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Artificial Intelligence encounters Internet of Things

Olusesan Ajina

Department of Information System, Seidenberg School of Computer Science,
Pace University, New York, NY. United States of America

Abstract—We are right in the middle of a surge in creativity with different kinds of everyday objects been fitted with a microprocessor, which gives them an ability to send, receive and process data. Artificial intelligence or AI for short is phenomenon where computers become intelligent and make decisions based on this intelligence. Both Artificial Intelligence and Internet of things are as a result of the ever-increasing power of the microprocessor, so as objects inevitably become smarter, there is also a big surge in the amount of data that is currently been generated by different devices. Due to this explosion in data, a whole industry has been created to address the need for the effective management of this data and also the issue of interoperability amongst different devices because of the communication protocol discrepancies, which has given rise to a communication conundrum in the industry.

This research paper aims to provide a basis for an open discussion on the problems currently plaguing the Internet of things industry and a vision of how the integration of Artificial Intelligence and deep learning will shape how we interact with technology in the future. Each of the key topics of the research has been carefully enumerated and the research challenges have also been carefully discussed.

Keywords: IoT (internet of Things); AI (Artificial intelligence); UI (user interface); Cloud computing; UX (user experience); Big Data.

I. INTRODUCTION

The technological revolution is at a point where software is trying to play catch up with hardware. Robert Noyce (A.K.A the father of silicon valley) said during the early days of the integrated circuit that the future generation would have to figure out what to do with all the processing power that they would have.

For you to understand this statement you have to understand the invention and evolution of the integrated circuit itself considering the fact that it is the most important piece of the IoT puzzle. Integrated circuit or IC for short was first developed in 1958 during a period when engineers were trying to figure out a way to assemble transistors, resistors and capacitors on a single board rather than separately to form a monolithic integrated circuit. The initial invention was initially unstable not until 1961 when Fairchild added silicon as the semiconductor material used in integrated circuit, which is what we are familiar with today. This invention effectively started a one trillion dollars a year industry as the integrated circuit led to the invention of computers like we know it today and many other electronics that need to process data.

Hardware technology has gone through different stages in its evolution and the current trends evidently shows that it is pointed in the IoT direction. The Moore's law effect drives down the cost of hardware, which essentially lowers the barriers of entry for hardware developers, engineers and hobbyist. This situation has given rise to a wide range of products in the IoT industry by creating an avenue for innovation and self-expression, which could be adequately described as using technology like an artist would use his paintbrush on a canvass. This new burgeoning industry also presents a challenge for the Internet and addressing protocols because it seeks to create a mesh network for millions of new interconnected enhanced objects that interacts with the physical world

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The image above shows a wide collage of IoT products.

Photo credit: Texas Instrument.

Artificial Intelligence makes use of deep learning, which is fundamentally a new application where billions of neurons and trillions of connection are trained in parallel. The same driving force responsible for advancement in the IoT industry is also creating a pathway for amazing inventions in Artificial intelligence (AI). Recently, graphic processing units (GPU), which accelerates the creation of images in a frame buffer to be displayed on a screen have become faster and cheaper. These improvements have allowed for faster creation of images for frames, which leads to more data available for analytics and machine learning application. One of the companies having some breakthrough in this area is a company in Sunnyvale California called Nvidia, they designed a new GPU called P100 GPU that is capable of going at speeds that is 12 times faster than standard GPUs in the market. Higher processing rate means more accurate big data analysis and better value to customers. The dream of designing a super intelligent computer that can learn, understand like humans or even smarter has been on the front burner for computer scientist and new AI application are about to make that a reality.

II. Cloud The Enabler

Cloud computing refers to the virtual hosting and delivery of computer services to customers. Such services could either be a software application or data service provided over the Internet, which allows for elasticity in resources thereby enabling companies to scale quickly with reference to demand. It also allows you to pay exactly for what you use in a measured service.

The reason cloud computing is very attractive is because all resources are hosted over the internet and made available via REST architecture which further lowers the entry barrier for new companies that want to make their mark in the industry. Cloud computing is usually based on three prominent categories, the first is systems as a service (SaaS) which is about running software applications over the cloud where data is processed and made available for consumption on different clients via mobile or website applications and an example is customer relation management (CRM), or virtual desktop. Secondly, we have platform as a service (PaaS), which refers to a type of cloud-based environment that supports the development and delivery of a software application throughout the lifecycle of its development. This service is devoid of the cost of buying and managing hardware and the complexity involved with provisioning and scaling during development, which makes this approach preferable to deploy because it is easy to scale. The third type of cloud service is called Infrastructure as a service (IaaS) and it describes a form of cloud computing that provides full virtualized computing services over the Internet, these include resources such as servers, network and data centers on a pay as you use basis.

