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An Impact of Healthcare Innovations on Big-data and VLSI Trends

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Abstract: With the ageing population the demand for healthcare has increased extremely. Healthcare has embraced technology significantly. The innovations are weaved around big-data and semiconductor industries. Henceforth, this paper reviews the literature on healthcare, big-data and VLSI technologies with reference to each other. The review focuses on the interrelationship/interdependencies between healthcare, software (big data) and hardware (VLSI technology) industries. Healthcare industry drives both the software as well as hardware industries, and their limitations would affect the healthcare industry adversely.

Keywords: Healthcare, Big-data, VLSI technology, Medical imaging

I. Introduction

Health is one of the important contributions to economic progress of a country, as healthy populations live longer, are more productive, and save more [1]. India spends below 1.3 percent of GDP on public healthcare which is not sufficient for the second highest populated country in the world. Its healthcare is a complex system with the challenges of accessibility and affordability due to shortage of hospitals and primary healthcare centers. According to WHO statistics, India has 1:921 (doctors: patient) in 2017 and the ratio changes to 1:1596 for allopathic doctors. Specialized doctors are even more less. The geographical terrain creates a lot of challenge in accessibility of healthcare services in rural areas [2]. In addition, change in the population pyramid will fuel the demand for the healthcare particularly because of lifestyle diseases. The higher medical equipment costs result in expensive care for patients making healthcare less affordable.

'Big Data' describes collection of data that is huge in size and yet growing exponentially with time [3]. That is, such a data is very large and complex that the traditional data management tools are not able to store it or process it effectively and efficiently. The three V's defines the dimensions of big-data: volume, variety and velocity [4]. Volume refers to the data generated through websites, portals and online applications that is in terms of zettabytes. Velocity refers to the speed with which data are being generated and variety refers to all the structured and unstructured form of data that has the possibility of getting generated either by humans or by machines. Big-data that is diverse and complex require new architecture, techniques, algorithms and analysis to manage it, and extract value and hidden knowledge from it. Big-data is been extensively used in prediction modeling in the applications like train delay prediction, social domain, banking, preventive healthcare, diagnostics, insurance, service delivery/hospital systems, etc. [5-7]. Hospitals/healthcare sector generates huge data and the big-data provides effective solutions.

Semiconductor technology has grown extremely fast in the recent past. Electronics system design manufacturing (ESDM) industry is one of the fastest growing industries in India. Very-large-scale integration (VLSI) is the process of creating an integrated circuit (IC) by combining hundreds and thousands of transistors into a single chip [8]. VLSI devices have been used in cars, cell phones, cameras, medical devices and many more. Advances in technology of process geometry, feature and product innovations has led to increasing need for design, develop and re-engineering of ICs. To meet the increasing demand core-based design has to be explored as it has the potential to improve the performance. Network applications are also of particular interest. There have been improvements in weight, size and power of ICs that are ideal for medical devices particularly for wearable devices.

In this paper, we review literature on the three areas: healthcare with respect to technology, big-data with respect to healthcare and VLSI technology with respect to healthcare. We indicate the significance of interdependencies in the growth of all these three industries. Healthcare in technology perspective

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depends on both; the medical devices and analytics as shown in Fig. 1. Devices are hardware based and analytics are software based. Therefore, healthcare equally requires innovations in software and hardware industries.

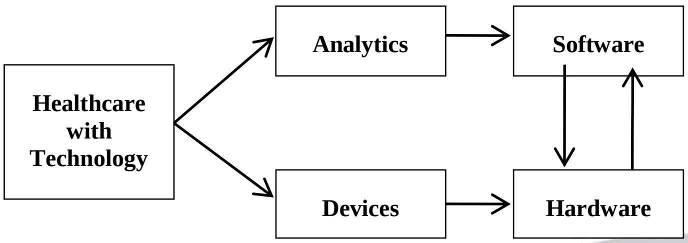

Fig. 1.Technology in Healthcare

The remainder of the paper is organized as follows: Section 2 presents literature review on healthcare, big-data and VLSI technology. In Section 3, we synthesize and discuss the growth, trends and inter-relation between the health-care, big-data and VLSI technology.

