Artificial Intelligence in IoT and QC: Future Computing

Dr. R. Deepa, Dr. P. Nandakumar, C.K. Indrakumar

Abstract— **The Internet of Things (IoT) is actually a recent revolution and pretty concept of the Internet which is adopted with great success in business, industry, healthcare, economic, and other sectors of modern Information Technology. It means binding all things in the world using internet. When something is associated with the internet, then there arises a possibility to send information or receive information, or both. This skill to man oeuvre information between mediums makes things smart.Adoption of the technologies in corporate Like Synergy of IoT and AI across the world has increased efficiency and made businesses customer-friendly.This article first provides an overview of the Internet of Things[IoT], Industrial IoT [IIoT], Artificial Intelligence[AI] and Quantum Computing [QC] fields, then it illustrate the factors that drive the development of 'IoT enabled by AI' and summarizes the concepts of 'Industrial IoT' (IIoT), 'Internet of Robotic Things' (IoRT), and 'Industrial Automation IoT (IAIoT). Secondly it explains the issues cornering the synergy of IoT and AI including Security aspects. Finally lists all the Applications related to AI, IoT and QC and industrial automation applications.**

Keywords: Artificial intelligence (AI), Internet of things (IoT), Industrial IoT (IIoT), Internet of robotic things (IoRT), Quantum Computing.

I. INTRODUCTION

The **Internet of Things** (**IoT**) is an augmentation of Internet connectivity into physical devices and objects of everyday utility. Embedded with electronics, Internet connectivity, and indigenous forms of hardware (such as sensors), these devices can disseminate and interact with others over the Internet, and they can be remotely monitored and controlled.[1][2][3][4] Kevin Ashton, in a presentation to Proctor & Gamble in 1999, coined the term "Internet of Things"- Every area, every device, every sensor, every software are connected to each other. These devices are accessed remotely.

IoT is a platform where there is a potential to merge everyday things embedded with electronics, software, and sensors to the internet allowing them to collect and exchange data. In this way, each of the devices will be learning from the experiences of other devices, just like humans. The presence of IoT will lead to the expansion ofinterconnection in the human - i.e. to interact, collaborate and contribute to things.

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The 'Thing' in IoT can refer to any device that might comprise any kind of built-in-sensors with the ability to collect and transfer data over a network or internet without manual intervention.[5] The Figure-1 shows the IoT devices which are co-related physicals.

Figure-1: IoT means a system of Co- related physical

The Industrial Internet of Things (IoT) refers to interconnected sensors, instruments, and other devices networked together with computers' industrial applications, including, but not limited to, manufacturing and energy management. This connectivity allows for data collection, exchange, and analysis, potentially facilitating improvements in productivity and efficiency as well as other economic benefits.[6] The IIoT is an evolution of a Distributed Control System (DCS) that allows for a higher degree of automation by using cloud computing to refine and optimize the process controls. Figure 2 shows the Industrial Internet of Things in Industry 4.0 or the industry of the future.

Figure-2 Industrial Internet of Things [IoT] an Industry4.0

IoT is at the heart of the 4th industrial revolution and covers:

- Communicating industrial equipment, products, and components.
- Embedded systems: sensors, RFID and NFC tags.
- Communication networks between objects and with company or partners IT systems Solutions for gathering, storing and analyzing data, applications
- Cloud platforms or edge computing
- Connected devices: smart phones, tablets, hybrid PCs, augmented and virtual reality headsets, etc. and mobile apps for professionals in the field.

In computer science, Artificial Intelligence (AI), is at times referred to as machine intelligence, is intelligence manifested by machines, contrary to the natural intelligence exhibited by humans and animals. Computer science establishes AI research as the learning of "intelligent agents": any device that recognizes its environment and takes actions that enlarges its chance of successfully achieving its goals.[7] Locally, the term "artificial intelligence" is used to provide a brief over machines that imitate "cognitive" functions that humans associate with other human minds, such as "learning" and "problem-solving".[8]

The term artificial intelligence was first fabricated by John McCarthy in 1956 when he conducted the first academic conference on the subject. But the journey to discovering if machines can truly think began much before that. In Vannevar Bush's seminal work As We May Think [9] he proposed a system that amplifies people's own knowledge and understanding. Five years later Alan Turing wrote a paper on the concept of machines being able to replicate human beings and the ability to do intelligent things, such as play Chess. [10] The Figure-3 shows the Artificial Intelligence System used in the Farm to protectplants.