How the cloud connects to different clients. (Photo credit: http://www.cpisc-csic.ca)

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Cloud computing is an important factor in the application of the concept of the Internet of things because it enables wireless ubiquitous access to resources that have been previously unreachable. The concept of IoT is based on a platform where enhanced objects interact with the physical world to gather data and also utilize the Internet for data transfer and analytics application. This means that cloud-computing services with all of its resources are imperative for a successful deployment of an IoT application because of the virtual infrastructure it provides.

While IoT is an exciting new industry independently, its full potential cannot be achieved without cloud computing. Cloud computing delivers the vital framework required for IoT applications and a euphemism called cloud based processing (CBP), which refers to a model where data is processed in the cloud and returned to device with end to end encryption is helping with value generation. This type of model enables IoT products to be ubiquitous in their application because cloud based processing allows it to integrate all of the backend features like storage, data processing, big data analytics, security, authentication and client delivery. The combination of cloud based processing model and IoT allows for analytics, which enables data to be transformed into insights that could be turned into value used to drive productivity. The combination of IoT and cloud based processing means that decision making and optimization is determined in the backend application hosted on the cloud platform and with this solution comes a new challenge for a common network architecture to seamlessly integrate all of these devices.

Cloud computing enables utility based models which allows clients to access applications on demand, anytime and anywhere as long as there is an internet connection. From my studies so far I have discovered that a successful IoT product will need to harness all of the resources that cloud based solution has to offer and also have the following characteristics:

- On Demand service: Cloud service is web based and that means you can access as long as there is a connection regardless of the client that is been used to access.
- Interoperability: This ensures that there is a broad array of connectivity options. This ensures that there is no single point of failure in a network of connected products.
- Efficient resource pooling: This means that resources can be easily and securely shared with authorized users and clients. IoT solutions required information to be shared securely between users and their IoT device.
- Rapid elasticity: Cloud based processing services should be very elastic to allow freedom for backend applications and services. This allows IoT companies to scale properly with relative to growth.
- Measured Service: This refers to the to the flexibility of the cloud based services been offered. Cloud based services are supposed to offer different kind of measured services which means clients pay for what they use as opposed to just packaged services offer.

Cloud based processing is a critical component of the IoT data structure because they help to connect together all of the system that make up the IoT application. The cloud platform that is chosen goes a long way to help determine the level of successful implementation of the IoT product.

III. Big Data and Hardware

So far, we have seen how ubiquitous connectivity and cloud computing contribute to the successful deployment of an IoT application, the next piece in the IoT imperialism puzzle is hardware development and this refers to electronic circuit boards, 3D printing, robotics and manufacturing. The Internet of things is about a connected world where the physical environment becomes accessible and this is made possible because of a hardware revolution in sensory technology.

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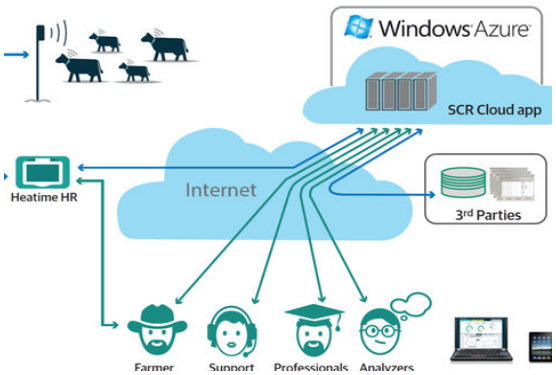
A. New Tools

In recent years, there has been massive improvement in the tools used in prototyping, printing and manufacturing which have made it easier to design, develop and ship hardware products in very short timelines. Moore's law predicts a continuous drop in the cost of hardware, which has freed up the space to enable the microchip to be deployed in different kind of ways that we did not previously imagine until now. Thanks to this breakthrough, technology has been extended to places that have been overlooked like in farming and agriculture. An example of this is a project called HealthyCow24 that uses neck tags, motion sensors and microphone to monitor herd's activity and rumination level. Using a backend application both on Microsoft azure cloud technology and on site, the cow monitoring system provides farmers with valuable insights, which boosts production.



