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ARTIFICIAL (A: ATTRACTIVE, R: READY FOR ANY TIME, T: THERAPEUTIC, I: INTELLIGENCE, F: FIGHTS FOR LIFE, I: INSIDE THE BODY, C: COMPUTING, I: INTERACTIVE, A: ALMOST THE GOD, L: LASTS LONG) INTELLIGENCE: READY FOR THE GREATER GOOD OF MEDICAL SCIENCE

[1*]Kushal Nandi, [1]Dr. Dhrubo Jyoti Sen, [2]Dr. Dhananjoy Saha, [3]Sipra Sarkar and [4]Angshul Saha

[1]Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector-V, EM-4, Kolkata-700091, West Bengal, India.

[2]Deputy Director, Directorate of Technical Education, Bikash Bhavan, Salt Lake City, Kolkata–700091, West Bengal, India.

[3]Department of Pharmaceutical Technology, Brainware University, 398, Ramkrishnapur Road, Barasat, Near Jagadighata Market, Kolkata, West Bengal-700125, India.

[4]Kendriya Vidyalaya No-1, Salt Lake, Sector-I, Labony, Kolkata-700064, West Bengal, India.

***Corresponding Author: Kushal Nandi**

Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector-V, EM-4, Kolkata-700091, West Bengal, India.

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ABSTRACT

Artificial intelligence in healthcare is an overarching term used to describe the use of machine-learning algorithms and software, or artificial intelligence (AI), to mimic human cognition in the analysis, presentation, and comprehension of complex medical and health care data. Specifically, AI is the ability of computer algorithms to approximate conclusions based solely on input data. What distinguishes AI technology from traditional technologies in health care is the ability to gather data, process it and give a well-defined output to the end-user. AI does this through machine learning algorithms and deep learning. These algorithms can recognize patterns in behavior and create their own logic. To gain useful insights and predictions, machine learning models must be trained using extensive amounts of input data. AI algorithms behave differently from humans in two ways: (1) algorithms are literal: once a goal is set, the algorithm learns exclusively from the input data and can only understand what it has been programmed to do, (2) and some deep learning algorithms are black boxes; algorithms can predict with extreme precision, but offer little to no comprehensible explanation to the logic behind its decisions aside from the data and type of algorithm used.

KEYWORDS: Dendral, Mycin, Internist-1 and Casnet, CT, MR, icometrix, QUIBIM, Robovision, IMAGRT, ANN, BN, Telemedicine, HER, NLP, OCD, GENTRL, HEALS, UBTECH, BCI, GDPR, HIPPA, Automation.

INTRODUCTION

The primary aim of health-related AI applications is to analyze relationships between prevention or treatment techniques and patient outcomes. AI programs are applied to practices such as diagnosis processes, treatment protocol development, drug development, personalized medicine, and patient monitoring and care. AI algorithms can also be used to analyze large amounts of data through electronic health records for disease prevention and diagnosis. Medical institutions such as The Mayo Clinic, Memorial Sloan Kettering Cancer Center, and the British National Health Service, have developed AI algorithms for their departments. Large technology companies such as IBM and Google, have also developed AI algorithms for healthcare. Additionally, hospitals are looking to AI software to support operational initiatives that increase cost saving, improve patient satisfaction, and satisfy their staffing and workforce needs. Currently, the United States government is investing billions of dollars to progress the development of AI in healthcare. Companies are developing technologies that help healthcare managers improve business operations through increasing utilization, decreasing patient boarding, reducing length of stay and optimizing staffing levels.[1]

As widespread use of AI in healthcare is relatively new, there are several unprecedented ethical concerns related to its practice such as data privacy, automation of jobs, and representation biases.

History: Research in the 1960s and 1970s produced the first problem-solving program, or expert system, known as Dendral. While it was designed for applications in organic chemistry, it provided the basis for a subsequent system MYCIN, considered one of the most significant early uses of artificial intelligence in medicine. MYCIN and other systems such as INTERNIST-1 and CASNET did not achieve routine use by practitioners, however.

The 1980s and 1990s brought the proliferation of the microcomputer and new levels of network connectivity. During this time, there was a recognition by researchers and developers that AI systems in healthcare must be designed to accommodate the absence of perfect data and build on the expertise of physicians. Approaches involving fuzzy set theory, Bayesian networks, and artificial neural networks, have been applied to intelligent computing systems in healthcare.

