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An Overview of Algorithms in Three Emerging Technologies: Big Data, Internet of Things, and Wearable Technology

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Abstract*—The world is going through a transformative technological revolution that was almost unimaginable several decades ago. Everything we use today, from the cars we drive, tattoos, phones, home appliances, to smart cities, etc. - run algorithms and are connected together. The main enabling factor are algorithms, coordinating, making decisions, and taking corrective measures sometimes without human intervention. The maturity of several technologies, along with algorithm sophistication, have given birth to among other things to the Internet of Things (IoT), which are a myriad of devices connected. This technology has lately transcended to things like wearable on our body. This leads to a hot trend in emerging technology called wearable technology. Always, these IoT devices are collecting massive amounts of data that pose the question, "What do we do with the collected data? What does it say about our behavioral patterns? Are these data point repositories being used outside of our consent? In this paper, we are going to present a brief heuristic view of algorithms in computing and how they are the engine that propels not only the Internet of Things, but how we aim to manage the Big Data generated by these devices.

***Index Terms*— Algorithms, big data, biometric fabric, body-borne, electronic tattoo, Internet of things, IoT, wearable computing, wearable technology, wearables.**

I. Introduction

In this paper, we examine several technologies that are revolutionizing the way we live, the way we interact with each other, and how we interact with the environment.

The question we want to answer is what makes IoT work with the sea of big data? What glues these technologies together to form the IoT? Is it the engine of big data technology and NoSQL technology? To answer these questions, we chose to study the components that make possible IoT, big data and wearable technologies, so we can understand what glues them together.

Although there are several well-known algorithms for big data, we won't focus on all of them. However, the ones that will be covered in this paper are the type: divide and conquer, backtracking, decrease and conquer, greedy, and dynamic programming algorithm.

The logical decisions that sensors make when sending or receiving information, the queries the NoSQL databases make to extract usable information from terabytes of raw data, and the intelligent software behind big data are based on one or many of the above mathematical algorithms.

A. What Is An Algorithm

In mathematics and computer science, an algorithm is a self-contained step-by-step set of operations to be performed. Algorithms exist that perform calculations, data processing, automated reasoning and more.

Algorithm are an effective method that can be expressed within a finite amount of space and time [1] and in a well-defined formal language [12] for calculating a function. The transition from one state to the next is not necessarily deterministic. The concept of algorithm has existed for centuries, however a partial formalization of what would become the modern algorithm began with attempts to solve the Entscheidungs problem ("determining whether or not the returning boolean value of two Boolean functions are equivalent") posed by David Hilbert in 1928 [11]. With all the advances we have today, however, giving a formal definition of algorithms, corresponding to the intuitive notion, remains a challenging problem.

Algorithms normally behave as they are designed, performing a number of tasks. But, when left unsupervised, can and will do strange things. As we put more and more of our world under the control of algorithms, we can lose track of who, or what, is pulling the strings. Algorithms entered the general public newscast through the Flash Crash [15], but they did not leave. They soon showed up in stories about dating, shopping, entertainment, medicine, and everything else imaginable.

B. Algorithms Are Taking Over Everything.

The bounds of algorithms expand every day. They have displaced humans in a growing number of industries, something they often do well [15]. Algorithms are faster than humans, and when things work as they should, they make far fewer mistakes than we do. But as algorithms acquire power and independence, there can be unexpected consequences. They observe, experiment and learn – all independently of their human creators. Using computer science advanced techniques such as machine learning and neural networking, algorithms can even create new and improved algorithms based on observed results. For example, algorithms have already written symphonies as moving as those composed by Beethoven, picked through legalese with the deftness of a senior law partner, diagnosed patients with more accuracy than a doctor, written news articles with the smooth hand of a seasoned reporter, flown airplanes and driven vehicles on urban highways with far better control than humans [15]. All of these interactions are generating and analyzing massive amounts of data, frequently in real time. What will become of our obligations as humans? What will happen to our employment if they continue to evolve and become pervasive?