II. Literature Review

A literature review helps to identify the interdependency and the impact of one industry on the other. As three different areas are compared in this study, we did not limit our search for

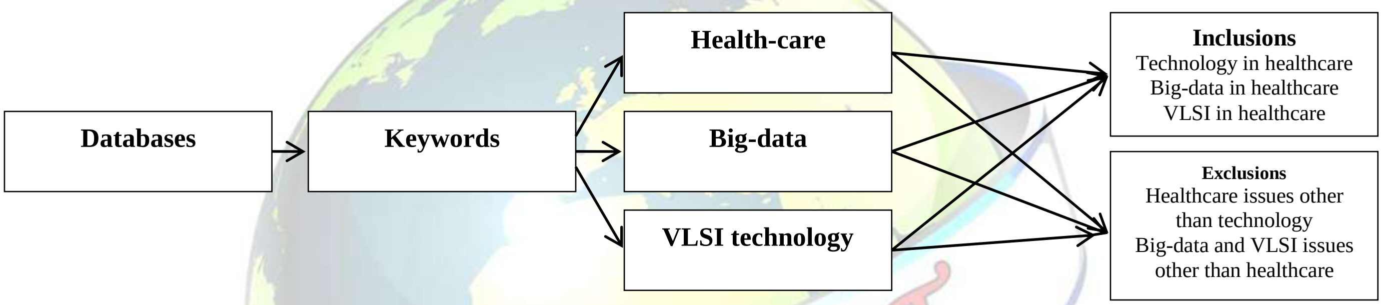

Fig. 2. Literature search process

articles to any one database. The databases used were Google Scholar, Springer, Elsevier, Web of Science, Pub Med and IEEE. Suitable keywords like healthcare, big-data and VLSI technology were used to search relevant literature between 2005 and 2018. Further, the search was restricted to more specific keywords: technology in healthcare, big-data in healthcare and VLSI in healthcare. We do not list the statistics related to the articles but rather analyze the interconnectivity or inter-relationship among these areas. Pharmacy-related articles were excluded. In this paper, the authors adopted the literature search process as shown in Fig. 2. In this section, we will present the literature review for healthcare, big-data and VLSI technology separately.

A. Health care

Recently, the healthcare sector has experienced a tremendous change due to technological innovations. Technology like device technology, software technology-EMR/EHR[1], HIMS[2], big data analytics, biotechnology has significantly improvised the healthcare delivery. Hospitals as a service provider benefit from the use of technology. The innovations in technology are a boon to healthcare and have resulted in affordable and accessible healthcare. Technological interventions such as telemedicine have significantly contributed towards improving accessibility [9-11]. Telemedicine is widely used in ophthalmology, cardiology, nephrology, pulmonology and many other medical specializations [12, 13]. Further, the trends in low cost devices have extended the affordability of healthcare [14]. Healthcare utilizes different types of devices that are implantable, tracking devices, non-invasive, wireless devices, diagnostics and personalized devices [15-17].

The government initiative of Digital India has strengthened Smart Healthcare. A lot of investments are being made in healthcare technologies with large players like Amazon stepping into health sector. Few of the innovations include cognitive computing solutions for analyzing diagnostic, clinical and workflow applications. Creation of direct interfaces between technology and the human mind without the need of input and output devices is a cutting-edge area of research that has significant applications in healthcare. Artificial intelligence (AI) has

[1] Electronic Medical Record/Electronic Health Record
[2] Hospital Information Management System

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various applications such as robot-assisted surgery, virtual nursing assistants, fraud detection, clinical trial participation, image diagnostics and workflow optimization [18-20]. AI has applications also in inpatient care and medical diagnosis, predictive and preventive healthcare [21, 22].

Prediction models and Decision Support System are being developed for disease management and patient management. Artificial intelligence, digital technologies and devices (e.g., smart phones and advanced robotics) allow patients to participate and interact directly with technology-based facilities [23]. The AI/robot/machine learning/deep learning revolution is changing the healthcare sector rapidly, and will likely see continuous change and growth over the next decade [24].

Healthcare cost has been growing fast over the last couple of decades due to need for emergency capacity – on a round-the-clock basis, complexity in disease and diagnostics and ageing population. The infrastructure that supports broad real-time data acquisition, along with adequate storage capacity would suffice the need. For this, Information and Communication Technology (ICT) infrastructure needs to include wireless access, handheld devices and point-of-care operations [25]. The system's perspective for hospitals, equipment, and information needs to be integrated with patient workflow [26]. This also includes tracking of assets/equipment by utilizing RFID[3] or ultrasonic tags. Many literature reviews have been performed on future research in Health IT [27, 28]. Healthcare providers today collect a huge amount of data that are constructively used in predictive analytics for preventive healthcare, operations management and patient experience [26, 29]. Hospitals have been upgrading their EMR systems to utilize the potential of data analytics. The amount of data the hospitals capture is different in formats (text, image, structured, unstructured) and requires an efficient infrastructure to store and process them in real-time. Along with hardware requirements, there are issues of interoperability, privacy and security of data. EMR have its share of challenges which we do not discuss in detail in this article.

To sum up, the new revolution in healthcare is not only about disease and medicine, but it is also about using technology to deliver quality and timely care with help of real-time information that drives safe and efficient patient care. Integration of medical devices, instruments and data/information systems in hospital leads to reliable and immediate communications that are necessity for the hospital of tomorrow.