Medical and technological advancements occurring over this half-century period that have enabled the growth healthcare-related applications of AI include:

1. Improvements in computing power resulting in faster data collection and data processing
2. Growth of genomic sequencing databases
3. Widespread implementation of electronic health record systems
4. Improvements in natural language processing and computer vision, enabling machines to replicate human perceptual processes
5. Enhanced the precision of robot-assisted surgery
6. Improvements in deep learning techniques and data logs in rare diseases

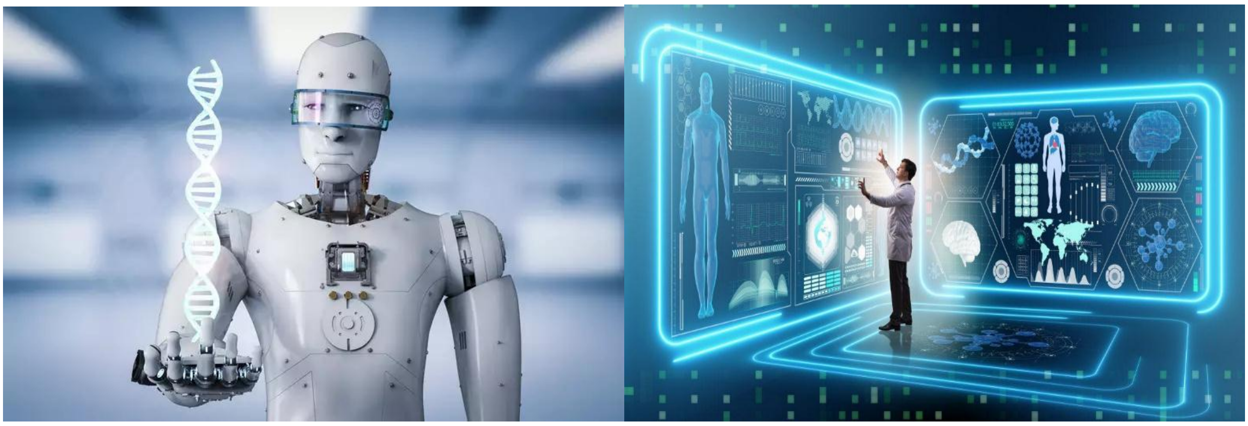

Figure-1: Artificial Intelligence.

Current research: Various specialties in medicine have shown an increase in research regarding AI. As the novel coronavirus ravages through the globe, the United States is estimated to invest more than $2 billion in AI related healthcare research over the next 5 years, more than 4 times the amount spent in 2019 ($463 million).

Dermatology: Dermatology is an imaging abundant specialty and the development of deep learning has been strongly tied to image processing. Therefore, there is a natural fit between the dermatology and deep learning. There are 3 main imaging types in dermatology: contextual images, macro images, micro images. For each modality, deep learning showed great progress. Han et. al. showed keratinocytic skin cancer detection from face photographs.[2]

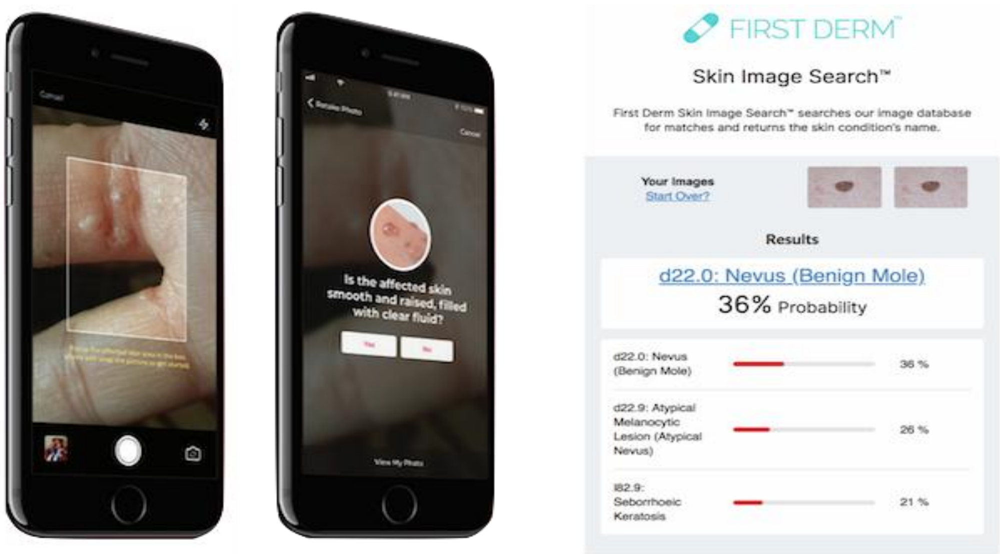

Figure-2: Artificial Intelligence In Dermatology.

