Guest Editorial

Artificial Intelligence in Healthcare Explained for Computer-Non-Experts

Sarwat Hussain, *Professor of Radiology, University of Massachusetts, Richmond VA Medical Center 1201 Broad Rock Boulevard Richmond, VA 23223*

Introduction

"Man is created of haste…" Al Quran 21:37

It is human nature to find ways to do more with less and faster. This instinct is at the root of all advances and inventions that resulted in the Industrial Revolutions (IR). The first industrial revolution in 1760 marked the development of the steam engine. Then the mass industrial production and electricity, automation, and electronics denoted the second and the third industrial revolutions. Currently, the 4th industrial revolution (4IR) is upon us. With the advancements in information technology and the emergence of Artificial Intelligence (AI), boundaries have blurred between the physical, digital, and biological worlds. AI, synonymous with the 4IR, encompasses a wide range of applications of data sciences into a broad scope of functionalities and data-driven predictions in our daily lives, including healthcare.

Artificial Intelligence (AI) is not new to the practice of medicine. Simple examples of IA in healthcare are a handwritten flow chart of patient triage in an emergency department, or stratifying the risk of hip fracture based on the severity of osteoporosis. These tools share three common elements: input data, the formula of calculation (Algorithm), and the output or the answer. In the case of patient triage, the input data is the patient condition, the algorithm includes the measurable (vital signs) factors of risk stratification as to how long a patient can safely wait, and the output is an urgency-based rank order of patient queue.

The ability to forecast the future accurately is of great benefit in every walk of life. In business, for instance, forecasting provides the ability to render data-driven financial and operational decisions, and develop future strategies. In healthcare, data form the basis of evidence-based medicine. Clinical informatics and predictive analytics help in the early identification of patients requiring interventions.

In the fast-changing world of AI, some of the detail discussed below may have changed by the time this review is printed. But the fundamentals will remain the same for some time to come.

The purpose of this review is to describe, for non-expert computer users, some basic concepts in AI, and introduce common AI applications in healthcare. The readers will be able to better understand AI literature, some may become interested in research to develop innovative healthcare AI applications for their environment.

A Short History of Artificial Intelligence:

Alan Turing (1912-1954), an English mathematician and computer scientist first introduced the concepts of algorithm and computation for what was then called the Turing machine. It is considered the first general-purpose computer[1]. Thus, Turing is widely considered the father of theoretical computer science[2]. Turing first conceptualized AI. In a 1948 lecture in London, he stated "What we want is a machine that can learn from experience," and that the "possibility of letting the machine alter its instructions, and provides the mechanism for this."

The term Artificial Intelligence was first coined in 1956 by John McCarthy (1927-2011) of Dartmouth College, New Hampshire, USA. He also, for the first time, introduced programming languages, developed a time-sharing computer operating system, and worked on making computers understand or mimic human common-sense decision-making. McCarthy is considered a founding father of Artificial Intelligence along with Alan Turing[3].

The program that first demonstrated the ability of computers to learn (Machine Learning) could play a game Checkers (or game of Draft) against humans. The Checkers software program was written by Arthur Samuel in the year 1952 for an IBM prototype computer[4].

Then for several decades, due to paucity of research funding, AI remained merely a topic of science fiction movies. Then in 1997, AI captured everyone's imagination when an International Business Machines (IBM) computer called Deep Blue defeated the reigning world chess champion and grandmaster Gary Kasparov in a six-game match[5]. This event was billed as a triumph of IA technology and a major public relations success for IBM. Later the development of new classes of computer chips and programming languages, and the emergence of the Internet of Things (AoT) catapulted IA into its current status.

Definitions and Short explanation of commonly used AI terms

Artificial Intelligence (AI): AI is an approach to make a computer, a robot, or an electronic product to demonstrate human-like intelligence of rational thinking, learning from experience, and problem-solving[6]. AI is virtually synonymous with Machine Learning (ML), Deep Learning (DL), and Artificial Neural networks (ANN) (Fig.1). Artificial intelligence is, therefore the practice of using algorithms to analyze data, learn from it, and then decide or predict about something in the world.