The image depicts connected cow solution's information architecture. (Source: Efficient farm solution)

B. Agile approach incorporated into hardware development

Hardware is driven by a couple of factors and these include low cost 3D printing, cheap CNC machine tools and low cost on the shelf microcontrollers units with embedded firmware systems. PCH manufacturing companies have also helped speed up the hardware race with faster turnaround times and they are able to do so with solutions that are designed and customized for each product which includes everything in the production lifecycle like prototyping, hardware engineering, manufacturing, packaging and distribution.

The revelation here is that the agile methodology approach of product development that has been previously applied to software development is now been applied to hardware development. The effect of this is faster development of hardware, which means more products will be introduced into the market in the next few years than ever before and technology will become more pervasive than we have ever seen. One important area where IoT has been gaining ground is smart cities, which involves fitting sensors all around the city to take data that could then be analyzed in different ways to deliver value used to efficiently manage resources. An example is in Barcelona where parking meters have been enhanced with light sensors and metal detectors to determine if the parking spot is occupied or not which has helped drivers in Barcelona to find parking spots using a smartphone or web application.

C. Handling inconsistent and massive data

IoT provides us with a lot of data, however work still needs to be done to that data to convert it into actionable contextualized solution, which is why big data analytics tools are used to gain new insights. As previously mentioned in this research paper, big data is getting even bigger as a result of the advancements in hardware engineering and development and the exponential increase in the amount of data that is been generated has made it necessary to develop big data analytics used to develop tailor made data driven business models. The model could either be prescriptive, descriptive or predictive depending on the value proposition of the business model. In this perspective, big data can be noted by the following characteristics namely:

- Volume: This characterizes the large size that big data comes in.
- Speed: This describes the rate at which information is received in big data. It is very often in real time
- Variety: This refers to the diverse mixture of structured and unstructured type of information received.
- Veracity: The volume, speed and variety of data sometimes cause a lag in accuracy.

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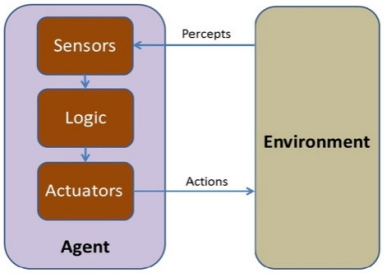
The unconventional nature of the type of big data that is generated in IoT means that conventional database management system like relational database management system (RDBMS), cannot not be used to process such data. This has led to the development of alternative tools like NoSQL database or Apache's Hadoop to help in the management of these data.



The figure below describes how sensors are used to perceive the environment and activated via actuators. (Source: http://www.waylay.io)

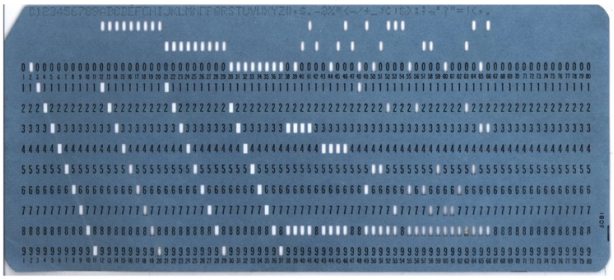
It is a fact that IoT and big data are closely related and with more IoT products to be connected more than ever before, big data will have to be properly managed to deliver the dividends of IoT. For applications to able to achieve this they would need to abide by the following analytic metrics:

- Make sure to have easy and secure access.
- The data should be available in real time
- It has a large footprint (affects a big part of the solution)
- Can make meaningful change given proper analysis

As we have seen, there is a big level of divergence in the type of data transferred and in its volume, which means actionable data have to be based on certain metrics. Following these conditions ensures that big data is securely processed and transformed into value that increases the level of productivity.