[3] Radio Frequency Identification

B. Big-data

Big-data has emerged as a significant area of study for both practitioners and researchers [30]. Big-data in healthcare is defined as the 'electronic health data sets so large and complex that they are difficult (or impossible) to manage with traditional software and hardware; nor can they be easily managed with traditional or common data management tools and methods [31]. As compared with other sectors, it is found that the big-data availability in the healthcare sector is huge and is projected to grow exponentially in the coming years. In most of the developed countries, the big-data is collected and stored by the health care providers and is related to different patient services (electronic health records or wearable devices) [32, 33]. Health care providers comprise the doctors, public and private hospitals, dispensaries and clinics, support services providers (such as X-ray and sonography technicians), and health professionals (such as physiotherapists and optometrists) [34]. Most complex data sets include photos, X-rays, MRIs[4], EEG[5], ECG[6] and audio files. Big-data at times, gets shared with the external parties such as government agencies and insurance companies [32]. More specifically, healthcare big-data analytics is evolving into a promising field for providing awareness with the use of extensive data sets and thus improving outcomes while reducing costs.

There exists a lot of literature reviews on big-data in healthcare [7, 35]. Along with its wide applications, big-data has its own share of challenges. Complicated issues such as non-uniform data distribution and parallel processing with many variables are introduced that are inefficiently handled by existing analytical methods. This data is huge and heterogeneous (different formats) in nature. Big-data analytics improves operational efficiencies and reduces healthcare costs [32]. The challenges for big-data in healthcare fall into two main categories: policy and technology. The biggest technical barrier is the state of health data. Health data is largely fragmented into institution-centered silos because of customized EMR systems [36]. The problem is not of data fragmentation alone. It's about aggregating data, processing data and extracting meaningful information and using in an efficient way. Data aggregation becomes the basic building block for AI technology that has many applications in healthcare.

[4] Magnetic Resonance Imaging
[5] ElectroEncephaloGraphy
[6] ElectroCardioGram

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Natural language processing (NLP) is most widely used big-data analytical technique for healthcare [34].

Earlier, we discussed about 3V's and the other two V's are value and veracity. Value is the quality of data stored and further use of it. Veracity is about how trustworthy the data source, type, and processing of it is [37]. Most of the processing tools used for analytics are based on Hadoop; not only application related limitations but there are challenges regarding infrastructure as well. The computing infrastructure required to process big-data is different as variety of data is segregated from different locations and analyzed.

We are more serious about analytics than ever before and big-data offers better solutions, but with a lot of data storage (whether in on-site or off-site (cloud)). Focus should be on architectural, storage and networking that support big-data analysis.

C. VLSI Technology

In 1965, Intel co- founder Gordon E, made observation that the number of transistors placed in an IC or chip doubles approximately every two years (Moore's law) and thus, processor speed or overall processing power for computers will double every two years. The size of the transistor has shrunk well into Nano-scale. A large single VLSI chip can contain over one billion transistor. The world of computers and especially microprocessors has been advanced at exponential rates in both productivity and performance. The integrated circuit industry has followed a steady path of constantly shrinking device geometries and increase functionality that larger chips provide. As technologies scales, the designers have to face more challenges to meet the specifications of specific application to make efficient and effective chips. Some of the challenges include:

1) The challenges in DSM digital design which includes micro and macroscopic issues, ultra-high speed design, reliability and power dissipation.
2) Design challenges of low power which includes low power in algorithms and architectures.
3) Active power management
4) Leakage power management
5) VLSI circuit reliability, fault avoidance and fault tolerance.

Device performance improves with group III-V materials and Germanium (instead of Silicon). These new high mobility materials will be grown epitaxial on silicon substrate. New transistors operating on new principles (tunneling or spin) have become requisite for Emerging Research Devices (ERD) as they operate at low power. Memory devices are drivers of Moore's law, and the new memory devices operate on new principles (FIN-FET devices). Despite enhanced scaling capability, 2D scaling will eventually approach fundamental limits towards the end of this decade. This has led exploration of vertical dimension (3D). As the feature size of semiconductor process technology further scales down, the industry is greatly challenged in manufacturing and design [38].

Like many other applications VLSI has its application in healthcare such as Implantable Medical Devices (IMDs), such as defibrillators, pacemakers; medical imaging, Neural devices like Deep Brain Stimulation (DBS) and prostheses for Central Nervous System (CNS), Peripheral Nervous System (PNS), cochlear and retinal applications, ECG and EEG [39, 40]. CMOS[7] IC Technology is now widely available in the market [41]. CMOS ASIC[8] manufacturing is more than bipolar ICs and mixing analog and digital IC is a well-known concern. The designer has to explore different ways for using CMOS technology to implement analog functions efficiently. VLSI tools like Xilinx has been used in biomedical applications such as signal processing [42]. Digital front-ends to real-time ultrasound phased array signal processors that are used in ultrasound processing would be more effective compared to any other medical imaging process. VLSI is equivalent to around 100,000,000 transistors. This includes the current generation of microprocessors that have about 40-50 million transistors [40]. Currently, the chip design is at VLSI level. The next level of VLSI is ULSI (Ultra Large Scale Integration) with about one billion transistor which some have coined [40].

