Artificial Intelligence and Healthcare in India

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Nirupam Bajpai and Manisha Wadhwa

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Abstract

Artificial Intelligence (AI), also referred to as the new electricity, is the emerging focus area in India. AI refers to the ability of machines to perform cognitive tasks like thinking, perceiving, learning, problem solving and decision making. Most of the AI systems rely on historical large datasets for predicting future trends and outcomes at a pace which humans would not be able to match. The development of AI in India is in the initial stages and there is no regulatory body focused solely on AI. However, recently, Government of India has taken various initiatives related to AI such as establishment of Artificial Intelligence Task Force, formulation of NITI Aayog's National Strategy for Artificial Intelligence #AIFORALL, setting up of four Committees for AI under Ministry of Electronics and Information technology etc. Some of India's state governments have also taken few initiatives, such as establishment of Centre of Excellence for Data Science and Artificial Intelligence (CoE-DS&AI) by Karnataka, Safe and Ethical Artificial Intelligence Policy 2020 and Face Recognition Attendance System by Tamil Nadu, AI-Powered System for monitoring driving behaviour by West Bengal, AI System to fight agricultural risks by Maharashtra etc. As with any other technology, AI brings with it a span of opportunities and challenges.

In healthcare, AI could be beneficial in mining medical records; designing treatment plans; forecasting health events; assisting repetitive jobs; doing online consultations; assisting in clinical decision making; medication management; drug creation; making healthier choices and decisions; and solving public health problems etc. AI could be very helpful in areas where there is scarcity of human resources, such as rural and remote areas. AI technology has been helpful in dealing with COVID-19 in India. It has helped in preliminary screening of COVID-19 cases, containment of coronavirus, contact tracing, enforcing quarantine and social distancing, tracking of suspects, tracking the pandemic, treatment and remote monitoring of COVID-19 patients, vaccine and drug development etc. The path for adoption of AI driven healthcare in India is filled with a lot of challenges. The unstructured data sets, interoperability issues, lack of open sets of medical data, inadequate analytics solutions which could work with big data, limited funds, inadequate infrastructure, lack of manpower skilled in AI, regulatory weaknesses, inadequate framework and issues related to data protection are some of the key challenges for AI-driven healthcare.

It is recommended that government should support companies to invest in AI; encourage public private partnerships in the domain of AI and Health; enact and effectively enforce laws and legislation related to AI and Health; frame policies addressing issues related to confidentiality and privacy in the AI-driven healthcare; and establish a certification system for AI-based healthcare solutions. To adopt AI-based healthcare, it is important to train workforce in AI so that they can carefully handle sensitive health information, protect data against theft and use AI systems effectively. It is also crucial that healthcare decisions based on AI solutions should have a rationale and are explainable.

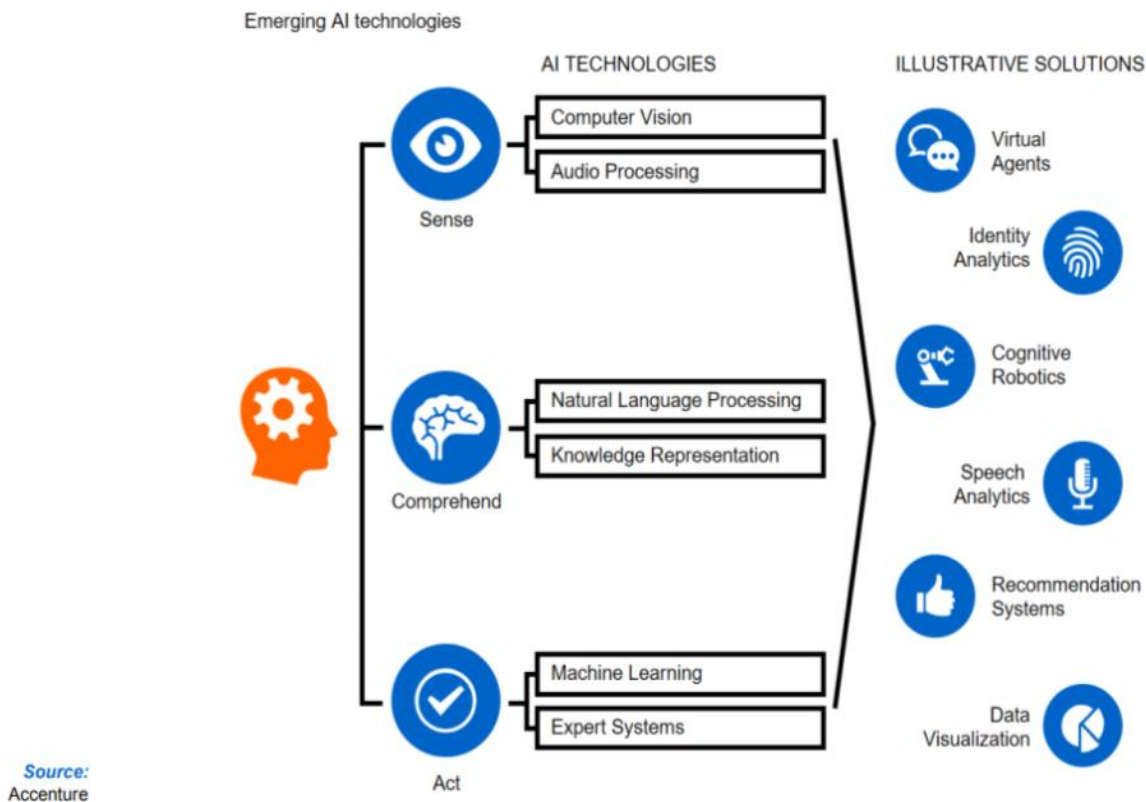Keywords: Artificial Intelligence, India, COVID-19, initiatives, applications