Figure-3 : Artificial Intelligence System in the Farm

Artificial Intelligence is a form of making a computer, a computer-controlled robot, or a software comprehend intelligently in a relative manner to that of which the intelligent humans think. Goals of AI:

- To Construct Expert Systems − the systems which portray intelligent behavior, learn, demonstrate, explain, and councils its users.
- To Invoke Human Intelligence in Machines − Designing systems that understand, think, learn, and act like humans.

Cognitive IoT is the application of cognitive computing technologies in collaboration with data generated by connected devices and the actions those devices can perform. Cognition means *thinking*, and while computers are not yet competent of general human-like thought, they can now perform some of the same identical functions that humans perceive as *thinking*.

Cognition involves three key elements:

- Understanding
- Reasoning
- Learning

In a computer, system *understanding* means being able to take in large measures of both structured and unstructured data and extract meaning from it—that is, establish a model of concepts, entities and linkages. *Reasoning* means using that model to be able to derive answers or solve identical problems without having the answers and solutions particularly programmed. And *learning* means being able to automatically assume new knowledge from data, which is a key component in understanding at scale. [11]

Cognitive computing exhibits the third era of computing. In the first era, (19th century) Charles Babbage, also known as 'father of the computer' introduced the concept of a programmable computer. Used in the navigational calculation, his computer was designed to categorize polynomial functions. The second era (1950) sensed digital programming computers such as ENIAC and heralded an era of modern computing and programmable systems. And now to cognitive computing which works on deep learning algorithms and big data analytics to provide observations. Thus the brain of a cognitive system is the neural network, elemental concept behind deep learning. The neural network is a system of hardware and software that resembles the central nervous system of humans, to estimate functions that depend on the huge amount of unknown inputs.[12]

Some characteristics that cognitive systems may express are:

- Adaptive: They maybe learnt as information changes, as goals and requirements evolve. They may resolve uncertainty and tolerate unpredictability. They may be organized to feed on dynamic data in real time, or near real time.

- Interactive: They may communicate easily with users so that those users can define their needs comfortably. They may also cooperate with other processors, devices, and cloud services, as well as with people.
- Iterative and stateful: They may aid in defining a problem by asking questions or finding additional source input if a problem statement is ambiguous or incomplete. They may "recollect" previous connections in a process and return information that is suitable for the particular application at that point in time.
- Contextual: They may comprehend, analyze, and derive contextual elements such as meaning, syntax, time, location, appropriate domain, regulations, user's profile, process, task and goal. They collect from various sources of information, including both structured and unstructured digital information, as well as sensory inputs (visual, gestural, auditory, or sensor-provided).

This paradigm is the combination of concepts from artificial intelligence, natural language processing, ontologies, and big data analytics [13] for the development of smart systems.

II . INTERNET OF ROBOTIC THINGS [IoRT]

The Internet of Robotic Things is a developing vision that brings together prevalent sensors and objects with robotic and sovereign systems. The Internet of Things (IoT) and robotics communities have so far been driven by unique yet highly complementary objectives, the first concentrated on supporting information services for pervasive sensing, tracking and monitoring; the latter on producing action, interaction and autonomous behavior. For this reason, it is increasingly claimed that the creation of an internet of robotic things (IoRT) meshing the results from the two communities will bring a strong added value.[14][15]

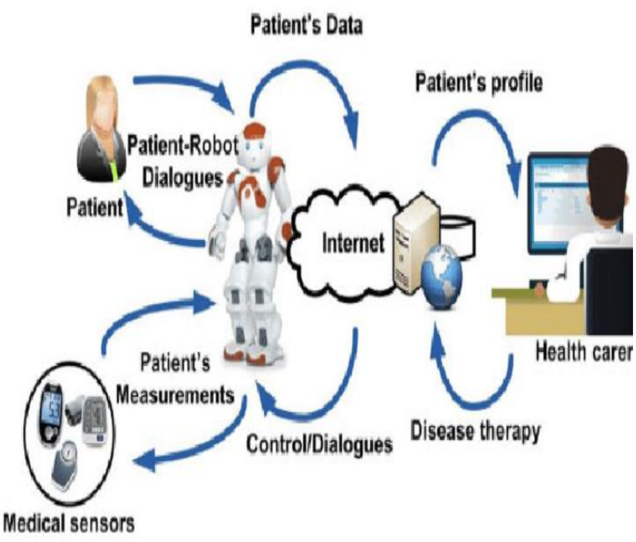

Figure-4 Internet of Robotic Things [IoRT]

Figure-4 shows the robot acts as a master Bluetooth device that reads out glucose sensors and transfers them to the custodians. The robot is then used to provide verbal information regarding the patient's diet, insulin bolus/intake, and so on.