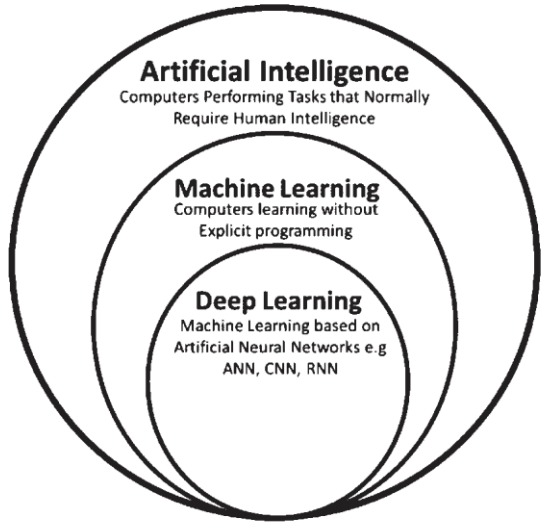

Figure 1: *Artificial Intelligence (AI) and its branches Machine Learning (ML) and Deep Learning (DL). The terms, AI and ML may be used synonymously.*

Processing Unit and Core: A processing unit is an electronic circuit inside the computer that executes instruction to perform computing operations, arithmetic, logic, control, data input and result output. A core is a unit inside the processing unit that receives and executes instructions. The larger the number of and the speed of each core, the faster will be the computer. A central processing unit (CPU) is used in all traditional computers. The AI enabled-computers (AIEC) use Graphics Processing Units (GPU) in place of CPU. GPU was originally developed for computer gaming that requires very fast parallel processing so that each pixel value can be processed by each core. Included in the category of GPUs are Tensor Processing units (TPU). The GPU and TPU with 10-4,000 cores are several folds faster than the CPU 2-18 cores. For instance, if the CPU handles tens of operations per cycle, GPU can handle tens of thousands of operations per cycle and the TPU up to 128,000 operations per cycle[7]. It is estimated that the computers of today are about 30 million times faster than those in the 1960s.

Programming language: Just as English Grammar and syntax govern the meanings of the spoken and written communication, similarly, a computer programming language allows for clear-cut instructions to the computer on what specific tasks to perform and in what sequence so that an algorithm can run on a computer. The language is written in numbers, letters, or pictures called codes, that computers have been programmed to identify as instructions to perform specific tasks. Python is the most commonly used programming language for writing AI algorithms. Lisp, prolog, Java, and C++ are some of the other languages in use[8,9].

Algorithm: An algorithm is a step-by-step, rule-based clear-cut instruction, in the form of codes, for the computer to execute certain computing tasks or solve a problem[10].

Smart Devices: A smart device is a gadget that is connected to other devices and the internet and has some memory. These are smartphones, thermostats, health monitoring devices, navigation systems, self-driving cars and many more. Smart devices are ubiquitous around us.

Internet of Things (IoT): IoT is an ecosystem of a vast network of smart devices connected wirelessly with each other and with the Internet. As stated above, these include devices of communication, transportation, home alliances, and all fields of business and government agencies (Fig.2). Smart devices can transmit data to the gateway of IoT. From the gateway, the data is available for processing locally or sent to the Cloud for further dispensation. An estimated 2.8 quintillion bytes of data is generated every day by about 17 billion connected devices throughout the world[11].

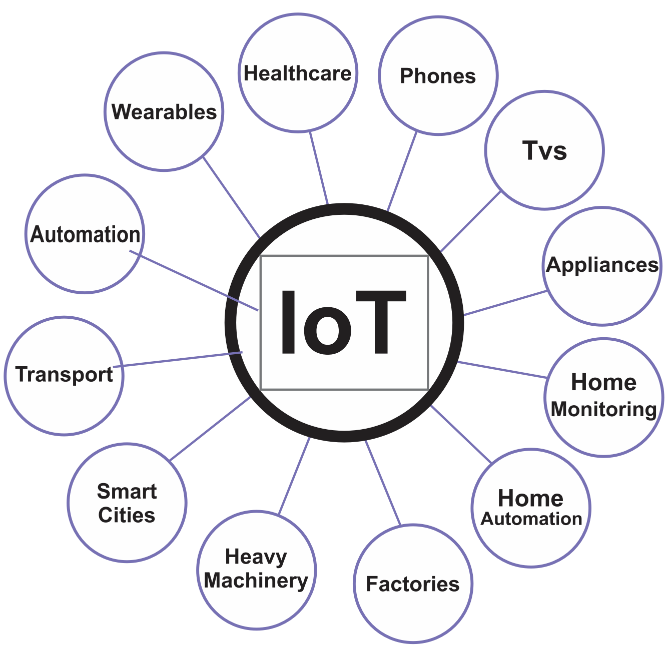

Figure 2: *Locations and the origins of data from Smart Devices in the ecosystem called the Internet of Things (IoT). Smart Devices generate data with a unique Identifier for collection and processing.*

Big data: Big data is a field of computer sciences that deals with the data gathered through the IoT, and analysis of that collected data sets that are too large and complex to be dealt with by the traditional processing approaches. Big data analytics provides insight into structured and unstructured data such as medical records, email, customer databases, social media sites, jet engines and like[12]. Big data has certain characteristics (Fig.3). These features allow the data to be analyzed for machine learning projects, predictive modeling in business, and other advanced analytics.