Introduction

As per Stanford Professor John Mc McCarthy, who coined the term Artificial Intelligence in the year 1955, Artificial Intelligence(AI) is defined as "the science and engineering of making intelligent machines, especially intelligent computer programs."(McCarthy 2007)

"AI refers to the ability of machines to perform cognitive tasks like thinking, perceiving, learning, problem solving and decision making."(NITI Aayog, Government of India 2018)

Artificial Intelligence is the new general purpose technology (GPT) which is capable of revolutionizing virtually every sector(Bajpai, Biberman, and Yip Yingxin 2020). Artificial Intelligence not only complements human labor, but is a substitute for it altogether. Over the next few decades, AI would take over "human" tasks like logical reasoning, creativity in design, business management etc.

Figure 1: What is Artificial Intelligence?

Source: NITI Aayog, Government of India. 2018. "National Strategy for Artificial Intelligence #AIFORALL."
https://niti.gov.in/writereaddata/files/document_publication/NationalStrategy-for-AI-Discussion-Paper.pdf

Types of AI

There are three types of Artificial Intelligence: Artificial narrow intelligence (ANI), artificial general intelligence and artificial super intelligence(Wikipedia 2020a; Marda 2018) (see Figure 2).

Figure 2: Types of Artificial Intelligence

Artificial narrow intelligence (ANI)	Non-sentient machine intelligence, typically focused on a narrow task (narrow AI).
Artificial general intelligence	(Hypothetical) machine with the ability to apply intelligence to any problem, rather than just one specific problem, typically meaning "at least as smart as a typical human".
Artificial super intelligence	(Hypothetical) artificial intelligence far surpassing that of the brightest and most gifted human minds. The idea that computers can surpass human intelligence, social skills and scientific knowledge across domains.

Source: Wikipedia. 2020a. "Outline of Artificial Intelligence." 2020.
https://en.wikipedia.org/wiki/Outline_of_artificial_intelligence
Marda, Vidushi. 2018. "Artificial Intelligence Policy in India: A Framework for Engaging the Limits of Data-Driven Decision-Making." *The Royal Society* 376 (2133).
https://doi.org/10.1098/rsta.2018.0087

There are different subfields of AI. Some of them are described in Table 1(Wahl et al. 2018).

Table 1: Subfields of Artificial Intelligence (AI)

Expert System	It is also referred as knowledge-based system. It is a type of AI program that has expert-level competence and can solve specific problems. For instance, fuzzy logic systems for detection of chronic health conditions or prediction of cholera outbreak.
Machine Learning	It is a subfield and an application of AI. It is a method that iteratively identifies pattern in the data by automating data analysis using algorithms.
Natural language processing (NLP)	This subfield of AI helps in the identification of key words and phrases in natural language corpora such as unstructured written text.
Automated planning and scheduling	This new branch of AI is also referred as AI Planning. It helps in organising and prioritising the activities to achieve a desired goal.
Image and signal processing	Image and signal processing algorithms help in processing large amounts of data from images and signals (such as motion and sound).

Source: Wahl, Brian, Aline Cossy-Gantner, Stefan Germann, and Nina R Schwalbe. 2018. "Artificial Intelligence (AI) and Global Health: How Can AI Contribute to Health in Resource-Poor Settings?" *BMJ Global Health* 3 (4): e000798.
https://doi.org/10.1136/bmjgh-2018-000798

Artificial Intelligence policy landscape in India

The development of AI in India has been a fragmented process. Under the umbrella of Digital India Initiative, the Government of India plans to invest funding in the areas of emerging technologies such as Artificial Intelligence(Ministry of Electronics & Information Technology, Government of India 2020). There is no single regulatory body in India which is focused solely on AI, however a number of initiatives has been taken. Some of these are discussed below:

Artificial Intelligence Task Force

The Ministry of Commerce and Industry under Government of India established the task force for Artificial Intelligence on 25th August 2017[1]. Figure 3 highlights the vision, mission and domains of focus of Artificial Intelligence Task force.

Figure 3: The vision, mission and Domains of Focus of Artificial Intelligence Task Force

Vision   • Embed AI in our Economic, Political and Legal thought processes so that there is systemic capability to support the goal of India becoming one of the leaders of AI-rich economies
Mission   • Leverage AI for Economic Benefits   • Creation of policy and legal framework to accelerate deployment of AI technologies   • Concrete 5 year horizon recommendations for specific Government, Industry and Research programs
Domains of Focus   • Manufacturing   • Fintech   • Healthcare   • Agriculture/Food Processing   • Education   • Retail/Customer Engagement   • Human and Robot interaction/intelligent automation   • Aid for Differently Abled/Accessibility Technology