It's no coincidence that the most ascending people in society right now are those who can manipulate code to create algorithms that can sprint through oceans of data [15]. In the history of thought, before the discovery of calculus, mathematics had been a discipline of great interest; afterward, it became a discipline of great power. Only after, the advent of a computer algorithm in the twentieth century has represented a mathematical idea of comparable influence. Calculus and algorithms are the two leading ideas of Western science.

II. The History Of Algorithms

Algorithms have been around since the beginning of time and existed well before a special word had been coined to describe them [2]. Before there were computers, there were algorithms. But now that there are computers, there are even more algorithms, and they are at the heart of computing [4] and their power has exponentially increased.

Algorithms are not confined to mathematics. The Babylonians used them for deciding points of law. Latin teachers used them to get their grammar right. They have been used in all cultures for predicting the future, for deciding medical treatment, or for preparing food [2].

A. Derivation

The word algorithm derives directly from al-Khwarizmi, a Persian mathematician and the author of the oldest known work of algebra - Muhammad ibn Musa al-Khwarizmi, in the first half of the 9th century; his book, Al-kitāb al-Mukhtaṣar fī ḥisāb al-ğabr wa'l-muqābala (The Compendious Book on Calculation by Completion and Balancing), gave us the word "algebra" from 'al-jabr" [2].

B. Early Examples

Sumerian Division: around 2500 BC, is one of the earliest pieces of evidence of algorithms of this type. This evidence was found on a clay tablet near Baghdad which concerns a problem of sharing.

Babylonian and Egyptian algorithms for arithmetic: throughout the four thousand years of their civilization, Egyptians used a number system that was additive and denary. They also used fractions. Chinese civilization did so, as well.

III. Classes Of Algorithms

Algorithms have grown over the years to influence human existence in several other ways. The versatility of algorithms and the diverse contributions from different individuals over the years has led to different types.

Brute Force Algorithm: attempts to test all possibilities in order to achieve the most satisfactory solution in optimization.

Divide and Conquer Algorithm: consists of at least two recursive calls. The first process involves dividing the problems into smaller components or sub problems. The second process is to combine the solutions from the sub-problems to solve the original problem.

Backtracking Algorithm: generally identifies all or most of the possible solutions to a computational problem. It then systematically traces back to find the best solution, discarding each partial candidate-solution that cannot be validly completed.

Decrease and Conquer Algorithm: this is almost similar to the Divide and Conquer Algorithm, except that in this case, we decrease the problem on iteration by a constant size rather than constant factor.

Greedy Algorithm: searches and identifies the best solution to the optimization problem now with little regard to future consequences. The graphs between Greedy Algorithm and Dynamic Programming differ in that, Greedy algorithm is more interested in solving the local problem, whereas Dynamic Programming applies the solution to solve the main or global problem.

Dynamic Programming Algorithm: the solution to an optimization problem may depend on first realizing the solution to the sub-problem. Dynamic Programming therefore applies the results of an earlier sub-problem to determine the solution to a new problem. Unlike Divide and Conquer or Decrease and Conquer, sub-problems in dynamic programming overlap.

IV. Big Data Of Internet Of Things

The term, Internet of Things (IoT), is a concept rather than an object. This is a process whereby all devices are embedded and connected. IoT is not a single technology, it's a concept in which most new things are connected and enabled, such as street lights, embedded sensors, image recognition functionality, augmented reality, and near field communication are integrated into situational decision support, asset management, and new services [17].

The 1980's were the beginning of the idea of the IoT. Machine-to-Machine communication capabilities were speculated in the early century. Ironically, there were lots of jokes being made about kitchen appliances plotting against you, etc. Nevertheless, the IoT terminology was added to the lexicon after the trajectory became clear.