FPGA was used to implement low-cost, light-weight and portable Tele-cardiac system [43]. Tremendous attention is on the hardware implementation of deep neural networks (DNNs), Artificial Intelligence and virtual augmentation: as these applications in fact require high-speed operations. However, there is a requirement for numerous elements and complex interconnections that leads to a large chip area and ample power consumption. This is done through FPGA and ASIC implementation. The proposed architectures can save up to 33% energy consumption with respect to the binary radix implementation by using quasi-synchronous implementation without any compromise on performance [44].

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[7]Complementary Metal Oxide Semiconductor
[8]Application Specific Integrated Circuits

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III. Synthesis And Conclusion

This study conducted a literature review in healthcare (technology centric), big-data and VLSI technologies (healthcare perspective) and examined the interdependencies among these three industries. All the three industries are booming with their respective growth, yet have certain limitations, at this point of time.

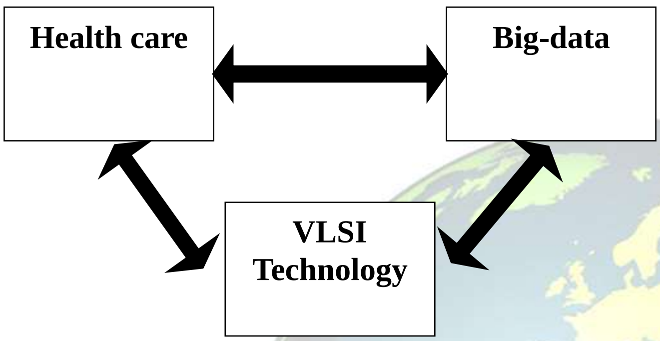

Fig. 3. Relation between Healthcare, Big-data and VLSI technology.

From this study, we found that the growth and trends in these industries are inter-related. Technological innovations have increased tremendously in healthcare. The miniaturization of devices and increase in the measure of number of biomarkers leads to demand for efficient processing and data storage which are achieved through VLSI technologies. On the other hand, the huge amounts of data generated in healthcare require be storing and processing securely and efficiently. The need for memory devices those are smaller in size and more in density demands in further scaling of transistors [45]. The big-data (information processing technology) is also driving the semiconductor industry.

The combination of 3D device architecture and low power device leading to "3D power scaling" should be appropriate for medical devices as they are sensitive to biomedical changes. Technically, due to small volume of the floating gate charge amount and charge retention (in flash memory) will become fundamental problems as fewer electrons will be available for the memory function. Big-data has encouraged new memory technologies. Persistent memory (PM) is silicon-based solid-state memory that stores data – even if there is a power failure – ensuring ongoing data access for high-performance computing. The PM technology has been in active development by semiconductor companies. Big-data, particularly in healthcare poses challenges on the storage, processing, communication and power delivery in computing farms. Amount of data in real-time that requires hardware acceleration is managed by complex event processing model. Field-programmable gate arrays (FPGAs)-accelerated processing system that includes compilation from software-oriented event language into the FPGA fabric that can be configured for a wide range of big-data applications and Internet of Things (IoT). Medical devices with learning capabilities are on a rise. The new way of computing is the artificial neural network that is more efficient than a microprocessor cluster. Additionally, there are emerging architectural concepts such as neuro-inspired architectures, program-centric and data-centric architectures.

It's been debated from last 50 years on validity of Moore's law, but it continues to hold good. The point to note is when old technology becomes obsolete; there is a need for new technology for Moore's law to continue with the semiconductor trends. Example: equivalent scaling→ geometrical scaling→3D power scaling→??. Semiconductor industry is now addressing the increasing importance of a new trend: More than Moore, "MtM".

Because of big-data, healthcare innovations, IoE (Internet of Everything), new ways of integrating a system have become essential to produce systems of higher functionality. To cater big data challenges especially for handling healthcare which is very sensitive, processing should be very fast, effective and efficient. Therefore, focus should be on

1. The architecture of processing node/system
2. Technologies used in internal and external memory
3. Interconnect networks

This indicates that there is a need in advances in VLSI technology and its applications to cater healthcare and big-data challenges. Big-data friendly solutions are motivated by reduced cost with respect to data volumes and improved analysis capabilities. Some of these solutions will likely come from outside of the semiconductor industry. The advances in semiconductor industry need to be synchronized with the demand in healthcare and big-data.

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