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[1] The Task Force consists of 18 members in total. Of these, 11 members are from the field of AI technology both research and industry, three from the civil services, one from healthcare research, one with and Intellectual property law background, and two from a finance background. The specializations of the members are not limited to one area as the members have experience or education in various areas relevant to AI. https://www.aitf.org.in/. There is a notable lack of members from Civil Society. It may also be noted that only 2 of the 18 members are women

- AADHAAR/Big Data

- Environment

- National Security

- Enablers for AI Technology development

- Enablers for AI entrepreneurship

- Enablers for AI product commercialization

- General/other issues related to AI

- Public Utility Services

Source: Department for Promotion of Industry and Internal Trade, MoCI, GoI. 2018. "The
    Artificial Intelligence Task Force."
    https://dipp.gov.in/sites/default/files/Report_of_Task_Force_on_ArtificialIntelligence_20
    March2018_2.pdf

The Artificial Intelligence Task Force submitted its report on March 21st 2018(Department for
Promotion of Industry and Internal Trade, MoCI, GoI 2018). The task force has made specific
recommendations to Government of India. Some of the key recommendations are highlighted in
Figure 4.

Figure 4: Key recommendations by the Artificial Intelligence Task Force

Recommendations

- Creation of an Inter-Ministerial National Artificial Intelligence Mission(N-AIM) as a nodal
  agency for coordinating AI related activities in India, under union budget of INR1200 crores
  over a period of five years;
- Establishment of digital data banks, marketplaces and exchanges to ensure availability of
  cross-industry data and information for AI-applications, with the requisite sharing related
  regulations;
- Establishment of standards for the design, development and deployment of AI-based systems;
- Establishment of enablers to boost AI based development including data sharing policies and
  tax and other incentives;
- Establishment of AI-based curriculums; AI-related education and re-skilling; and
- Leveraging key international relationships and participation in AI based international
  standards setting discussions.

Source: Department for Promotion of Industry and Internal Trade, MoCI, GoI. 2018. "The
    Artificial Intelligence Task Force."
    https://dipp.gov.in/sites/default/files/Report_of_Task_Force_on_ArtificialIntelligence_20
    March2018_2.pdf.

NITI Aayog's National Strategy for Artificial Intelligence: #AIFORALL
In the budget speech 2018-2019, the Hon'ble Finance Minister of India mandated NITI Aayog to
establish a national program on Artificial Intelligence with a view to guide research and

development in emerging technologies. A three-pronged approach was adopted by NITI Aayog-i) carrying out exploratory proof-of-concept AI projects in various areas such as agriculture, health etc.; ii) designing a national strategy to build a vibrant AI ecosystem in India and iii) collaboration with experts and stakeholders. In June 2018, NITI Aayog has put forward a discussion paper on the National strategy for Artificial Intelligence #AIforAll(NITI Aayog, Government of India 2018).

"#AIforAll will aim at enhancing and empowering human capabilities to address the challenges of access, affordability, shortage and inconsistency of skilled expertise; effective implementation of AI initiatives to evolve scalable solutions for emerging economies; and endeavors to tackle some of the global challenges from AI's perspective, be it application, research, development, technology, or responsible AI. #AIforAll will focus on harnessing collaborations and partnerships, and aspires to ensure prosperity for all. Thus, #AIforAll means technology leadership in AI for achieving the greater good."(NITI Aayog, Government of India 2018)

NITI Aayog identifies five primary sectors: education, agriculture, healthcare, smart cities and infrastructure, and smart mobility and transportation, where AI could benefit the most in solving the societal needs. The discussion paper on the National strategy for Artificial Intelligence #AIforAll proposes two institutions:1) **Centers of Research Excellence (CORE),** which would focus on core research on AI, consolidate existing research and generate new knowledge to facilitate technological advancements; and 2**) International Center of Transformational AI (ICTAI)**, which would provide an ecosystem for both development and deployment of applied research. These two institutions would operate under an umbrella organization the '**Centre for Studies on Technological Sustainability (CSTS)**' which would focus on issues related to finance, social sustainability and global competitiveness of the AI technologies developed.

Four Committees for AI under Ministry of Electronics and Information Technology
In February 2018, the Union Ministry of Electronics and Information Technology has set up four committees to prepare a roadmap for establishing a national AI programme(Marda 2018; Agarwal 2018; Ministry of Electronics and Information Technology, Government of India 2018). The four committees are as below:

   a. Committee on Platforms and Data for AI
   b. Committee on Leveraging AI for identifying National Missions in Key Sectors
   c. Committee on Mapping Technological capabilities, key policy enablers required across sectors, skilling & re-skilling, R&D
   d. Committee on Cyber Security, Safety, Legal and Ethical Issues

INDIAai -The National AI Portal of India
INDIAai is a joint venture by the Ministry of Electronics and Information Technology(MeitY), the National E-Governance Division (NeGD) and the National Association of Software and Service Companies (NASSCOM). It was launched by the Indian Government on 1st June 2020(Advani 2020).It has been set up with the vision to prepare the nation for an AI future. "It is the single central knowledge hub on artificial intelligence and allied fields for aspiring

entrepreneurs, students, professionals, academics, and everyone else. The portal focuses on creating and nurturing a unified AI ecosystem for driving excellence and leadership in India's AI journey, to foster economic growth and improve lives through it"(Ministry of Electronics and Information Technology, Government of India 2020). The objective of this one-stop platform for AI is to allow(Advani 2020)