Before the terminology of the IoT existed, many manufacturers of devices had already installed intelligent sensors and controllers on their devices. However, versatility of algorithms, price and limited functionality of the sensors and controllers deemed the data not useful. Furthermore, the knowledgebase on the potential business use of the data was not quite understood. In addition, the algorithms needed to analyze the data was not optimal.

Luckily, the growing demand for sensors led to further research on how to miniaturize sensors further reducing the price significantly. The miniaturization and affordability of sensors allows the deployment of billions of sensors. In addition, NoSQL databases and Hadoop software, which are Big Data technologies, turned out to be ideal for analyzing data streams from sensors and controllers.

Today, automobiles, jet engines, mobile devices and health monitors constantly stream data. Due to the complexity and the extreme amount of data coming from the IoT devices, there is a need for data routing and event processing, provisioning and management of the software on the sensors.

The illustration below in Figure 1 showcases the Industrial Internet Consortium, seeking to standardize vertical solutions for industry groups attempting to define standards.

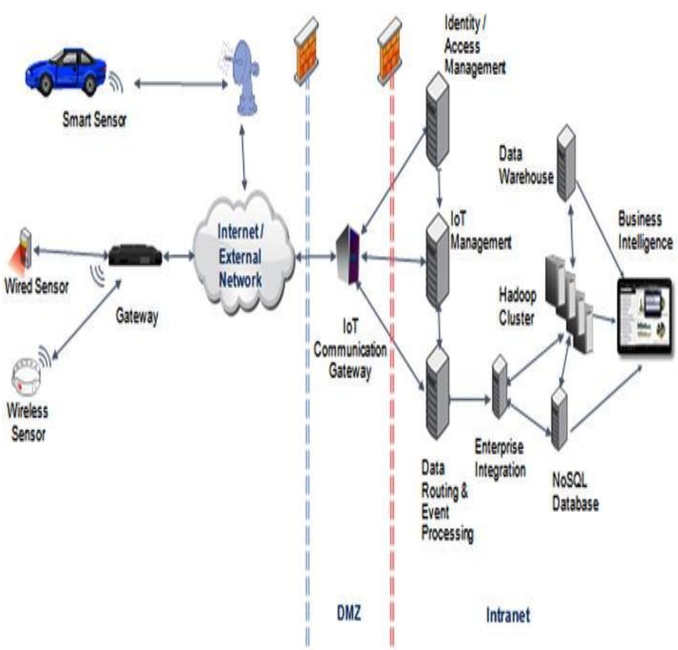

Figure 1. Internet of Things components [7].

V. Real-World Application Of Algorithms And Internet Of Things

The importance of algorithms in our lives today cannot be overstated [14]. They are used virtually everywhere, from financial, medical institutions, to dating sites. Even though algorithms are not visible to the common man, they are the backbone and the engine room that Internet of Things runs on.

Today, over five billion devices, such as mobile phones, personal computers, MP3 players, digital cameras, web cams, PDAs, and data servers, serve a population of about 6.7 billion people. Only a fraction are currently using the Internet [5].

The potential benefits of IoT are many and changing the way we work and live by saving time and resources, and opening new opportunities for growth, innovation and knowledge creation [18]. IoT allows private and public-sector organizations to manage assets, optimize performance, and develop new business models [18].

IoT is manifested in manufacturing, agriculture, healthcare, public transportation/smart cities, telecommunications, home and building automation, to mention a few.

In manufacturing, the potential for cyber-physical systems to improve productivity in the production process and the supply chain is vast. Consider processes that govern themselves, where smart products can take corrective actions to avoid damages, and where individual parts are automatically replenished. Such technologies already exist and could drive what some German industry leaders call the fourth industrial revolution [8].

A. *Agriculture*

Companies like John Deere is at the forefront of traditional companies that use the IoT to change its industry. It is the multinational farming equipment and supplies firm. It has developed a system that uses field-installed probes to monitor soil moisture levels at various depths. The platform then sends the information to a web-based interface where farmers can see the data and make timely irrigation decisions from anywhere [3].