IV. Moving Away From a Terminal World.

User interaction or UI for short is a term that describes how humans interact with technology and these may include command lines, GUI (graphic user interface) keyboards, stylus screen or mouse. When it comes to gadget and device designs, UI refers to everything that is included in product development that enables interaction between users and computers. It is an important part of any program or product because it determines how easily you can communicate with technology to make it do what you want it to do



A sample punch card used in early computer history (Photo credit: thetomorrowtalks.wordpress.com)

A. Evolution of User interface

Initially, the way users communicated with computers was via mechanical switches and flashing lights. Following that, users interacted with computer using printing devices such as punch cards, which eventually evolved into command lines, but both were still tedious, error prone and not user friendly. Along came GUI (graphic user interface), which was designed by Xerox in Palo Alto, and it changed the way we interacted with computer from command lines to friendly image icons that is a friendlier and an easier representation of data, which is what we currently have as standard operating system. UI also includes user experience and this describes aesthetic design of the product, it's response time and context in which information is presented to the user.

Until recently, the way that we have interacted with technology has been terminal, which means it requires a screen with an input device or a stylus screen but due to significant advancement made with user interaction and artificial intelligence applications the way that we interact with technology is changing. Progress in hardware development has led to new UI methods such as voice interfaces, which has opened up new opportunities as well as challenges in developing new products. This new way of interaction with technology has empowered new generation of users who are living in an increasingly connected world and need to interact with technology in a more personal and meaningful way. Devices have become smaller and more pervasive like health monitoring devices, wearable and home automation technology which has made an alternative form of user interaction imperative for an effective and enjoyable user experience. Voice

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activation technology has the potential to significantly enhance the manner in which we interact with technology because talking to devices and having them understand us as long been a human fantasy and advancement in artificial intelligence and deep learning technology are making that a reality through thoughtful design integration that makes user interaction and user experience enjoyable and magical.

B. New deployment techniques

Speech will be deployed as a unifying modality for gadgets of the future with the development of software like the natural language processing application, which is aided by crowd sourced data, aimed at designing a platform that lets you command your gadgets of the future via your voice commands. For now, some level of refinement is still needed with the algorithm and data integration so it is not uncommon for you to find people talking to an uncooperative robot, smartphone or a remote control. This is demonstrated in the remarkable success of Amazon's latest hardware product called Echo, which is essentially a speaker that integrates the highest level of speech recognition technology for user interaction and a cloud based processing application called Alexa, which serves as an interactive voice that responds to your voice commands and also lets you control other smart devices in your home via voice commands. There have been nicer looking and better sounding speakers before Echo but the fact that is the first product with only speech recognition as the form of user interaction and no kind of terminal interface to it brings a magical feeling to consumers who have been enamored by that particular reason which is why it is one of Amazon's best success stories.

Machine learning breakthroughs in facial recognition, gesture understanding and emotion analysis have also been very promising in artificial intelligence as we have seen a significant decrease in the failure rate of facial recognition technology to a very realistic minimum which can let a computer now accurately tell who or what is in a picture with a 97% success rate. Progress has also made with emotion analysis applications, which can let you tell the emotion state of a person in a picture based on their facial expression and as we move into the future, we are going to see more commercial and consumer products infused with this new kind of user interface technology in order to invoke a new user experience for users.

V. CONCLUSION

All of the evidence and indicators that have been gathered from market trends point to the fact that IoT is here to stay and there will be an integration of artificial intelligence application with IoT products. As technology becomes increasingly omnipresent and hardware keeps progressing, alternative forms of user interaction have also been simultaneously evolving and this is changing the way we use technology and also expanding the limits to which we could implement them. Most of our interaction with computers has been terminal but all of that is bound to change in the nearest future.

President Obama been introduced to humanoid robot in Japan. (source: Carolyn Kaster/AP Photo)

The widespread nature of technology is having a huge impact on all industries across the board but a notable one in this context is in health and wearable technology. Some of these gadgets either do not have enough room for an attached L.E.D screen or the user experience doesn't embrace the use of a screen and they are finding their way into our personal and everyday lives.The Internet-of-Things provides us with lots of sensor data; however, data by themselves do not provide value unless we can turn them into actionable, contextualized information. Big data and data visualization techniques allow us to gain these new insights by batch-processing and off-line analysis of large amounts of data.

Finally, the fact that data is handled by a virtual infrastructure that provides REST service architecture allows sensors to be controlled over the Internet and be effectively integrated into a bigsolution. This reality

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coupled with a new type of user interaction experience courtesy of progress made in artificial intelligence application and hardware development will drive the technological products of the future to either fulfill our fantasy like a human droid assistant in star wars or to deliver a magical experience like a 3D virtual reality video communication.

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