- Sharing of useful AI resources like technical papers and articles, and funding information for AI start-ups, companies, and educational firms
- Distribution of documents, case studies, research reports
- Learning opportunities
- New job roles and job postings in the domain of AI

*"AI will unlock the unique potential of each person and will empower them to contribute more effectively to the society" (*Hon'ble Prime Minister Narendra Modi*)(Ministry of Electronics and Information Technology, Government of India 2020)

*"We welcome AI because it has enormous potential for development and also bring in further equity and delivery"(*Hon'ble Minister Ravi Shankar Prasad*)(Ministry of Electronics and Information Technology, Government of India 2020)

International Center for Transformative Artificial Intelligence (ICTAI)
On 11 September 2020, NITI Aayog, Intel and Tata Institute of Fundamental Research (TIFR) announced a collaboration to establish a model International Center for Transformative Artificial Intelligence (ICTAI) in Bangalore, India (INDIAai 2020a; Intel Blog Admin 2018). The center will focus on AI based research projects in three important areas: healthcare, agriculture and smart mobility. The center also plans to develop policy, frameworks, standards, tools, assets related to Information Technology (IT) and AI. Another focus area of ICTAI would be to collaborate with industry leaders, AI companies and start-ups in order to productize technologies and IP developed at ICTAI.

National Program for Government Schools: Responsible AI for Youth
A '**National Program for Government Schools: Responsible AI for Youth'** have been designed by the National e-Governance Division, Ministry of Electronics and Information Technology, Government of India in collaboration with Intel India(National E-Governance Division NEGD,Ministry of Electronics and Information Technology, Government of India 2020). The objectives of the program are as below:

- To demystify AI for youth and equip them with the skill sets and the mind-set required for AI readiness.
- To democratize access to AI tools and train youth to use them skillfully.
- To enable youth to create meaningful social impact solutions as evidence of achievement.

AI policies and Initiatives by Indian State Governments
Table 2 illustrates the AI policies and initiatives taken by the Indian State Governments.

Table 2: AI policies and initiatives by Indian State Governments

Tamil Nadu Safe and Ethical Artificial Intelligence Policy 2020 "The Tamil Nadu State's policy for Safe & Ethical AI has been carefully crafted, after considering the pros and cons of the technology, to provide a road map for the state's policy makers for the adoption of AI-based solutions. This policy recommends the Six-Dimensional TAM-DEF Framework for evaluation of AI-based systems. The framework's factors like transparency & audit, accountability & legal issues, misuse protection, digital divide & data deficit, ethics and fairness & equity, ensure that the evaluation is aligned to democratic values. In addition, the policy also recommends the use of DEEP-MAX scorecard. DEEP-MAX provides a path to guide the roll-out of AI solutions. Further, the policy also provides guidelines for government agencies, so that they can procure AI-based solutions that adhere to the AI policy norms"(Government of Tamil Nadu 2020).
Centre of Excellence for Data Science and Artificial Intelligence (CoE-DS&AI) The Government of Karnataka, in collaboration with NASSCOM, has established the Centre of Excellence for Data Science and Artificial Intelligence (CoE-DS&AI). "It is based on a public-private partnership model to accelerate the ecosystem in Karnataka by providing the impetus for the development of data science and artificial intelligence across the country and position is as one of the top five global innovation centres in AI over the next five years. The Centre will work with partner organisations to expand AI capacity across academia, the government, and businesses by investing technological infrastructure and industry-oriented research, equipping academic institutions to provide education and skill development in DS and AI, encouraging innovation and adoption of data-driven decision making by enterprises and government"(Paul et al. 2018).
FRAS (Face Recognition Attendance System)– Tamil Nadu The TN government has implemented an Artificial Intelligence-based attendance system called "FRAS (Face Recognition Attendance System)" in government schools(Tamil Nadu e-Governance Agency (TNeGA) 2019). Under the FRAS, the teacher would need to take a picture of the class and the AI- based system would then analyse the faces in the picture and help identify the students who are absent. The system has already been implemented in two- government schools in Chennai and soon will be functional in all government schools across the state. FRAS (Face Recognition Attendance System) has been developed by Tamil Nadu e-Governance Agency(TNeGA), Information Technology Department, Government of Tamil Nadu. FRAS has been designed to work on extremely low frame rates. It does not require internet connection or a high computing platform or an expert to operate and delivers results with an accuracy of more than 99.5 per cent.
AI-Powered System For Monitor Driving Behaviour – West Bengal The IT Department under the government of West Bengal is working in collaboration with the state police to develop an AI-powered system to monitor the movement of vehicles(Sarmah 2019). The system would send a signal to the police if someone is found with suspicious or abnormal driving behaviour.
AI System To Fight Agricultural Risks – Maharashtra As a part of the Maha Agri Tech project initiative, the government of Maharashtra has decided to come up with an AI solution to help farmers reduce agricultural risk such as keeping track of the sowing area, atmosphere, possible diseases on crops and predicting yield(Sarmah 2019).