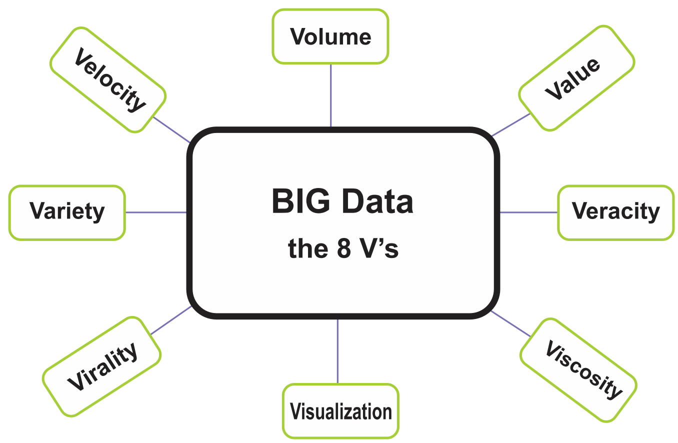

Figure 3: *Eight characteristics of Big Data.*

Volume: Any data above gigabytes is considered big data. It could be petabytes, terabytes, exabytes in size. This data is too big to be processed by traditional computers.

Value: Value in terms of business insight out of the data.

Veracity: Trustworthiness of the data source and its fitness for processing.

Viscosity: Does that stay and conveys a message.

Visualization: The process of displaying data with charts, graphs and other visual forms.

Virality: Does the data convey a succinct message after processing.

Variety: Data is from various sources and of assorted types, structured, unstructured, semi-structured, or even very complex structured .

Velocity: Velocity means the speed of data generation, delivery and analysis.

How is Traditional Computer Different from the Artificial Intelligence Enabled Computer (AIEC): The traditional computers perform a descriptive analysis of data while the AIEC executes predictive analysis. With the traditional computers, the algorithm does not change with operations, variation in the input is reflected by a change in the output. With AIEC, there is a departure from the input-an algorithm-output sequence, the data interacts with the algorithm that learns in the process (Fig.4). Many AI algorithms have the capacity, not only to learn from data but also to generate new algorithms. There are many models of data/algorithm interactions, discussed below.

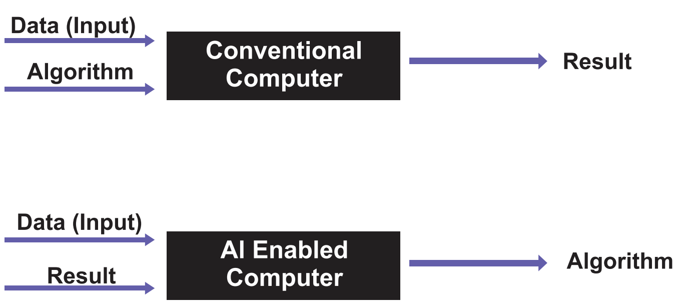

Figure 4: *Difference in relationships between Data-Algorithm-result in Conventional versus Artificial Intelligence Enabled Computers.*

The convergence of three elements have led to the emergence of AI-enabled computing:

i) Very high-speed data processing units (GPU, TPU),
ii) Huge amount of data from the Internet of Things (IoT), and
iii) Development of superior computing languages such as Python, Java, Lisp, etc.

These elements allow the AIE computers to process a colossal amount of data in a short period.

Labeled and Unlabeled data: Labeled data comes with a tag or an identifier, such as a name, a characteristic, or IP address. Unlabeled data has no tag for examples photos, audio recordings, tweets or news items.

Machine learning (ML): Machine learning is a subset of AI and an umbrella term that includes deep learning (DL) or artificial neural network (ANN)[13]. ML is the study of processes by which computer algorithms can learn by repeated exposure to the problem-specific training or past data. When training is repeated thousands or millions of times, the algorithm learns to predict and perform tasks when presented with unknown data. There are several approaches to training the algorithms of ML, depending upon the task at hand. The following 3 types are most commonly employed (Fig.5).