Esteva et al. demonstrated dermatologist-level classification of skin cancer from lesion images. Noyan et. al. demonstrated a convolutional neural network that achieved 94% accuracy at identifying skin cells from microscopic Tzanck smear images.

Radiology: AI is being studied within the radiology field to detect and diagnose diseases within patients through Computerized Tomography (CT) and Magnetic Resonance (MR) Imaging. The focus on Artificial Intelligence in radiology has rapidly increased in recent years according to the Radiology Society of North America, where they have seen growth from 0 to 3, 17, and overall, 10% of total publications from 2015-2018 respectively. A study at Stanford created an algorithm that could detect pneumonia in patients with a better average F1 metric (a statistical metric based on accuracy and recall), than radiologists involved in the trial. Through imaging in oncology, AI has been able to serve well for detecting abnormalities and monitoring change over time; two key factors in oncological health. Many companies and vendor neutral systems such as icometrix, QUIBIM, Robovision, and UMC Utrecht's IMAGRT have become available to provide a trainable machine learning platform to detect a wide range of diseases. The Radiological Society of North America has implemented presentations on AI in imaging during its annual conference. Many professionals are optimistic about the future of AI processing in radiology, as it will cut down on needed interaction time and allow doctors to see more patients. Although not always as good as a trained eye at deciphering malicious or benign growths, the history of medical imaging shows a trend toward rapid advancement in both capability and reliability of new systems.[3]

Figure-3: Artificial Intelligence In Radiology.

The emergence of AI technology in radiology is perceived as a threat by some specialists, as it can improve by certain statistical metrics in isolated cases, where specialists cannot.

Screening

Figure-4: Artificial Intelligence In Screening.

Recent advances have suggested the use of AI to describe and evaluate the outcome of maxillo-facial surgery or the assessment of cleft palate therapy in regard to facial attractiveness or age appearance.

In 2018, a paper published in the journal Annals of Oncology mentioned that skin cancer could be detected more accurately by an artificial intelligence system (which used a deep learning convolutional neural network) than by dermatologists. On average, the human dermatologists accurately detected 86.6% of skin cancers from the images, compared to 95% for the CNN machine.

In January 2020 researchers demonstrate an AI system, based on a Google DeepMind algorithm, that is capable of surpassing human experts in breast cancer detection.

In July 2020 it was reported that an AI algorithm by the University of Pittsburgh achieves the highest accuracy to date in identifying prostate cancer, with 98% sensitivity and 97% specificity.

Psychiatry: In psychiatry, AI applications are still in a phase of proof-of-concept. Areas where the evidence is widening quickly include chatbots, conversational agents that imitate human behaviour and which have been studied for anxiety and depression. Challenges include the fact that many applications in the field are developed and proposed by private corporations, such as the screening for suicidal ideation implemented by Facebook in 2017. Such applications outside the healthcare system raise various professional, ethical and regulatory questions.

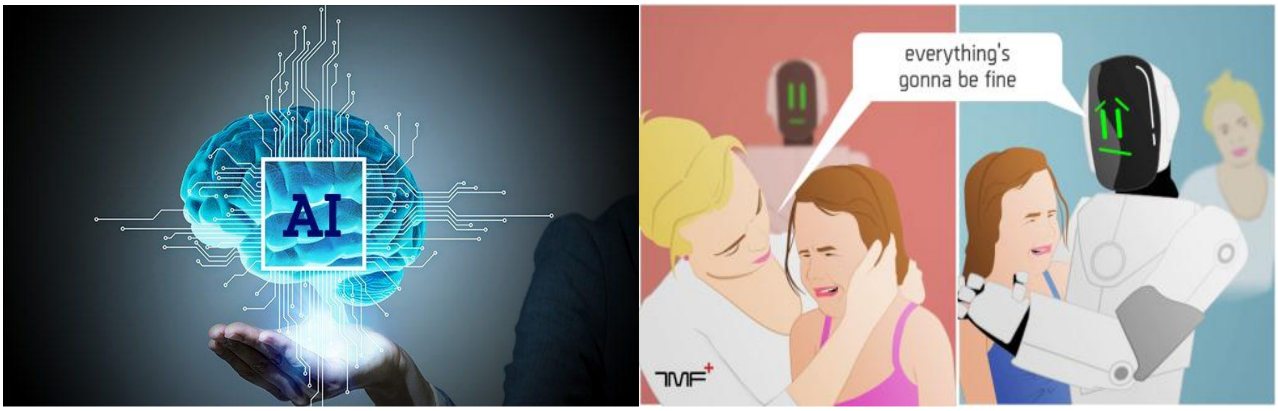

Figure-5: AI In Psychiatry.