Source: (Sarmah 2019; INDIAai 2020b; Government of Tamil Nadu 2020; Tamil Nadu e-Governance Agency (TNeGA) 2019; Paul et al. 2018; NASSCOM CoE DSAI 2020)

Applications of AI in Health

"For India, a country with over 1.3 billion people and an acute shortage of doctors, artificial intelligence can't be just a novelty but is likely to prove essential"(Murali and Jayadevan 2019)*.*

"Artificial Intelligence (AI) has the potential to transform healthcare in various ways. It can turn large amounts of patient data into actionable information, improve public health surveillance, accelerate health responses, and produce leaner, faster and more targeted research and development" (Raghupathi and Raghupathi 2014)*.*

The uses of AI in Healthcare can be divided into three broad categories(Paul et al. 2018; Raghupathi and Raghupathi 2014):
- **Descriptive**: This involves quantifying events that have already occurred, and use this data to further detect trends and other insights;
- **Predictive:** It involves making predictions about the future using the descriptive data; and
- **Prescriptive:** This not only detects the trend and predicts future but also suggests possible treatments options in public health or clinical trials in research and development.

There is a vast range of application areas in health where AI could be beneficial. Some of these applications include mining of medical records; designing treatment plans; forecasting health events like dengue or malaria incidence; assisting repetitive jobs; doing online consultations; assist in clinical decision making such as analyzing radiology images to spot and detect problems; medication management; drug creation; making healthier choices and decisions; solve public health problems such as by analyzing vast amount of real time data to identify at risk population for any disease etc. (Gupta and Kumari 2018). One of the biggest advantage of AI in Healthcare is that it could be very helpful in areas where there is scarcity of human resources especially in rural and remote areas. AI can help in(Malhotra and Roy 2019)
- Creation of electronic health data repositories which has adequate high-quality annotated health data for machine learning applications
- Creation of a national level clinical decision support system which could enable better management of routine clinical problems by less-skilled healthcare providers
- Creation of self-learning digital systems in fields such as radiology, genomics, pathology to enhance the future of healthcare

"There is a huge assistance from AI in the delivery of healthcare today. Now the physician has a complete picture of what could be the different diagnosis and you try to compute it from there. The power of AI can also be leveraged to help newer physicians, who don't have much of experience to actually be able to come to the right conclusions." (Dr. Naresh Trehan, Chairman & Managing Director, Medanta-The Medicity) (Mabiyan 2018)
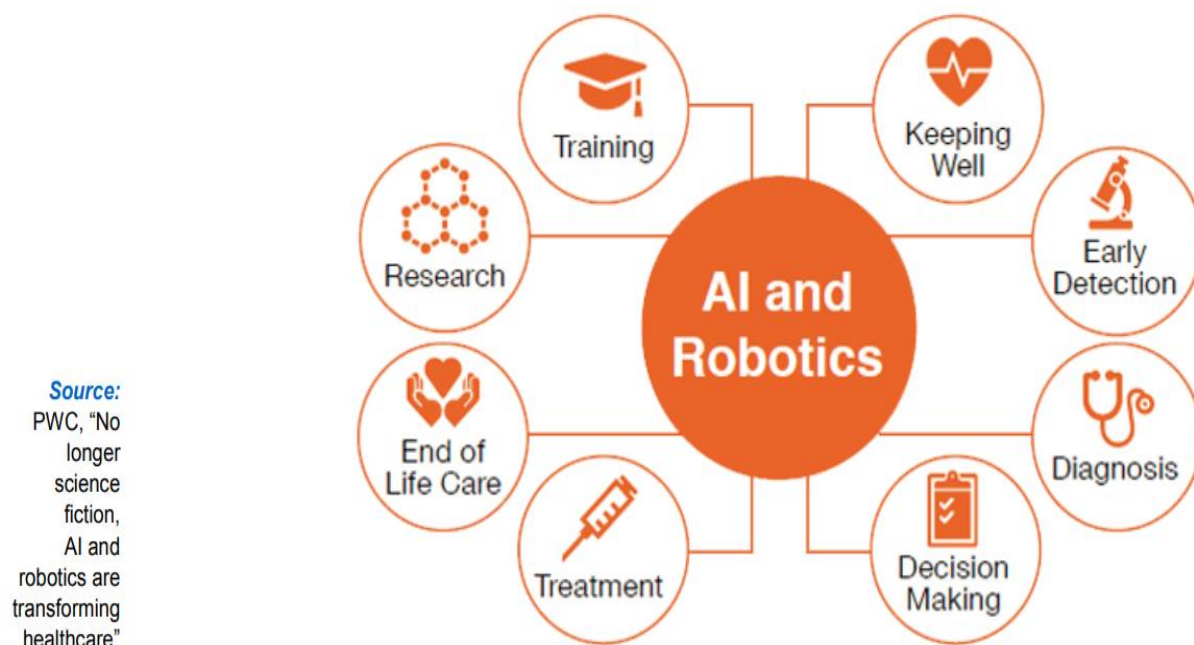
"With the development of more and more technology and artificial intelligence, healthcare can eventually be delivered at a lower cost because when efficiency is increased, diagnostics will be more focused." (Dr. Naresh Trehan, Chairman & Managing Director, Medanta-The Medicity)(Mabiyan 2018)

"With the help of data we can predict the people who are likely to face health issues. We can get a skeletal picture as the robot actually measures every muscle in your body and instruct the preventive steps that patients need to take in order to avoid further health complications" (Dr. Naresh Trehan, Chairman & Managing Director, Medanta-The Medicity)(Mabiyan 2018)

Potential Use Cases for AI in Healthcare in India

Figure 5 illustrates the potential use cases of AI in Healthcare

Figure 5: Potential use cases of AI in Healthcare

Source:
PWC, "No longer science fiction, AI and robotics are transforming healthcare"

Source: Department for Promotion of Industry and Internal Trade, MoCI, GoI. 2018. "The Artificial Intelligence Task Force." https://dipp.gov.in/sites/default/files/Report_of_Task_Force_on_ArtificialIntelligence_20 March2018_2.pdf.