ABI Research formulated the term "The Internet of Robotic Things in 2014" and outlined three main components [16] that characterize IoRT devices:

- The device (robot) can be regarded intelligent due to having embedded monitoring and sensing capabilities. At the same time, it is able to obtain sensor data from other which are fused together to drive the "acting" purpose of the device.
- A second intelligent perspective of the device is that it is able to leverage local and distributed "intelligence". This means that it can inspect data from monitoring events and can also access inspected.
- These two aforementioned components allow the device to independently determine which action of controlling or manipulating an object in the physical world it will perform. If it is designed to do so, the device can also move in the physical world. Additionally, it can also "warn" or "notify" based on the analysis of a physical event to the actions.

Basically, IoRT is the next level of IoT in which robots employ IoT data and technology to autonomously manipulate the physical world.

III. SYNERGY OF IoT AND AI

Synergy means, **"**The combined power of a group of things when they are working together that is greater than the total power achieved by each working separately". AI and IoT are now at very developed states and their synergy promises a lot of benefits. IoT, which by many industry thinkers is regarded to be the driver of the 4^{th} Revolution, has inspired a variety of technological advances and changes covering a wide range of fields. Many scholars believe that IoT really needs AI, and in fact that the future of IoT is AI.[17] They assume that in the near future most IoT implementations will make commendable use of AI techniques and tools (particularly machine learning and reasoning algorithms and software tools). Actually, IoT and AI have been used together in many businesses and other areas for quite some time now. IoT collects data (actually, huge amounts of data) and AI is the proper tool to interpret huge amounts of data. AI is the engine that performs 'analysis', processes the data, and 'makes decisions' based on this data. AI facilitates to 'understand patterns' and therefore helps to make more informed decisions. The use of machine learning, along big data, has opened new opportunities in IoT.

IoT and AI together could be the trigger to really drive smart city business cases – creating not just an acquainted city but an intelligently acquainted city.

Big retailers that run IoT/AI-based systems include: Amazon Go, Walmart, Carefour, Catalyst, Smartrac, Rebecca Minkoff Connected Store, Panasonic, and Coresight Research, 2018.

The ten top industries that adopted AI-IoT are:

- Smart manufacturing
- Smart retail
- Smart automobile
- Smart health
- Smart transportation
- Smart education
- Smart finance
- Smart entertainment
- Smart home
- Smart security/surveillance

IV. CHALLENGE AND ISSUES OF AI IN IoT

A national AI strategy needs to be designed on a framework based on India's unique needs and aspirations, while at the same time worthy of achieving the country's full potential of leveraging AI developments.

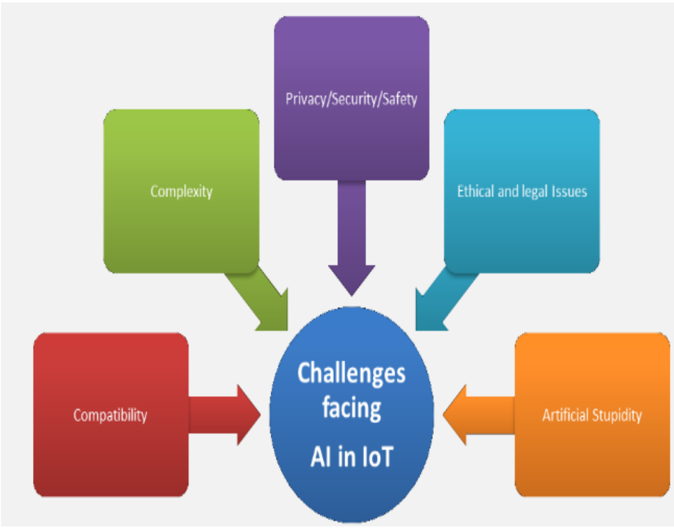

Figure-5 : Challenges facing AI in IoT

1. **Compatibility**: IoT is an archive of many parts and systems, they are fundamentally different in time and space.

2. **Complexity**: IoT is a complex system with many moving parts and non –stop stream of data making it a very complicated ecosystem

3. **Privacy/Security/Safety** (PSS): PSS is always an issue with every new technology or concept. One of the new solutions for such problem is using Blockchain technology.