Primary care: Primary care has become one key development area for AI technologies. AI in primary care has been used for supporting decision making, predictive modelling, and business analytics. Despite the rapid advances in AI technologies, general practitioners' view on the role of AI in primary care is very limited–mainly focused on administrative and routine documentation tasks.[4]

Disease diagnosis: An article by Jiang, et al. (2017) demonstrated that there are several types of AI techniques that have been used for a variety of different diseases, such as support vector machines, neural networks, and decision trees. Each of these techniques is described as having a "training goal" so "classifications agree with the outcomes as much as possible.

Figure-6: AI In Disease Diagnosis.

To demonstrate some specifics for disease diagnosis/classification there are two different techniques used in the classification of these diseases include using "Artificial Neural Networks (ANN) and Bayesian Networks (BN)". It was found that ANN was better and could more accurately classify diabetes and CVD.

Through the use of Medical Learning Classifiers (MLC's), Artificial Intelligence has been able to substantially aid doctors in patient diagnosis through the manipulation of mass Electronic Health Records (EHR's). Medical conditions have grown more complex, and with a vast history of electronic medical records building, the likelihood of case duplication is high. Although someone today with a rare illness is less likely to be the only person to have suffered from any given disease, the inability to access cases from similarly symptomatic origins is a major roadblock for physicians. The implementation of AI to not only help find similar cases and treatments, but also factor in chief symptoms and help the physicians ask the most appropriate questions helps the patient receive the most accurate diagnosis and treatment possible.

Telemedicine: The increase of telemedicine, the treatment of patients remotely, has shown the rise of possible AI applications. AI can assist in caring for patients remotely by monitoring their information through sensors. A wearable device may allow for constant monitoring of a patient and the ability to notice changes that may be less distinguishable by humans. The information can be compared to other data that has already been collected using artificial intelligence algorithms that alert physicians if there are any issues to be aware of. Another application of artificial intelligence is in chat-bot therapy. Some researchers charge that the reliance on chat-bots for mental healthcare does not offer the reciprocity and accountability of care that should exist in the relationship between the consumer of mental healthcare and the care provider (be it a chat-bot or psychologist), though.

Figure-7: AI In Telemedicine.

Since the average age has risen due to a longer life expectancy, artificial intelligence could be useful in helping take care of older populations. Tools such as environment and personal sensors can identify a person's regular activities and alert a caretaker if a behavior or a measured vital is abnormal. Although the technology is useful, there are also discussions about limitations of monitoring in order to respect a person's privacy since there are technologies that are designed to map out home layouts and detect human interactions.[5]

Electronic health records: Electronic health records (EHR) are crucial to the digitalization and information spread of the healthcare industry. Now that around 80% of medical practices use EHR, the next step is to use artificial intelligence to interpret the records and provide new information to physicians. One application uses natural language processing (NLP) to make more succinct reports that limit the variation between medical terms by matching similar medical terms. For example, the term heart attack and myocardial infarction mean the same things, but physicians may use one over the over based on personal preferences. NLP algorithms consolidate these differences so that larger datasets can be analyzed. Another use of NLP identifies phrases that are redundant due to repetition in a physician's notes and keeps the relevant information to make it easier to read.

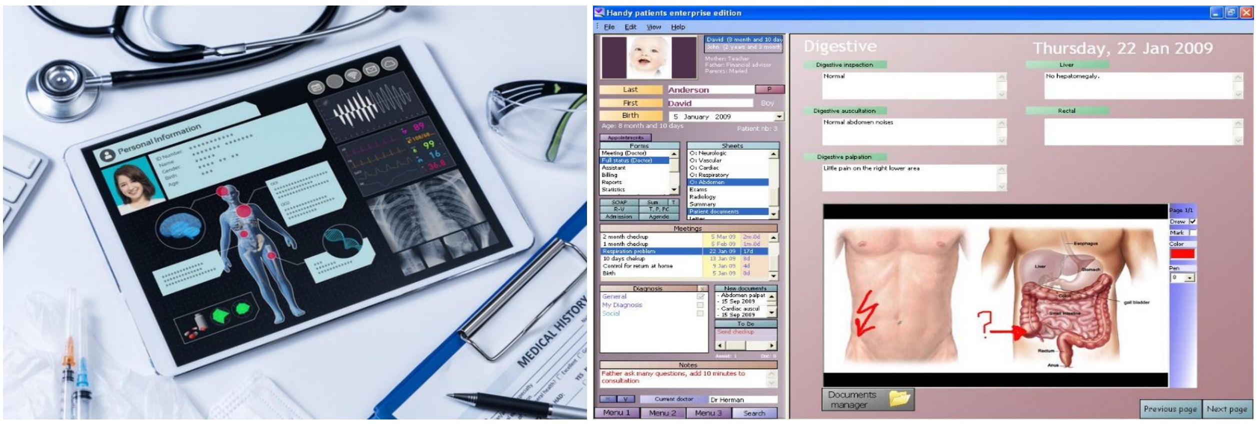

Figure-8: Electronic Health Record.