Cancer Screening

The Incidence of cancer is on rise in India. Around 1 million news cases are diagnosed every year. But, India hardly has only few thousands of experienced oncopathologists. In such a situation, AI could prove as a boon. AI solutions can assist a pathologist in making quality diagnosis. However, one of the pre-requisite for AI solutions to work is the availability of good quality pathology datasets."NITI Aayog is in an advanced stage for launching a programme to develop a national repository of annotated and curated pathology images(NITI Aayog, Government of India 2018)" AI based Radiomics is also an emerging field that refers to "the

comprehensive quantification of tumour phenotypes by applying a large number of quantitative imaging features"(NITI Aayog, Government of India 2018). As per NITI Aayog report, development of Imaging Biobank for Cancer is also being discussed(NITI Aayog, Government of India 2018).

Tuberculosis (TB) Diagnosis

In August 2019, the Central TB Division under the Ministry of Health and Family Welfare(MoHFW) has signed a Memorandum of Understanding (MoU) with Wadhwani Institute for Artificial Intelligence to explore the Artificial Intelligence technology application in fighting against Tuberculosis(TB)(Ministry of Health & Family Welfare, Government of India 2019)."As a part of the collaboration, Wadhwani AI would be supporting National TB programme become AI-ready which would include, developing, piloting, and deploying AI-based solutions. It would support the programme in vulnerability and hot-spot mapping, modelling novel methods of screening and diagnostics and enabling decision support for care-givers apart from supporting the RNTCP in adoption of other AI technologies"(Ministry of Health & Family Welfare, Government of India 2019).

Diabetic retinopathy screening

NITI Aayog is working on a pilot project with Microsoft and Forus Health to explore the use of AI for early detection of diabetic retinopathy (DR)(Mahapatra 2019). "The objective is to develop an AI algorithm for the detection of signs of DR in diabetic patients and to scientifically validate the algorithm to be used as a screening tool in primary care"(INDIAai 2020a). Two studies will be undertaken as a part of this project:

1. Development of an algorithm with AI to detect signs of DR in patients with diabetes, and
2. A prospective study comparing the diagnostic capacity of the AI algorithm with respect to the actual system of family physicians evaluating the images.

It is proposed that integrating AI capabilities using Microsoft's retinal imaging APIs to '3Nethra', a portable device developed by Forus Health for screening common eye problems, could provide AI-powered insights even in rural and remote areas with poor connectivity to the cloud(Mahapatra 2019).

Chronic Obstructive Pulmonary Disease Diagnosis and management

AI based solutions can also help in effective diagnosis and management of Chronic Obstructive Pulmonary Disease Diagnosis (COPD). Some of the application areas are as below(Mahapatra 2019):

1. AI based early warning system uses specialized spirometer and advanced analytics which could help patients in identification of triggers, symptoms, trends and other personalized insights related to COPD.
2. AI aided inhaler based medication adherence solutions help in monitoring the correctness of drug delivery technique and tracks patient's adherence to the prescribed drug regimen

3. AI aided lung imaging use high-resolution CT Scans or X-ray images, advanced Computational Fluid Dynamics (CFD) tools along with AI and help pulmonologists in visualization of structural and functional parameters of lungs.

Microsoft – Apollo Hospitals' partnership

Microsoft – Apollo Hospitals' partnership is one of the recent development with the focus to create an AI-focused network within cardiology (a specialty of medicine).

"We built a partnership where they bring in the technology and we bring in the data, algorithms and the clinical insights into what is impacting and how this can translate into number one risk scoring and then in differential pattern and methodologies" (Sangita Reddy, Joint MD, Apollo Hospitals)(Mabiyan 2018)

"AI is going to help us in not only identifying the vulnerable patients early but also in terms of modifying the intensity of treatment after classifying them into high risk or very high risk group" (Dr. (Prof) N N Khanna, Senior Consultant - Interventional Cardiology and Vascular Interventions, Indraprastha Apollo Hospitals)(Mabiyan 2018).

The list of top AI organizations in Healthcare in India is given in Annexure 1.

AI and COVID-19 in India

AI and its applications have proven to be a boon in dealing with the COVID-19 situation in India. This new technology is helpful in tracking the pandemic, screening of COVID-19 cases, containment of corona virus, contact tracing, enforcing quarantine and social distancing, tracking of suspects, treatment and remote monitoring of COVID-19 patients, vaccine and drug development etc. A global study was conducted by PwC India and as per its report, India witnessed the highest increase in use of artificial intelligence (AI) during COVID-19 times(Press Trust of India 2020a). As per the survey, around 73% of healthcare and pharma companies adopted AI during the year.