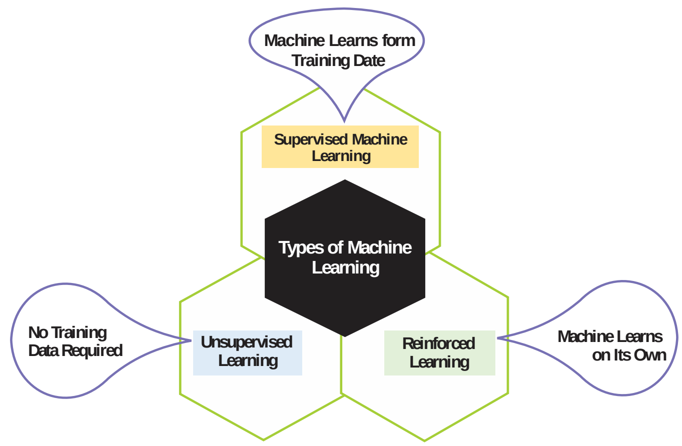

Figure 5: *Three types of Machine Learning (ML). Each type ML is used to solve specific problem. Supervised and Unsupervised ML are most commonly used. Reinforced ML is most complex of the three types.*

i) Supervised ML training is done on the labeled data. For example, input a photo of a cat and "tell" the computer it is a cat (Fig 6A). Thousands of labeled pictures of different cats are input into the computer until the algorithm learns to correctly recognize when shown an unlabeled photo of any cat. Supervised training is used for automatic labeling for classification and regression. ML trained algorithm is used for making, data based, future prediction, and eliminates the need for laborious work of manual classification of data.

ii) In unsupervised ML, only unlabeled data is input into the computer. The algorithm is designed to identify the similarities in data and group them into matching clusters (Fig 6B). Clustering and correlation techniques may be used for market research, image processing or to detect populations at risk for disease outbreaks.

iii) With Reinforcement (or semi-supervised) learning, part of the data is labeled, part is not (Fig

6C). The machine learns by feedback to maximize cumulative, net score. The algorithm learns in an interactive environment where a correct answer is rewarded with a positive score. If the result is not correct, training is repeated until the desired accuracy is obtained. Thus, the ML algorithm becomes "smarter" over time. Some examples where applications of reinforcement learning are; Robotics, aircraft controls, and chatbots[14].

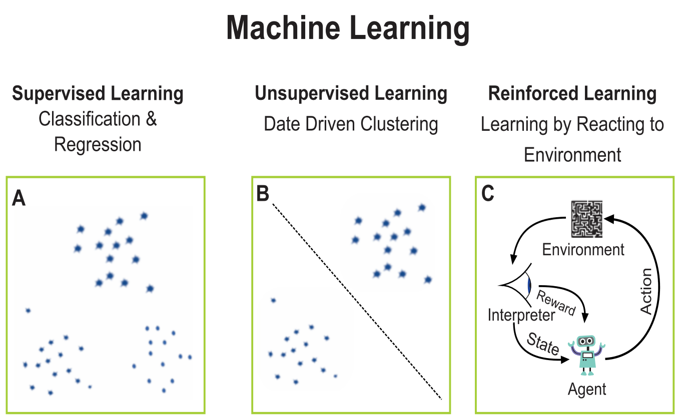

Figure 6: *Three types of Machine Learning (ML). A) Supervised learning is used for task driven analysis for classification and regression. B) Unsupervised learning employed for data driven clustering. C) In Reinforced learning, the algorithm learns by reacting to the data environment.*

Deep Learning (DL): DL, a branch of ML is primarily used for image recognition and analysis. DL is synonymous with Artificial Neural Network (ANN) which is inspired by the interconnections of the neurons in the human brain. The hardware of the ANN is made up of dozens, or more, interconnected layers of artificial neurons or "percepton". Each neuron consists of multiple nodes (Fig 7). All nodes of one layer are connected with each node in the subsequent layer. The transmitted information via each connection is digitally weighted. This continues until the entire data passes through all the nodes of each layer from the input to the output layer, including the hidden layers in between. Thus, a very complex computational matrix is formed where no two connections transmit identical data. If the final output result is inaccurate, then through a process of "back propagation", the weightage of the nodal connections is adjusted until the neural network is optimized to generate the correct result. This is how the ANN learns from the feedback. ANN are customizable depending on the need of the enterprise. Of the several types of the ANN for DL, the two most commonly used are, convolutional neural network (CNN) for static image processing and recurrent neural network (RNN) for analyzing videos[15]. CNN models are used for automated detection and interpretation of the medical images, in radiology, ophthalmology, pathology, cardiology, and dermatology (Fig.8).