B. *Healthcare*

There are people all over the world whose health may suffer because they don't have ready access to effective health monitoring. But small, powerful wireless solutions connected through IoT are now making it possible for monitoring to come to these patients instead of vice-versa. These solutions can be used to securely capture patient health data from a variety of sensors, like the electronic tattoo experiment that will be discussed later, apply complex algorithms to analyze the data and then share it through wireless connectivity with medical professionals who can make appropriate health recommendations [13]. Another example, is the US company, Preventice, that has developed a platform which brings together mobile, tablet, cloud, and physiological monitoring technologies for remote patient monitoring. Its BodyGuardian

Sensor and sophisticated algorithm implementations allow doctors and nurses to monitor a patient's health remotely so he or she may not stay in the hospital longer than necessary [3].

C. Public Transportation & Smart Cities

Global positioning systems (GPS) in cars and personal devices, such as mobile phones, have already brought IoT squarely into the mainstream of mobility and transportation systems [16]. City of Long Beach, California, Los Angeles, California, Boulder, Colorado, New York, Songdo, South Korea and Madrid, Spain have all used cutting edge IoT technologies to improve quality of life for their residents.

New York City, for example, is creating the world's first "quantified community", where nearly everything about the environment and residents will be tracked. The community will be able to monitor pedestrian traffic flow, how much of the solid waste collected is recyclable, food waste, and air quality. The project will even collect data on residents' health and activity levels through an opt-in mobile app [9].

Los Angeles uses data from magnetic road sensors and traffic cameras to control traffic lights and thus the flow (or congestion) of traffic around the city. The computerized system controls 4,500 traffic signals around the city and has reduced traffic congestion by an estimated 16 percent [10].

The city of Long Beach, California is using smart water meters to detect illegal watering in real time. It has been used to help some homeowners cut down their water usage by as much as 80 percent. That's vital when the state is going through its worst drought in recorded history and the governor has enacted the first-ever state-wide water restrictions [9].

As our cities get smarter and start collecting and sending more and more data, new uses will emerge that may revolutionize the way we live in urban areas [10]. Smart policing, smart deliveries using drones, and license plate recognition to fighting crimes, will take a major stage as the journey into the IoT gets deep rooted into our culture.

VI. An Algorithmic Approach In Wearable Technology Using Electronic Tattoos As Biomedical Sensors

Wearable technology has been a hot topic in the Information Technology world in recent years. While it may seem like a recent trend thanks to marketing efforts, history shows us that the concepts of wearable technology can be traced back centuries. MIT has stated that a precursor to wearable computing can date back as far as 1268, when Roger Bacon first mentioned the concept of eyeglasses. Certainly, eyeglasses are a form of technology that we use every day to correct vision, and no one would argue that they are not wearable. However, recent trends are more concerned with computing devices, and typical eyeglasses are not considered computing devices.

Current trends in this topic, such as Google Glass, Apple Watch, Fitbit and other common wearables of today may seem like they are motivated by big business and the need to invent new devices to keep generating revenues. Certainly, those are some of the more popular go-to examples of body-borne technology, and it does have its entertainment value. However, there can be significant health-related benefits that have and can continue to come out of the development of this field. One such area of body-borne technology is in the biomedical application of electronic tattoos and similar epidermal applications; see figure 2.

A. Unobtrusive Biomedical Sensors

Health informatics has always been an important part of what drives new innovations in technology. We have long-since used technology to collect biomedical data in a variety of ways, including the measuring of vital signs such as heart rate, blood pressure (BP), blood oxygen saturation (SpO2), and electrical information gathered from an electrocardiogram (ECG) [6] [19]. New advances in body-borne technology could improve current processes of non-invasive biomedical data collection by introducing unobtrusive wearable physiological imaging platforms that might replace magnetic resonance imaging (MRI), computed tomography (CT Scan), and ultrasounds [19]. Unobtrusive biomedical sensors are being investigated to provide a non-invasive solution that is easy and comfortable to wear on the body. It is an area that deals with how to constantly monitor physical activities and behaviors, and the inter-related physiological and biochemical parameters exhibited by a human subject over a prolonged period of time, such as the person's daily routine [19].