Modelling the pandemic

Artificial Intelligence-based predictive models have emerged as one of the powerful weapons in the fight against COVID-19 in the country. Decision makers have used computer simulations to understand how COVID-19 situation will evolve over time. Many scientists and companies such as TCS(Tata Consultancy Services), KPMG India also developed machine-learning models to predict the severity of the disease and identify at-risk populations across the country(KPMG 2020; Ghosh, Ghosh, and Chakraborty 2020; Shinjini 2020). For instance, TCS(Tata Consultancy Services) in collaboration with Pune-based Prayas Health Group has developed 'Digital twin', a virtual computerized model to forecast the spread of COVID-19 in urban districts in India(Kulkarni 2020).

"*Macro models don't work well in countries like India which have high heterogeneity. So we developed ward-level digital twins that modelled the spread of the disease as a function of the number of proximal contacts, average duration of contacts, people and place characteristics,*
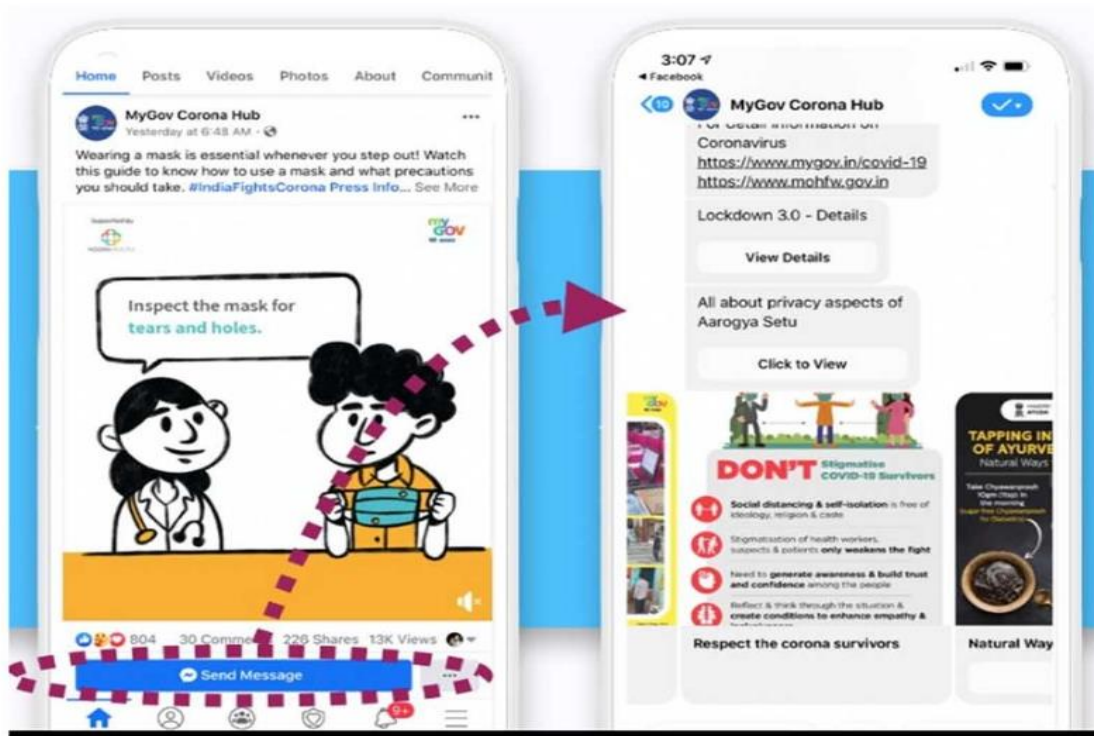
and population demographics like age, gender, comorbidities, etc. The model predictions closely match the observations reported by city corporations and empower the administration to take better locality-specific decisions" (Vinay Kulkarni, distinguished chief scientist, TCS) (Kulkarni 2020)

AI for pandemic preparedness

Conversational AI-enabled MyGov

MyGov, world's largest citizen engagement platform launched by the Government of India, partnered with Amplify.ai, a company which deals in conversational AI technology with the aim to make people aware of COVID-19 and provide them real-time updates(Das 2020). The virtual assistant or chatbot also allows citizens to ask relevant questions and clear their doubts related to COVID-19.

Figure 6: My Gov virtual assistant Chatbot

Source: Das, Sejuti. 2020. "How Government Of India Used Conversational AI During COVID-19: A Case Study." 2020. https://analyticsindiamag.com/how-government-of-india-used-conversational-ai-during-covid-19-a-case-study/.

IBM Watson Assistant

The Indian Council of Medical Research (ICMR) in collaboration with the tech giant IBM has implemented the Watson Assistant, an AI-based query answering system, on its portal. The Watson Assistant responds to the queries on COVID-19 raised by front-line workers and data

entry operators across testing and diagnostic facilities in India(Rajan 2021). The Watson Assistant works 24*7 and responds both in English and Hindi(The Economic Times 2020).