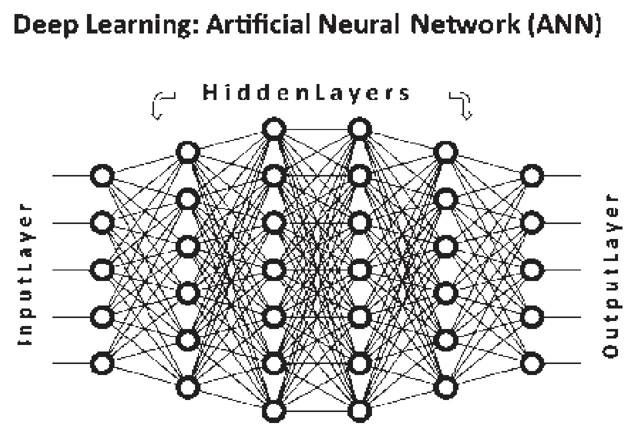

Figure 7: *Introduction to ANN. ○ depicts a node, each column of . ○ represents an artificial neuron. Connecting lines indicate transmission of data forward. Each connection is uniquely weighted. The hidden layer is called "Hidden" because their function is not directly observable from the systems inputs and outputs.*

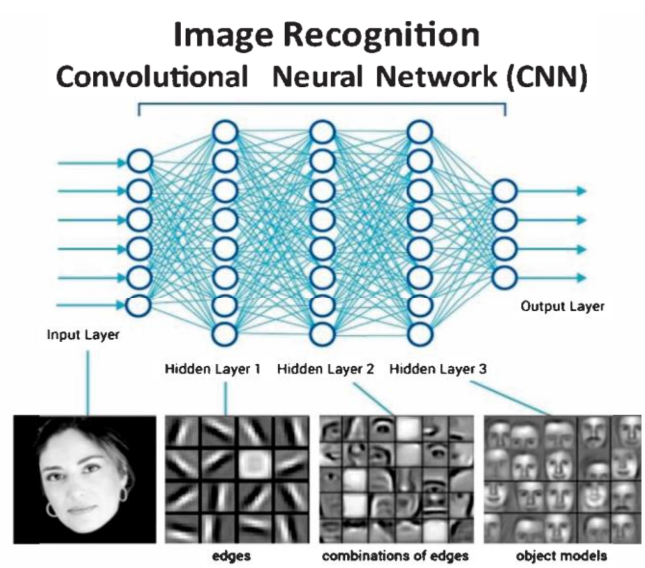

Figure 8: *Object Detection: Image processing by Convolutional Neural Network.*

(ResearchGate 2018 10.13140/RG.2.2.34552.96002.)

One major difference between ML and DL algorithms is that in ML algorithm the data is input after feature extraction, with DL feature engineering is done automatically by the algorithm (Fig.9).

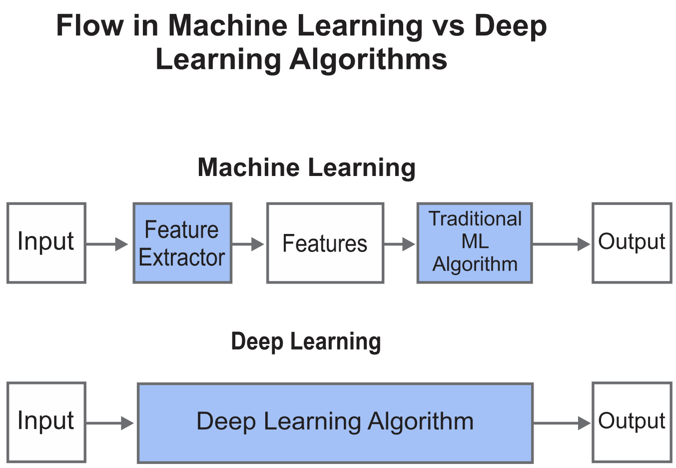

Figure 9: *Data Processing Schemes in Machine Learning (ML) versus Deep Learning (DL): In ML the relevant features of the data are extracted and presented to the ML algorithm for processing. In DL the algorithm extracts the relevant features by itself.*

It is important to conceptualize that ML and DL are not just two techniques to process data or images for predictive analysis within AI. Each ML and DL, as terms, represent large groups of assorted sets of mathematical formulas and techniques used in AI. Each of these are applied to train algorithms for intended functions and outcome. In practice data scientists determine which ML or DL technique or formula may be used to solve business problems requiring regression, classification, forecasting, clustering associations, or medical images and video analysis.

Chatbot: Chatbot also called Bot, is an artificial intelligence program that makes possible conversation between humans and computers. The program can interpret a text or voice question by natural-language Processing (NLP), via ANN. Chatbot software interprets the words in a query, and provide answers after searching the library of answers. Chatbots are also called intelligent personal assistants (IPA). "Siri" a chatbot of the Apple iPhone is a commonly known IPA. "Florence" is an online personal health assistant chatbot, providing instant answers to health-related questions. In general, health Bots provide valuable support to physicians, nurses, therapists at the point of care, and to patients and families in health and illness. They offer instant and usually, accurate medical information. Overall, there are over 300,000 Chatbots in use at this time [16]. During the COVID-19 pandemic, many organizations turned to chatbots to reduce the burden on overworked staff and afford timely service to patients. In the future, patients with common ailments will probably consult health bots first. Based on the patient's condition, the bot will call an ambulance, transfer the case to emergency department or schedule a visit to the doctor's office [17,18].