Researchers have explored several different paths to designing such unobtrusive biomedical sensors. These include a variety of physical devices that can be worn on the body like jewelry, accessories, and clothing, such as evident in figure 2. Even direct epidermal applications are being researched, such as e-skin devices, shown in figure 2c, and electrochemical tattoos, evident in figure 2a and e, which could potentially be printed directly on the skin or on a very thin substrate applied to the skin.

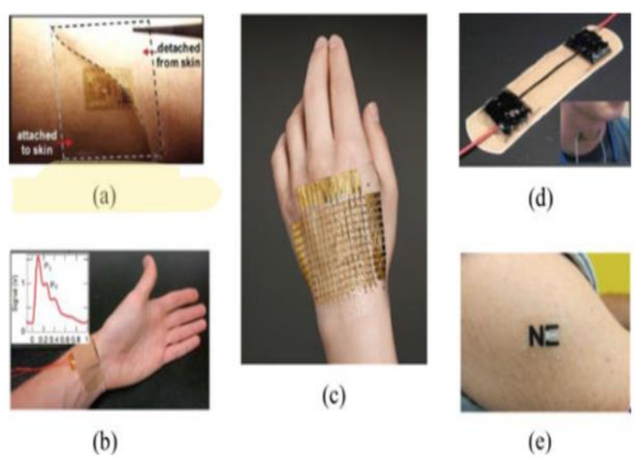

Figure 2. Flexible and stretchable wearable devices for healthcare applications developed by different groups [19].

B. Electronic Tattoos

An electronic tattoo is an application of wearable technology that uses biosensors which are either printed directly on the epidermis of a human subject, or embedded within an ultra-thin flexible substrate that can be applied to the skin much like a small bandage, to monitor biomedical data for prolonged periods of time. Recent research in this area of body-borne technology has focused on creating and testing temporary-transfer electrochemical biosensors that can discern specific chemical compounds found on the skin of a human subject to analyze health information about that person [6].

In order for electronic tattoos to be an efficient means of unobtrusive biodata collection, the devices that eventually get designed and utilized have to be able to be applied to the skin and not deteriorate over a short period of time, but also have to be durable enough to withstand the rigors of deformation caused by the skin flexing and bending through repetitious motions. If the data being collected by the biosensors will transmit electrical voltage, however small an amount, then the tattoos also have to be constructed in such a way that they insulate the epidermis from direct contact with the electrical conductive components of the biosensors, thereby protecting the human being from being accidentally shocked [6] [19]. Investigation is taking place on electronic tattoos to provide a non-invasive approach to monitoring the lactate of sweat on the human body during a sustained exercise routine in order to study an athlete's performance.

C. Non-Invasive Lactate Monitoring as an Application

A detailed study (Jia, et. al.) on the use of electrochemical tattoo biosensors for the explicit purpose of collecting lactate levels in the human perspiration emitted on the epidermis of athletes as they performed a prolonged and controlled exercise routine with modified intensity, as shown in figure 3. They had to create these tattoo-based sensors from scratch themselves, building it onto a substrate that would be easily applied to the human subject, yet durable enough to withstand skin deformations during motion, protective enough that the people participating in the study would not be subjected to unintentional shocks, and selective enough that they would accurately measure the presence of a specific chemical, lactate, in the collection of perspiration. This is what made the biosensors on the tattoos specifically electrochemical in nature.

Physical sensors that monitor typical vital signs like blood pressure, heart rate, respiration rate, and skin temperature are plentiful in today's biomedical technology. However, they tend to focus only on physical attributes of a human being in order to produce diagnostic results about a patient's overall well-being. They lack the ability to track chemical attributes that could further delineate, in a non-invasive way, specific to ailments. A future goal of developing electrochemical biosensors is the hope that one day they could provide a more detailed profile of the individual's overall health that lead to producing faster, more accurate diagnoses than just by collecting physical attributes, and without the need for invasive diagnostics [6].

