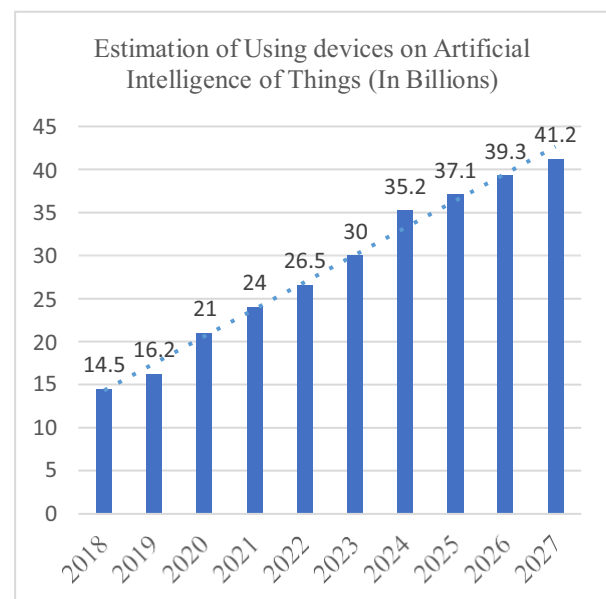
Fig. 3. Estimation of IoT devices integrated in Artificial Intelligence of Things technologies. [18]

With Calculation of compound annual growth rate (CAGR)

CAGR = $(41.2/14.5)$ ^ $(1/10)$-1 x 100
   = 11%

The compound annual growth rate of IoT devices uses on Artificial Intelligence of Things with rate of 11% and this analysis shows two findings:

- Increase number of IoT devices demand in industry 4.0 applications.

- The rate of 11 % encourage the investors and technology companies to invest in the artificial intelligence tools and Internet of Things solutions.

4.1 Performance of AIoT in industry Applications

Machine Learning algorithms such as Conventional Neural Network (CNN) need requirements on memory with fusion of Artificial Intelligence / Machine Learning with IoT systems result on high frame rates. Example, real-time object detection processing like autonomous car and use real-time image [19]. Table 2 shows Frame Rates of different algorithms which is used for object detection systems, accomplished by using Intel Movidius which is AIoT Hardware combined with Raspberry Pi card.

Table 2. Results of Frame rates and evaluation of the best algorithm to pair with AIoT Hardware. [20]

Algorithm model	Flops	FPS rate
YOLO fast	-	17.83
YOLOv2	62.94	40
Retinanet 101-500	-	11
YOLO v3-Tiny	5.56	220
TinyYOLO	5.41	244

- **Flops:** refers to Floating point operations per second it is a measure for computer performance or various cores of processors.
- **FPS:** refers to Frame Per Second it is a measure that correspond of number of images per second and the measure of frequency is expressed in hertz. The higher frame rates, the smother image shows.

As shown in table 2 they are two categories of algorithm models:

- The ones that don't exceed Frame Per Second (FPS) 40 are the algorithm that is too slow for application that requires real time processing such as you only look once (YOLO) and YOLO fast.
- The 2nd category of algorithm is tinyYOLO which are performant to execute applications with real time image processing.

According to the results, integration of the new technologies of Artificial Intelligence and Internet of Things on the industry 4.0 shows benefits such as low-cost energy consumption, autonomous predictive maintenance, controlling data.

Another solution of AIoT with industry 4.0 applications is Nexys 3, a system development of Field-Programmable Gate Array (FPGA). It is a hardware with circuit connected via programmable interconnects

and it uses Xilin spartan 6 FPGA. FPGA can be programmed from memory that contain .bit file with JTAG programming, the .bit file is transferred from PC to FPGA with usb port and reject any .bit file which is not appropriate to the proper FPGA.

The figure 4 shows the circuit of FPGA hardware configuration and the communication between human-machine.
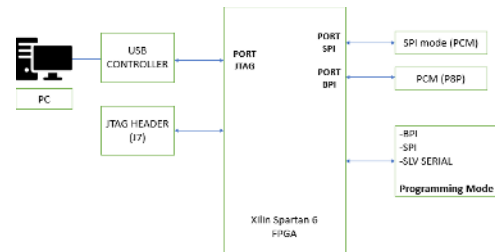
Fig. 4. Circuit of FPGA hardware connected with computer that uses AI technologies. [21]

FPGA industrial solutions enable industrial systems to reduce cost. FPGA solutions provide a fast development path with flexibility to adapt to evolve solutions for intelligent vision and applications for industry 4.0.

4.2 Benefits of AIoT impact in industry 4.0

Artificial Intelligence of Things shows benefits of the effect in industry 4.0

4.2.1 Efficiency

AIoT is the increase of efficiency because the data and the actions are available, with AIoT there is no waiting time for transfer data like in cloud or processing time, and AIoT technologies expect to identify problems.

4.2.2 Reduce failure in industry 4.0

With AIoT technologies, the data is generated and can be analyzed to identify failures, problematics, and parameters to prevent failures. This eliminates the costs and time-consuming.

4.2.3 Revenue stream in industry 4.0 with AIoT

AIoT opens a world of opportunities for businesses to offer new products and services that can boost their revenue and set the stage for new markets.
Many industries have started using AIoT in natural language processing (NLP) to better interact with humans, advanced fleet management systems to monitor the position of vehicles in real-time, drones to get to areas that are hard for humans to reach, and more. [22]

5 Conclusion

The fusion of Artificial Intelligence and Internet of Things offers an enormous potential in different industries, it pushes the limits of data threatment and

smart learning for the upcoming years. The studied sections show the importance of implementing the Internet of Things devices with Artificial Intelligence tools such as Machine Learning, Deep Learning and Natural Language Processing improviding benefits to the industry companies by reducing energy and time costs, efficiency, and new revenues streams. The innovation of AIoT will open new opportunities for human-machine communication instead of human-to-human communication which impact AIoT in industry 4.0 and make new technologies more powerful and easy to use.

The outcome of this study is to define how the Artificial Intelligence integrated with Internet of Things solutions impacts in industry 4.0. Nowadays, it still the best way to integrate AIoT in many industries such as automobile, pharmaceutical healthcare, supply chain management, smart manufacturing. The combinaison of AI and IoT helps to improve in industry 4.0.

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