Decision Support: A decision support system (DSS) is an ML-based AI program. DSS is used to arrive at data-based optimal and informed decisions in a variety of fields. Clinical Decision Support System (CDSS) assists doctors and nurses in making evidence-based decisions in clinical care according to the agreed protocols or prevailing practice. This practice reduces errors and improves patient access to healthcare. In business, DSS facilitates a variety of functions, such as loan verification, bids evaluation, or assessing agricultural production[19].

AI technology in healthcare: AI technology helps to enhance virtually every domain of healthcare ranging from health maintenance, medical practice, surgical procedures, education, research, drug discovery, quality and error reduction, to administration, finances, planning, biomedical engineering, universal healthcare, to name a few.

AI tools allows doctors, nurse and other paramedical staff make fast and accurate clinical decisions. For instance, image based early diagnosis of stroke, pneumonia and cancer, or diagnosis of acute coronary artery occlusion by AI based interpretation of electrocardiography, and detection of cervical cancer by automated pap smear analysis. AI technology is available to develop customized algorithms for disease prevention such as tuberculosis, diabetes, cardiovascular disease. AI predictive analytics can save lives by performing risk assessment of maternal and child perinatal morbidity and mortality. An AI-based expert system has been shown 77% sensitivity and 95% specificity in predicting infantile asphyxia requiring resuscitation [20].

At the public health level, AI-based techniques are able to track infants, using fingerprint technology to ensure proper vaccinations[14]. Point of care diagnosis can be important in the early detection of disease outbreaks and AI-based automated clinical diagnosis of multiple conditions from dengue fever to cataracts [21-24].

Some Common AI Applications in Healthcare

Health Monitoring and Sensing: Smart wearable devices such as commercially available "Fitbit" (fitbit.com, San Francisco, CA) automatically monitor and display vital signs and can track physical activity, calories spent, quality of sleep and breathing, and give feedback to users or transmit the data to doctors or instructors, thus affecting improved health outcome. The users of wearable devices can stay motivated individually challenged for competing with self or others. Incorporating monitoring devices in an integrated and intelligent health system can ensure that those living at home are not abandoned from surveillance[25].

AI in intensive care units: ML enables predictions of morbidity and mortality in ICU based on the accumulated historic data from the network of interconnected monitoring devices from the ICUs of a region or country. Analysis of these data assists in calculating risk scoring for the severity of illness and probability of mortality. These predictions assist in preempting therapeutic measures for at-risk patients for improved outcome. ANN trained on data from a big network of ICUs can be implemented, or customize for a smaller network or even for a specific ICU for predictive analytics. These can form the basis of developing management protocols[26].

Radiology and IA: AI algorithms can be programmed to perform real-time electronic surveillance and help improve service in many ways; automatically place urgent studies at the top of the list of cases to be reported, communicate significant findings to the referring physicians, facilitates audit by randomly selecting cases for double read and checking for the technical excellence of the images, and create ongoing performance reports on the radiology staff. All the aforementioned AI functionality positively influences the success of the department of radiology and teleradiology service [27]. In general, solutions for the practice and management of radiology services are also applicable to teleradiology.

Among the medical specialties, medical imaging has probably benefitted the most from advancement in computer sciences. Computer-aided detection (CAD) and diagnosis, 3-D and 4-D image reconstruction, segmentation, virtual reality, and functional imaging are some of the AI-based advances in radiology[28].

An AI startup, Nines, has developed an AI-based tool that can diagnose intracranial hemorrhage and detect a mass effect on brain CT scans without involving a radiologist[29]. Such applications not only relieve the growing workload on radiologists, address the shortage of their radiologists but also improve timely management of critically ill patients.

AI in Ophthalmology, Histopathology, and Dermatology: Digital retinal image acquisition and analysis using Convolutional Neural Network (CNN) permits rapid and automated diagnosis of diabetic retin-opathy[30]. Trained CNN is capable of performing the classification of histopathology images into malignant and benign tissue and diagnose subtypes of cancer. As the AI performs tissue differentiation, it learns to improve performance.

Similarly, dermatological diagnosis is based on visual perception. Training of ANN models with digital images of skin conditions has been successfully performed to diagnose cancers, psoriasis, atopic dermatitis, onychomycosis and the like (Fig. 9).

With research, diagnostic applications of AI in medical subspecialties are increasing in accuracy and scope. General practitioners and nurses, with little training, can use these tools for subspecialty level diagnoses. These applications are of particular benefit to patients in remote areas, and LMIC where access to specialists may be limited[31, 32].