Typically, while an athlete was performing a prolonged exercise, coaches would have to periodically collect blood samples by administering finger-stick processes to collect blood onto strips that would then be chemically analyzed off the body. Several problems exist with that methodology. First, it is an invasive technique because it perforates the skin with a foreign object, albeit minimally. Second, there is no way to administer the finger-stick without the athlete having to stop performing the routine. Interruption of action, especially when done periodically throughout the routine, can skew results as the body is not accurately maintaining the anaerobic process when it is coming to rest for blood collection. Third, this is a slow process of data collection and analysis, which defeats the desired goal of immediate response [6].

Other studies have been done that resulted in possible non-invasive solutions to measure the presence of lactate within the perspiration on the epidermis. Those largely yielded patch-based collection of sweat that would then need to be sent out to laboratories for evaluation. That did not solve the immediate need for information that is required by personalized healthcare fields, such as sports medicine [6].

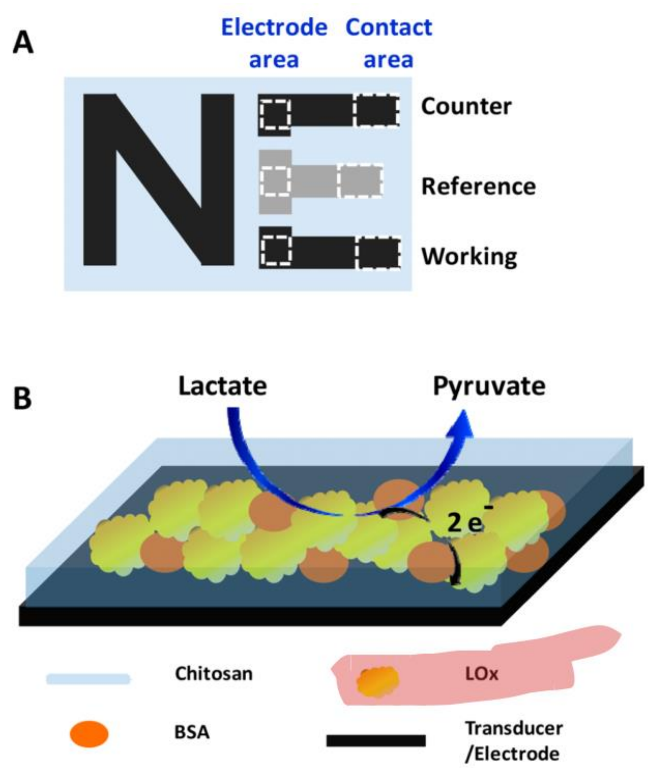

Figure 3 (A) Schematic of three-electrode "NE" tattoo biosensor for electrochemical epidermal monitoring of lactate. (B) Reagent layer of working electrode coated by biocompatible polymer (chitosan) [6].

VII. CONCLUSION.

Big Data, Internet of Things and Wearable Technologies heavily assisted by algorithms are three emerging technologies which promise to change the face of computing. This paper demonstrated that the driving force behind these technologies are algorithms. When working as expected, algorithms can be extremely beneficial. When their behaviors become erratic or unexpected, undesirable consequences can occur. This is clearly an active area of research, which goes beyond the scope of this paper.

Computer algorithms help increase the quality of healthcare, public transportation, agriculture, urban living and more. Internet of Things devices are predicted to grow at an invasively extraordinary rate; therefore, more sophisticated algorithms will be needed to handle the extremely large volume of data in real time or near real time generated by these IoT devices. It is only normal to think that algorithms are here to stay and govern every aspect of our societal lives. New ones will be created, existing ones will be improved, or “re-invented”.