Beyond making content edits to an EHR, there are AI algorithms that evaluate an individual patient's record and predict a risk for a disease based on their previous information and family history. One general algorithm is a rule-based system that makes decisions similarly to how humans use flow charts. This system takes in large amounts of data and creates a set of rules that connect specific observations to concluded diagnoses. Thus, the algorithm can take in a new patient's data and try to predict the likeliness that they will have a certain condition or disease. Since the algorithms can evaluate a patient's information based on collective data, they can find any outstanding issues to bring to a physician's attention and save time. One study conducted by the Centerstone research institute found that predictive modeling of EHR data has achieved 70–72% accuracy in predicting individualized treatment response. These methods are helpful due to the fact that the amount of online health records doubles every five years. Physicians do not have the bandwidth to process all this data manually, and AI can leverage this data to assist physicians in treating their patients.

Drug Interactions: Improvements in natural language processing led to the development of algorithms to identify drug-drug interactions in medical literature. Drug-drug interactions pose a threat to those taking multiple medications simultaneously, and the danger increases with the number of medications being taken. To address the difficulty of tracking all known or suspected drug-drug interactions, machine learning algorithms have been created to extract information on interacting drugs and their possible effects from medical literature. Efforts were consolidated in 2013 in the DDI Extraction Challenge, in which a team of researchers at Carlos III University assembled a corpus of literature on drug-drug interactions to form a standardized test for such algorithms.[6]

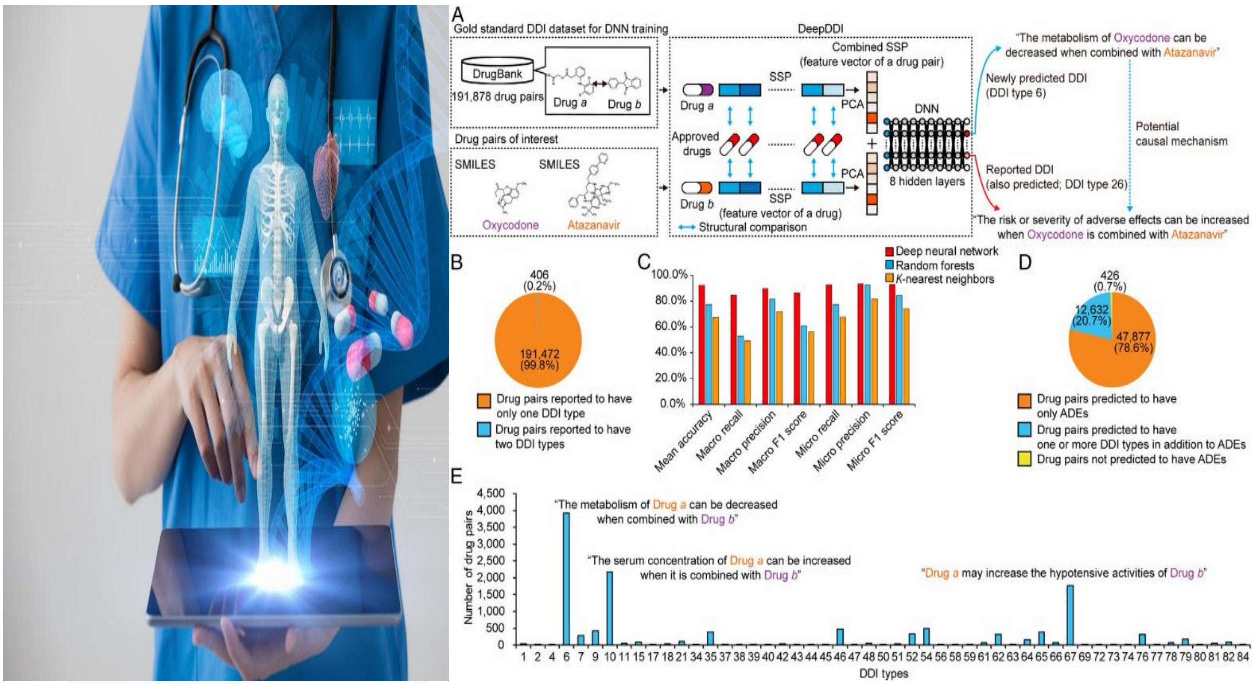

Figure-9: AI In Drug Interactions.