Robotics in Healthcare: Robots were first employed in car manufacturing in 1961. Later Robots were built to perform other repetitive and hazardous functions such as handling of unsafe materials, picking and packing crops, firefighting, and bomb disposal[33].

In healthcare, robotics surgery began in the 1980s with the invention of Robodoc (Integrated Surgical

Systems, Sacramento, CA), an image-guided orthopedic robot for hip replacement. Currently, robot-assisted surgery is performed on virtually all organ systems, including the heart and brain using robotic systems. Da Vinci Robotic Surgical System (Intuitive Surgical System, Sunnyvale California) has been in use since 2000 for multiple surgical procedures. By 2020 over 750,000 robotic surgeries have been performed on this system. It is estimated that within 10-15 years fully autonomous surgical robots are very likely to become operational[34]. Nonsurgical, assistive, and nursing robots have been developed for performing personal tasks to help deliver care to the elderly and the disabled. Aethon's TUG is an autonomous mobile Robot used in hospital premises to deliver medications, laboratory samples, and other sensitive items and documents. These robots navigate hospital building by communicating with elevators, fire alarms, and automatic doors. Other hospital Robots perform tasks like monitoring hospital systems, collect and analyze data from health monitors. Currently, surgical robots are very expensive, but with time they are expected to become increasingly intelligent and affordable.[35,36]

Monitoring and Sterilizing Healthcare Environment: Infection control is a challenge in hospital environments across the world. Fluorescent Ultraviolet (UV) light sources were used to sterilize spaces in the past. Currently, more powerful UV light-emitting diodes (UVD) carrying robots are in use to eliminate pathogens from the healthcare environment. Research is being conducted to develop sensing devices to detect and classify pathogens to assist with infection control in the community and healthcare facilities[37].

AI and Drug discovery and development: The relationship between the chemical structure of a drug and its biological action can be depicted by a mathematical formula. These formulas, as bioinformatics tools, can be used in a computer simulation, and to train the ANN that helps to shorten the drug discovery process. The recurrent neural networks (RNNs), the convolutional neural networks (CNNs) and the molecular graph-based neural networks (MGNNs) play pivotal roles in the development of new drugs by incorporating the information of the molecular structures into the computer models. These models can help the machines to analyze the rules directly and comprehensively. In addition, these processes can be trained in the qualitative and quantitative AI models, and can also cover the areas of ligand-based drug design, de novo drug design, and receptor-based drug design[38]. Thus, AI modeling by ANN can help to significantly reduce the time and resources required in drug development.

Virtual Personal Physician: Dr.AI (HealthTap, Mountainview, California), a virtual personal physician, is powered by artificial and emotional intelligence. This AI program has been trained by the input of over 100,000 doctors and millions of patients' queries. Dr.AI can hold empathetic consultations with patients about their health, and provide explanations for their symptoms. Based on the patients' symptoms, age, and gender, the Dr.AI offers possible diagnoses, suggests medications, and discusses other relevant aspects of the patient's well-being. After an initial consultation, if desired, the patients can talk to a real doctor right away. The Dr.AI continually improve performance as more and more users query the program[39].

Babylon Health of the United Kingdom has rolled out a similar program of digital consultation, where users can enter their symptoms into an app. If necessary, the app asks some questions and advises the patient whether they should go to the emergency department, urgent care, or wait to seek an appointment with their primary care physician. The app also schedules the earliest available appointment with the doctor[40]. Programs and applications with variations on this theme are mushrooming around the world.

AI in Mass Casualties: In mass casualties and major disasters there is always a relative shortage of medical staff for the number of patients requiring attention. Some patients need immediate lifesaving intervention. Therefore, accurate triaging is critical to the overall survival of the victims. Kim et al have developed a triage model that, using wearable devices, can efficiently and accurately triage patients without the involvement of medical personnel. Using machine learning algorithms, the system uses the patient's age, vital signs and continuously monitors the consciousness index for accurate triaging. Such applications can be usefully employed in the very busy emergency departments of today[41].

AI in Universal Health Coverage (UHC): The General Assembly of the United Nations in 2015 adopted a resolution entitled “Transforming our world: the 2030 Agenda for Sustainable Development” consisting of 17 Sustainable Development Goals (SDG’s)[42]. The SDG-3 resolves to Ensure healthy lives and promote well-being for all of all ages. Contained within SDG-3 is a stated goal to “achieve universal health coverage including financial risk protection, access to quality essential healthcare services and access to safe, effective, quality and affordable essential medicines and vaccines for all”. Achieving UHC is a colossal undertaking, particularly for the low- and middle-income countries.