References

[1] P. Axt, "On a Sub-Recursive Hierarchy and Primitive Recursive Degrees," Transactions of the American Mathematical Society, vol. 92, no. 1, pp. 85-105, July 1959.

[2] E Barbin, "A history of algorithms from the pebble to the microchip," 2012.

[3] H Botes, "3 Real-world use cases for the Internet of Things and big data" Tech-savy insight and analysis, October 2015.

[4] Thomas H. Cormen, Charles E. Lieserson, Ronald L. Rivest, and Clifford Stein, Introduction to Algorithms, 3rd ed. Cambridge, USA: MIT Press, 2009.

[5] E Fleisch, "What is the Internet of things? An economic perspective" vol. 5, no. 2, p. 125, 2010.

[6] Wenzhao Jia et al., "Electrochemical Tattoo Biosensors for Real-Time Noninvasive Lactate Monitoring in Human Perspiration," Analytical Chemistry, vol. 85, no. 14, pp. 6553-6560, 2013.

[7] Art Licht, Venu Mantha, Louis Nagode, and Robert Stackowiak, Big Data and the Internet of Things "Enterprise Information Architecture for a New Age: Apress, 2015.

[8] M Loffler and A Tschiesner, The Internet of Things and the future of manufacturing: McKinsley & Company, 2013.

[9] B Marr, "How Big Data and the Internet of Things Create Smart Cities," May 2015.

[10] B Marr, Using SMART big data, analytics and metrics to make better decisions and improve performance: John Wiley & Sons, 2015.

[11] Yiannis N. Moschovakis, "What is an algorithm?" in Mathematics Unlimited - 2001 and beyond. Berlin, Germany: Springer, 2001, pp. 919-936.

[12] C. Gordon Bell and Allen Newell, Computer Structures: Readings and Examples. New York, USA: McGraw-Hill Book Company, 1971.

[13] D Niewolny, "How the Internet of things is revolutionizing healthcare," White Paper, 2013.

[14] M Otero, The real 10 algorithmns that dominate our world: Medium.om, 2014.

[15] Christopher Steiner, Automate This: How Algorithms Took Over Our Markets, Our Jobs, and the World. New York, USA: Portfolio/Penguin, 2013.

[16] R Tafazolli, A roadmap for interdisciplinary research on the internet of things, 2012.

[17] O Vermesan and P Friess, Internet of Things: Converging Technologies for smart environments and intergrated ecosystems: River Publishers, 2013.

[18] O Vermesan and P Friess, Internet of Things-From research and innovation to Market Deployment.: River Publishers, 2014.

[19] Ya Li Zheng et al., "Unobtrusive Sensing and Wearable Devices for Health Informatics," EEE Transactions on Biomedical Engineering, vol. 61, no. 5, pp. 1538-1554, May 2014.

Wearable DL is a concept derived from a holistic comparison between the evolving big data system and the human nervous system (NS) in terms of architecture and functionalities.Â The convergence and deployment of wearable devices, Internet-of-things (IoT), and cloud computing together allow us to record, monitor, and store a wide range of the big data from individuals such as personalized health and wellness data, body vital parameters, physical activity, and behaviors, which are all critical data indicating the quality and the trend of daily life [5]. In.Â According to an overview [10], four emerging unobtrusive wearable technologies (WT) The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor The term â€œwearable technologyâ€ (often shortened to just â€œwearablesâ€ and sometimes used interchangeably with â€œwearable devicesâ€ or â€œsmart devicesâ€) originated to describe the integration of electronics and computers into clothing or accessories that could be worn comfortably on the body [4], given that the earliest developments, such as the 1999 â€œWearable Motherboard,â€ were motivated and enabled by the successive ubiquity of.Â In third-generation smart textiles, the highest degree of integration, the â€œsmartâ€ function is manifested innately as a part of the yarn or fiber and able to exist much more discretely within a textile design without interfering with its esthetic qualities and comfort level.