4. **Ethical and Legal Issues**: It's a new scope for many companies with no precedents, untested territory with new laws and cases rising rapidly.

5. **Artificial Stupidity**: Back to the very simple concept of GIGO (Garbage In Garbage Out), AI still needs "training" to decode human reactions/emotions so the decisions will make sense.

Impact of AI in India

- It will refine the quality of life and access of choice to a large sector of the country.
- Increased access to responsible health facilities
- Inclusive of financial growth for large sections of the population who have been excluded from formal financial products.
- Providing real-time council to farmers and help address unexpected factors to increase productivity,
- Building smart and efficient cities and infrastructure to meet the demands of the rapidly evolving population
- A national AI strategy needs to be created on a framework based on India's unique needs and aspirations, while at the same time capable of achieving the country's full potential of leveraging AI developments.

Key challenges in adoption of AI in India

- Lack of facultative data ecosystems.
- Low intensity of AI research
  i. Core research in fundamental technologies
  ii. Transforming core research into market applications.
- Inadequate availability of AI prowess, labour and skilling opportunities
- High resource cost and low awareness for adopting AI in business processes
- Unclear privacy, security and ethical regulations
- Unattractive Intellectual Property regime to incentivize research and adoption of AI

V. QUANTUM COMPUTING

Quantum Computing combines two great scientific revolutions of the 20th century: computer science and quantum physics. Quantum physics is the theoretical element of the transistor, the laser, and other technologies which facilitates the computing revolution. But on the algorithmic level today's computing machinery still functions on "classical" Boolean logic. Quantum computing is the construction of hardware and software that replaces Boolean logic by quantum law at the algorithmic level.

For certain computations such as optimization, sampling, search or quantum simulation this ensures dramatic speedups. Quantum gates are the basic computation segments for QC. They are very different from gates in classical computation systems. Quantum gates are not circuits with input and output; they are operators over a quantum register. These operators are always reversible; most of them originate from reversible computation theory. [18]

Quantum Artificial Intelligence (QAI)applies concepts of quantum theory to solve problems in Artificial Intelligence—which in turn help in solving problems in wide areas of science. The Quantum Artificial Intelligence Lab (also called the Quantum AI Lab or QuAIL) is a joint venture of NASA, Universities Space Research Association, and Google (specifically, Google Research) whose aim is to pioneer research on how quantum computing might aid with machine learning and other difficult computer science problems.[18]

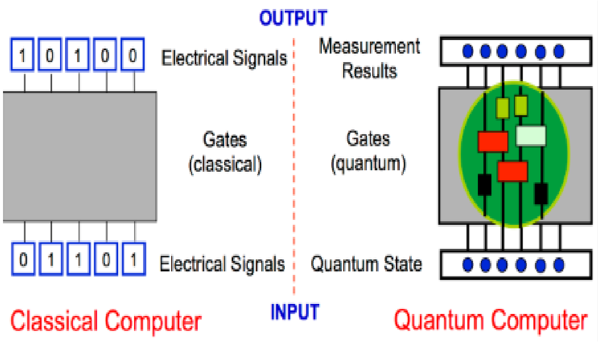

Figure-6: Classical vs. Quantum Computer

An infinite number of quantum gates can be defined (even for a single qubit) since it is possible to define an operator that rotates an arbitrary quantum register state anywhere in the Hilbert space. [19] The most common quantum gates are:

- *Identity Gate*: It is the quantum proportionate of a buffer.
- *NOT Gate*: It is used to complement the input.
- *Hadamard Gate*: It is used to set a qubit in a superposition of two states. Acts on a single qubit.
- *Phase Shift Gate*: In fact it is a class of gates with varying aspects. It changes the phase of a qubit in the Hilbert space.
- *Controlled NOT Gate* (CNOT or XOR): Like the NOT gate, but acts on two qubits. The first one is called control qubit, the second one target. The gate performs a complement of the target qubit only if the control qubit is “ket 1”. This effect is equivalent to a XOR operation between the two qubits, hence the alternative name.
- *Controlled Phase Shift Gate*: Like the Phase Shift gate, but acts on two qubits: control and target. It performs a phase shift on the target qubit only if the control qubit is “ket 1”.
- *Exchange Gate*: Acts on two qubits and exchanges their values. • The Controlled-Controlled NOT Gate (CCNOT or Toffoli): Like the CNOT, but with two control qubits. Both of them should be “ket 1” in order to complement the target qubit.
- *Fredkin Gate*: Like the Exchange gate, with a supplementary control qubit. The two target qubits exchange their values only if the control qubit is 1. Each gate is expressed as a matrix, so that the application of a quantum gate on the contents of a quantum register is expressed as a matrix multiplication. Quantum Algorithms are series of applications of quantum gates over the contents of a quantum register. [19] The most popular quantum algorithms are:

- *Parallel Computation*: Thought not exactly an algorithm, the innate property of quantum registers to support massively parallel computation is mentioned due to its use in almost every quantum algorithm. When a transformation is performed to the contents of a quantum register this affects the whole set of its superimposed values. Reading the outcome is a nondeterministic process, but it is possible to maximize the probability to occur AI/Knowledge bases 473 the intended result. This is called probability amplitude amplification [Gruska (1999)]. [20]
- *Grover's Algorithm*: It searches N=2n items superimposed on a quantum register of n qubits using a certain state as a search key. It is able to search an unordered set of items in (NO) time [Grover (1997)]. [21]
- *Quantum Fourier Transform (QFT):* A basic scrutiny in many specialized algorithms concerning factoring prime numbers and simulating actual quantum systems. QFT is a unitary operation acting on vectors in the Hilbert space. By altering their phases and probability amplitudes it can reveal periodicity in functions just like its classical analog [Coppersmith (1994)]. [22]
- *Shor's Algorithm*: It finds the period of a periodic function in polynomial time, a problem directly related to factorization of large integers [Shor (2004)]. [23] This algorithm is famous for making obsolete the current public-key encryption systems.

VI. CHALLENGE IN QUANTUM COMPUTING

There are four key challenges that could keep quantum computing from becoming a reality. [24] But if solved, we could create a commercially relevant quantum computer in about 10-12 years, a computer that might change your life:

1.Qubit Quality: We need to make qubits that we will be able to generate useful instructions or gate operations for on a large scale. As a community, we are not there yet. Even the few qubits in today's cloud-based quantum computers are not good enough for large scale systems. They still generate errors when running operations between two qubits at a rate that is far higher than what we would need to effectively compute. In other words, after a certain number of instructions or operations, today's qubits produce the wrong answer when we run calculations. The result we get can be indistinguishable from noise.

2. Error Correction: Now, because qubits aren't quite advantageous for the scale we need them to operate at, we need to engage error correction algorithms that check and then correct for random qubit errors as they occur. These are complex instruction sets that use many physical qubits to effectively increase the lifetime of the information in the system. Error correction is yet to be verified at scale for quantum computing, but it is a priority area of our research and one that I consider a prerequisite to a full-scale commercial quantum system.

3. Qubit Control: In order to implement complex algorithms, including error correction schemes, we need to establish that we can control multiple qubits. That control must possess low-latency—on the order of 10's of nanoseconds. And it must emerge from CMOS-based adaptive feedback control circuits

4. Too Many Wires: Finally, we need to recognize"fan-out"—or how to scale up the number of qubits within a quantum chip. Today, we need multiple control wires, or multiple lasers, to create each qubit. It is doubtful that we could build a million-qubit chip with many millions of wires connecting to the circuit board or coming out of the cryogenic measurement chamber.

VII. APPLICATION AREAS OF AI IN IoT AND QC

A machine upon Artificial Intelligence can do analysis, devising, communication, observation and ability to move and control objects. Several artificial intelligence are also being widely used in homeland security, speech and text recognition, data mining, and e-mail spam filtering. Applications are also being developed for gesture recognition (understanding of sign language by machines), individual voice recognition, global voice recognition (from a variety of people in a noisy room), and facial expression recognition for elucidation of emotion and non-verbal cues. Other applications are robot navigation, obstacle avoidance, and object recognition. Figure 7 shows the application of AI.