It is known that patients in rural areas, in general, are half as likely to have access to care as their urban counterparts. But health technology research and innovations are developing health maintenance and delivery applications for common use at affordable costs. Governments and health ministries in the LMIC are beginning to, albeit slowly, deploy data sciences, computer connectivity, and technology to enhance national health systems to bring universal health coverage (UHC) within reach.

The adoption of AI telehealth, bourgeoned by the COVID-19 pandemic, is fast becoming an integral part of healthcare systems all over the world. During the current pandemic, a shift of care to AI telehealth, not only acted as a major mitigator of viral transmission but also provided improved access to the rural areas as well.

To leverage the full potential of AI technology, there needs to be an investment in upskilling healthcare professionals in new technologies and change the way the medical students are trained. WHO estimated worldwide deficit of 12.9 million skilled health professionals by the year 2035[43,44]. This is a compelling reason to find innovative and cost-effective ways to deliver care using AI healthcare technology.

Will AI Replace Doctors?: Some AI enthusiasts surmised in 2016, that healthcare should stop training radiologists because, “ ……….it’s just completely obvious that within five years, deep learning is going to do better than radiologists”[45]. But pragmatists have argued that the role of AI in radiology, pathology, and healthcare in general, will be supportive, bringing proficiency to the care health workers deliver in preventive, diagnostic, treatment, and procedure domains. Hundreds of AI healthcare companies around the world are developing AI healthcare programs, yet, five years following the above statement, no doctor has been replaced by AI. Instead, there remains a worldwide shortage of doctors, especially radiologists. AI is unlikely to replace physicians, but it seems certain that physicians who can use AI to their advantage will replace those who do not. The role of the AI is to enhance doctors' intelligence by providing decision support, instant knowledge at the point of care, and support for many administrative and financial functions[46, 47].

Comments:

In this report, an attempt has been made to introduce Artificial Intelligence to the medical community by imparting some basic concepts. Based on this, understanding of the current status, future progress, and research opportunities can be developed. The applications of AI in healthcare have been briefly introduced above. Each subheading can be elaborated into a book chapter. This was beyond the scope of the review.

Computer terminology can be daunting for, even the educated non-computer scientists. Many senior physicians consider artificial intelligence as a subject confined to information technology, separate from healthcare. In reality, computers have been used in medicine since 1961. In 1967 Computed Tomography was introduced into medicine revolutionizing diagnostics[48]. Since then, digital images and data analyses in medicine have ridden the crest of rapid evolution in computer sciences, and permeated every field in healthcare: prevention, diagnosis, management, procedures, administration, planning, public health, health policy, global health, and universal health coverage and more.

Based on the projections and possibilities, it seems clear that AI is still in its infancy. In 2016, AI-related technologies added $ 600 million to the global economy. This figure is estimated to rise to $ 15 Trillion by the year 2030. Under the current circumstances, the economic boon will occur mostly in the HIC[49]. But early adoption of AI by LMIC has the potential to provide big dividends, not only to healthcare but also to national economy. To adopt AI, public and private data must be digitized. A dearth of digital data and paucity of computerization is a roadblock in deploying AI technologies. The scarcity of digital data can be considered as a challenge, to find ways to develop AI application using smaller data sets.

Despite all the potential and realized benefits, AI is not a silver bullet for the society. Many related issues still need to be addressed. Consensus is yet to emerge on privacy boundaries, ethical issues, or intellectual rights. Serious issues of racial bias in AI-based decision-making programs allegedly exist in the judiciary and banking. Snags have been identified where racial and social class bias have been baked in to the aforementioned programs, the biases of the programmers. Attacks on AI run public utilities, installlation of national security, and contamination by computer viruses are currently becoming hard to defend against[50].

Many prototypes of AI programs developed in public and the private sectors that perform well in research laboratories, often cannot be translated, commercealized, or deployed for routine use. Increasing the use of AI in healthcare requires constant change, that in itself can be attended with challenge: systems become obsolete (“software erosion”) and companies go out of business, requiring expensive replacements of software and hardware.

In theory, AI brings efficiency in care delivery, but in many societies, patients might find it difficult to trust a computer consultation in place of face to face interaction, but needs can change behavior.

AI is here to stay to bring about quantum advancement for humanity. One of the most advanced AI-based automation is a YouTube video entitled “gpt-interview”. Readers are advised to watch it[51].

The limitations of the paper are that this review is not meant to be an exhaustive review of the subject matter or for the students of computer sciences. It is meant to impart some basic concepts to health workers so they can build on the information provided. Each section on the AI applications in healthcare is a short introduction to the subjects, in order to stimulate readers’ curiosity. The medical and subspecialty literature is galore with scientific articles. For instance, over 6,000 articles have been published in Radiology alone in the last 10 years. For researchers and students, the AI field is wide open for discovery.

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