Competitors were tested on their ability to accurately determine, from the text, which drugs were shown to interact and what the characteristics of their interactions were. Researchers continue to use this corpus to standardize the measurement of the effectiveness of their algorithms. Other algorithms identify drug-drug interactions from patterns in user-generated content, especially electronic health records and/or adverse event reports. Organizations such as the FDA Adverse Event Reporting System (FAERS) and the World Health Organization's VigiBase allow doctors to submit reports of possible negative reactions to medications. Deep learning algorithms have been developed to parse these reports and detect patterns that imply drug-drug interactions.

Creation of new drugs: DSP-1181, a molecule of the drug for OCD (obsessive-compulsive disorder) treatment, was invented by artificial intelligence through joint efforts of Exscientia (British start-up) and Sumitomo Dainippon Pharma (Japanese pharmaceutical firm). The drug development took a single year, while pharmaceutical companies usually spend about five years on similar projects. DSP-1181 was accepted for a human trial.

Figure-10: AI in Drug Discovery and Development.

In September 2019 Insilico Medicine reports the creation, via artificial intelligence, of six novel inhibitors of the DDR1 gene, a kinase target implicated in fibrosis and other diseases. The system, known as Generative Tensorial Reinforcement Learning (GENTRL), designed the new compounds in 21 days, with a lead candidate tested and showing positive results in mice.

The same month Canadian company Deep Genomics announces that its AI-based drug discovery platform has identified a target and drug candidate for Wilson's disease. The candidate, DG12P1, is designed to correct the exon-skipping effect of Met645Arg, a genetic mutation affecting the ATP7B copper-binding protein.[7]

Industry: The trend of large health companies merging allows for greater health data accessibility. Greater health data lays the groundwork for implementation of AI algorithms.

A large part of industry focus of implementation of AI in the healthcare sector is in the clinical decision support systems. As more data is collected, machine learning algorithms adapt and allow for more robust responses and solutions. Numerous companies are exploring the possibilities of the incorporation of big data in the healthcare industry. Many companies investigate the market opportunities through the realms of "data assessment, storage, management, and analysis technologies" which are all crucial parts of the healthcare industry.

The following are examples of large companies that have contributed to AI algorithms for use in healthcare:

- IBM's Watson Oncology is in development at Memorial Sloan Kettering Cancer Center and Cleveland Clinic. IBM is also working with CVS Health on AI applications in chronic disease treatment and with Johnson & Johnson on analysis of scientific papers to find new connections for drug development. In May 2017, IBM and Rensselaer Polytechnic Institute began a joint project entitled Health Empowerment by Analytics, Learning and Semantics (HEALS), to explore using AI technology to enhance healthcare.
- Microsoft's Hanover project, in partnership with Oregon Health & Science University's Knight Cancer Institute, analyzes medical research to predict the most effective cancer drug treatment options for patients. Other projects include medical image analysis of tumor progression and the development of programmable cells.
- Google's DeepMind platform is being used by the UK National Health Service to detect certain health risks through data collected via a mobile app. A second project with the NHS involves analysis of medical images collected from NHS patients to develop computer vision algorithms to detect cancerous tissues.
- Tencent is working on several medical systems and services. These include AI Medical Innovation System (AIMIS), an AI-powered diagnostic medical imaging service; WeChat Intelligent Healthcare; and Tencent Doctorwork
- Intel's venture capital arm Intel Capital recently invested in startup Lumiata which uses AI to identify at-risk patients and develop care options.
- Kheiron Medical developed deep learning software to detect breast cancers in mammograms.
- Fractal Analytics has incubated Qure.ai which focuses on using deep learning and AI to improve radiology and speed up the analysis of diagnostic x-rays.

- Neuralink has come up with a next generation neuroprosthetic which intricately interfaces with thousands of neural pathways in the brain. Their process allows a chip, roughly the size of a quarter, to be inserted in place of a chunk of skull by a precision surgical robot to avoid accidental injury.

Figure-11: Surgical Robot.

Digital consultant apps like Babylon Health's GP at Hand, Ada Health, AliHealth Doctor You, KareXpert and Your.MD use AI to give medical consultation based on personal medical history and common medical knowledge. Users report their symptoms into the app, which uses speech recognition to compare against a database of illnesses. Babylon then offers a recommended action, taking into account the user's medical history. Entrepreneurs in healthcare have been effectively using seven business model archetypes to take AI solution[buzzword] to the marketplace. These archetypes depend on the value generated for the target user (e.g. patient focus vs. healthcare provider and payer focus) and value capturing mechanisms (e.g. providing information or connecting stakeholders).