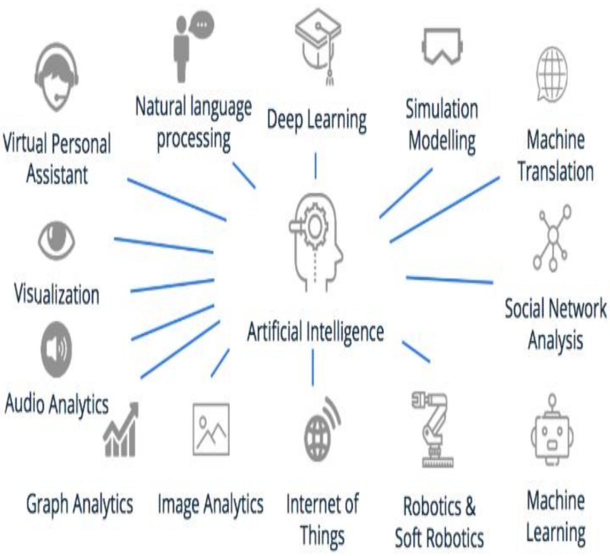

Figure -7: Application of AI

From home automation and building to wearable's, the IoT (Internet of Things) outlines every surface of our lives. Needless to say, that the current publicity around the Internet of Things is huge. It looks like every day a new corporation announces some IoT supported devices. The Figure 8 Shows the application of IoT.

Some applications of IoT with potential for tremendous growth.

- BUILDING & HOME AUTOMATION
- SMART CITIES
- WEARABLES
- HEALTH CARE
- SMART MANUFACTURING
- AUTOMOTIVE

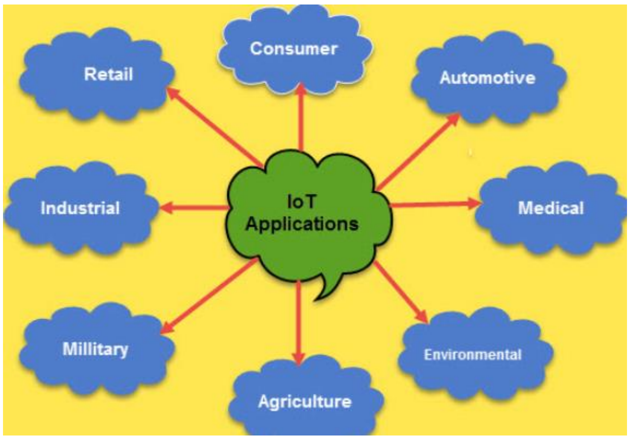

Figure -8: Application of IoT

The application of the ***Internet of Things (IoT)*** is not only restrained to these areas. Other privileged use cases of the IoT may also exist. Based on the application domain, IoT products can be classified broadly into five different categories: smart wearable, smart home, smart city, smart environment, and smart enterprise. The Figure -9 show some of the application domain of IoT.

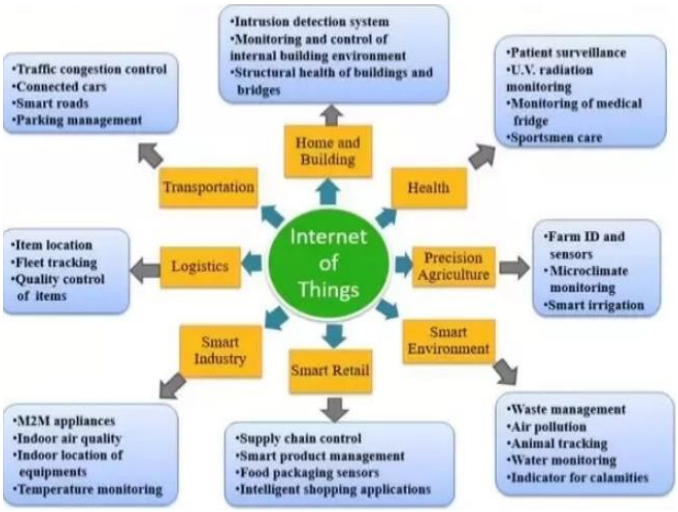

Figure -9: Application Domain of IoT

VIII. CONCLUSION

IoT/IIoT, Virtual Reality [VR], Augmented Reality, IR, M2M, Big DataAnalytics & AI is revolutionizing the business landscape, creating opportunities for new sources of revenue, smarter interactions with customers, and greater efficiencies. These are all going to be the most disruptive technology trends in the next decade, with sweeping inferences for businesses and policymakers. The real test for these technologies lies in their potential to combine machine-generated data with data put forth by humans for deeper insight, understanding, and real-time decision making together with flexibility, availability, and speed at which these technologies will transfer the data to real world that will revolutionize almost all the industry sectors. Predictive maintenance, scalability and admittance to all the data along with analytics and AI are ready to change the Industrial world. These technologies will have an eminent impact on nearly every single industry, creating new business models and new sources of operational efficiencies.

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