IFlytek launched a service robot “Xiao Man”, which integrated artificial intelligence technology to identify the registered customer and provide personalized recommendations in medical areas. It also works in the field of medical imaging. Similar robots are also being made by companies such as UBTECH ("Cruzr") and Softbank Robotics ("Pepper"). The Indian startup Haptik recently developed a WhatsApp chatbot which answers questions associated with the deadly coronavirus in India.

With the market for AI expanding constantly, large tech companies such as Apple, Google, Amazon, and Baidu all have their own AI research divisions, as well as millions of dollars allocated for acquisition of smaller AI based companies. Many automobile manufacturers are beginning to use machine learning healthcare in their cars as well. Companies such as BMW, GE, Tesla, Toyota, and Volvo all have new research campaigns to find ways of learning a driver's vital statistics to ensure they are awake, paying attention to the road, and not under the influence of substances or in emotional distress.[8]

Implications: The use of AI is predicted to decrease medical costs as there will be more accuracy in diagnosis and better predictions in the treatment plan as well as more prevention of disease. Other future uses for AI include Brain-computer Interfaces (BCI) which are predicted to help those with trouble moving, speaking or with a spinal cord injury. The BCIs will use AI to help these patients move and communicate by decoding neural activates. Artificial intelligence has led to significant improvements in areas of healthcare such as medical imaging, automated clinical decision-making, diagnosis, prognosis, and more. Although AI possesses the capability to revolutionize several fields of medicine, it still has limitations and cannot replace a bedside physician. Healthcare is a complicated science that is bound by legal, ethical, regulatory, economical, and social constraints. In order to fully implement AI within healthcare, there must be "parallel changes in the global environment, with numerous stakeholders, including citizen and society."

Expanding care to developing nations: Artificial intelligence continues to expand in its abilities to diagnose more people accurately in nations where fewer doctors are accessible to the public. Many new technology companies such as SpaceX and the Raspberry Pi Foundation have enabled more developing countries to have access to computers and the internet than ever before. With the increasing capabilities of AI over the internet, advanced machine learning algorithms can allow patients to get accurately diagnosed when they would previously have no way of knowing if they had a life-threatening disease or not.

Using AI in developing nations who do not have the resources will diminish the need for outsourcing and can improve patient care. AI can allow for not only diagnosis of patient is areas where healthcare is scarce, but also allow for a good patient experience by resourcing files to find the best treatment for a patient. The ability of AI to adjust course as it goes also allows the patient to have their treatment modified based on what works for them; a level of individualized care that is nearly non-existent in developing countries.

Regulation: While research on the use of AI in healthcare aims to validate its efficacy in improving patient outcomes before its broader adoption, its use may nonetheless introduce several new types of risk to patients and healthcare providers, such as algorithmic bias, Do not resuscitate implications, and other machine morality issues. These challenges of the clinical use of AI have brought upon potential need for regulations. Currently, there are regulations pertaining to the collection of patient data. This includes policies such as the Health Insurance Portability and Accountability Act (HIPPA) and the European General Data Protection Regulation (GDPR). The GDPR pertains to patients within the EU and details the consent requirements for patient data use when entities collect patient healthcare data. Similarly, HIPPA protects healthcare data from patient records in the United States. In May 2016, the White House announced its plan to host a series of workshops and formation of the National Science and Technology Council (NSTC) Subcommittee on Machine Learning and Artificial Intelligence. In October 2016, the group published The National Artificial Intelligence Research and Development Strategic Plan, outlining its proposed priorities for Federally-funded AI research and development (within government and academia). The report notes a strategic R&D plan for the subfield of health information technology is in development stages. The only agency that has expressed concern is the FDA. Bakul Patel, the Associate Center Director for Digital Health of the FDA, is quoted saying in May 2017: "We're trying to get people who have hands-on development experience with a product's full life cycle. We already have some scientists who know artificial intelligence and machine learning, but we want complementary people who can look forward and see how this technology will evolve."

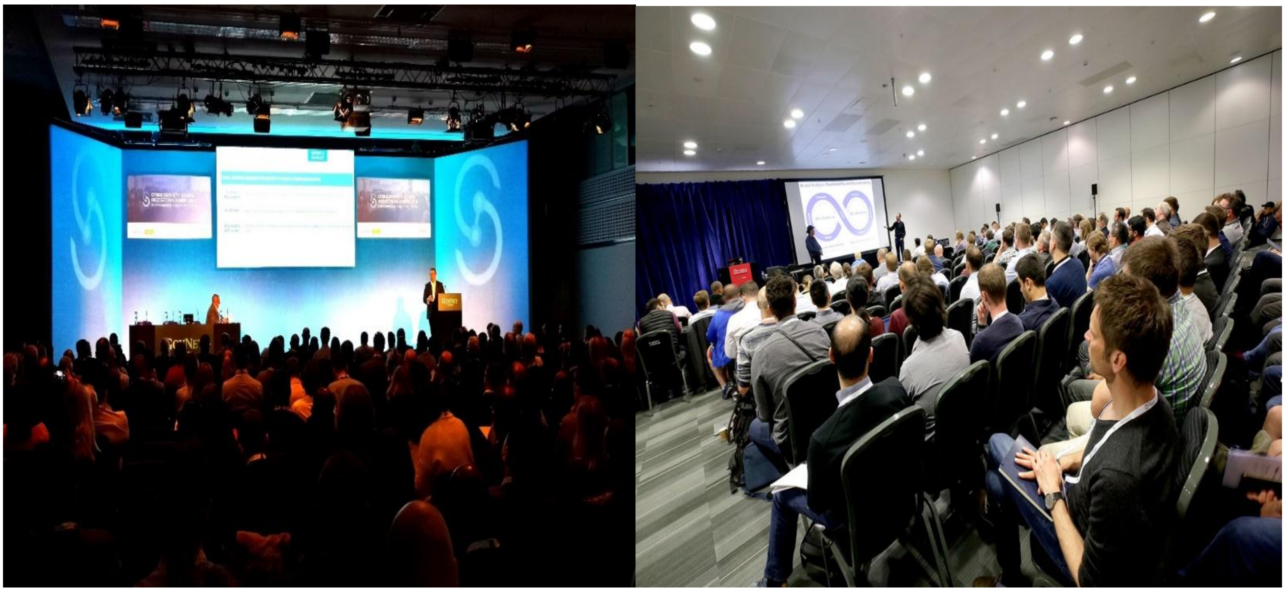

Figure-12: AI In Medical Seminar.

The joint ITU-WHO Focus Group on Artificial Intelligence for Health (FG-AI4H) has built a platform for the testing and benchmarking of AI applications in health domain. As of November 2018, eight use cases are being benchmarked, including assessing breast cancer risk from histopathological imagery, guiding anti-venom selection from snake images, and diagnosing skin lesions.[9]

Ethical concerns

Data collection: In order to effectively train Machine Learning and use AI in healthcare, massive amounts of data must be gathered. Acquiring this data, however, comes at the cost of patient privacy in most cases and is not well received publicly. For example, a survey conducted in the UK estimated that 63% of the population is uncomfortable with sharing their personal data in order to improve artificial intelligence technology. The scarcity of real, accessible patient data is a hindrance that deters the progress of developing and deploying more artificial intelligence in healthcare.

Automation: According to a recent study, AI can replace up to 35% of jobs in the UK within the next 10 to 20 years. However, of these jobs, it was concluded that AI has not eliminated any healthcare jobs so far. Though if AI were to automate healthcare related jobs, the jobs most susceptible to automation would be those dealing with digital information, radiology, and pathology, as opposed to those dealing with doctor to patient interaction.

Automation can provide benefits alongside doctors as well. It is expected that doctors who take advantage of AI in healthcare will provide greater quality healthcare than doctors and medical establishments who do not. AI will likely not completely replace healthcare workers but rather give them more time to attend to their patients. AI may avert healthcare worker burnout and cognitive overload. AI will ultimately help contribute to progression of societal goals which include better communication, improved quality of healthcare, and autonomy.[10]

CONCLUSION

Since AI makes decisions solely on the data it receives as input, it is important that this data represents accurate patient demographics. In a hospital setting, patients do not have full knowledge of how predictive algorithms are created or calibrated. Therefore, these medical establishments can unfairly code their algorithms to discriminate against minorities and prioritize profits rather than providing optimal care. There can also be unintended bias in these algorithms that can exacerbate social and healthcare inequities. Since AI's decisions are a direct reflection of its input data, the data it receives must have accurate representation of patient demographics. White males are overly represented in medical data sets. Therefore, having minimal patient data on minorities can lead to AI making more accurate predictions for majority populations, leading to unintended worse medical outcomes for minority populations. Collecting data from minority communities can also lead to medical discrimination. For instance, HIV is a prevalent virus among minority communities and HIV status can be used to discriminate against patients. However, these biases are able to be eliminated through careful implementation and a methodical collection of representative data.

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