"*It is critical to remain focused on testing, diagnosis and treatment in order to lower the growth curve. This collaboration with IBM will help automate responses from the field and facilitate access to accurate and updated data on COVID-19 diagnostics and reporting. This will help augment our teams' response time and allow them to concentrate on priorities like developing, updating testing and treatment protocols and guidance for COVID-19."(*Professor Balram Bhargava, Director General, ICMR)(The Economic Times 2020)

AI-powered tools for screening of COVID-19

- The Defence Institute of Advanced Technology (DIAT) in Pune, Maharashtra has developed an AI based COVID-19 detection tool(Press Trust of India 2020g). The tool uses the chest x-rays of patients to identify COVID-19 infection. It will be particularly helpful for radiologists and also in telemedicine. An IIT-Roorkee Professor has also developed similar software which can detect COVID-19 and measure its severity using X-ray scan of the suspected patient(Press Trust of India 2020e).
- An AI based voice tool has also been developed and designed by a professor and her students in Mumbai(Press Trust of India 2020d). This tool is able to detect COVID-19 through voice-based diagnosis using a smartphone app. The tool will detect COVID-19 based on the fact that the voice of COVID-19 patient is different from the healthy person as COVID-19 severely compromises the lungs and airways. Artificial Intelligence is able to detect these differences which a normal ear cannot. When a person speaks to the microphone on the app, this voice tool breaks down the voice in multiple parameters like frequency, noise distortion etc. The values of these parameters are then compared to normal person's values which help detect COVID-19. This tool is being pilot tested by University of Tor Vergata in Rome and has yielded 98% accurate results.
- The Norway India Partnership Initiative (NIPI) in collaboration with the Wadhwani Institute of Artificial Intelligence has developed an artificial intelligence (AI)-powered tool which enables identification of COVID-19 through cough sound analysis(Kumar 2020). The tool will detect COVID-19 based on the fact that the cough of a COVID-19 patient is different from other coughs. Based on the reference coughing pattern, this AI powered tool will be able to detect COVID-19 as soon as the person coughs in front of the machine.

AI-enabled thermal cameras

'Staqu', a Gurgaon based start-up, has launched AI-based thermal camera to identify anyone with body temperature above 37°C(Awasthi 2020). The camera can identify multiple suspects at the same time and that too in the range of 100 meters.

Some of the mobile applications for preliminary screening of COVID-19 are enlisted in the Table 3.

Table 3: Mobile applications for preliminary screening of COVID-19

State	Name of the mobile application	Purpose
Goa	Test Yourself Goa	Assists in carrying out a self-assessment test for COVID-19
Karnataka	Test Yourself Karnataka	Assists in carrying out a self-assessment test for COVID-19
Punjab	COVA Punjab	A platform for self-screening for COVID-19, provides access to real time dashboard for COVID-19 statistics, helpline numbers, prevention measures, government advisories, travel instructions; a geofencing app; and locates nearest COVID-19 hospital
Telangana	T-COVID'19	Provides self-assessment for COVID-19 ; live COVID-19 statistics, access to government and WHO advisories, details related to government approved labs and test centers, isolation wards in government and private hospitals and quarantine centers; a telemedicine platform

Source:(Mitter 2020; Anand 2020; ET Wing, Govt of Telangana 2020; Mizoram State e-Governance Society 2020; Press Trust of India 2020c; Nag 2020; ETGovernment 2020)

The above mentioned AI based tools acts as a first level of COVID-19 screening and those who test positive using these tools should go for laboratory based testing. These tools can help address the existing bottlenecks in the healthcare infrastructure and manpower. It provides one of the best solutions to reach the remotest part of the country by testing through a smartphone based app.

AI for containment of corona virus
Some of the AI based technologies that helped in the containment of the corona virus in many states in India are:
- 'Milagrow iMap 9' , a robot designed for floor disinfection purposes which can navigate and sanitize floors without any human involvement was launched by Milagrow HumanTech(Press Trust of India 2020f)[2].
- Garuda Aerospace, a Chennai based start-up, has developed an automated disinfecting Unmanned Aerial Vehicle (UAV) called "Corona-Killer 100" (a disinfectant spraying drone)[3]. Garuda Aerospace has deployed 300 "Corona-Killer 100" drones for disinfection purposes across 26 cities in India.

Contact tracing and investigation
Contact tracing is one of the key pillars in the control of communicable diseases including COVID-19. It involves identification of the individuals who may have come in contact with the infected person (called as "contact") and subsequent collection of relevant information from

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[2] Milagrow HumanTech is the No. 1 Domestic Robots company in India.
https://milagrowhumantech.com/content/4-about-us
[3] Garuda Aerospace focuses on the design, build and customization of unmanned aerial vehicles (UAVs) or drones for various applications. https://www.garudaaerospace.com/about-us/

these contacts. In situations like the COVID-19 pandemic, manual contact identification becomes a challenging task. In such situations, AI has played a crucial role in contact tracing and further investigation through mobile based applications. Some of these applications are enlisted in the Table 4.

Table 4: Mobile applications for COVID-19 contact tracing and further investigation

Name of the mobile application	Purpose
Aarogya Setu App	The Aarogya Setu App has been developed by National Informatics Centre (NIC), Ministry of Electronics and Information Technology, Government of India(Wikipedia 2020b; National Informatics Centre, Ministry of Electronics & Information Technology, Government of India 2020; Mitter 2020). It is a contact tracing app available in 11 languages. The app uses Bluetooth and location data to track movement of the user. An alert is generated whenever a user has been within six feet of a COVID-19 patient by cross-referencing the pan-India government database of COVID-19 patients.
Sandhane	Trace COVID-19 suspects in rural and remote areas
SAHYOG	The SAHYOG app is developed by Survey of India (SOI), India's National Mapping Agency (NMA) under the Department of Science & Technology, Government of India(Geospatial World 2020; Survey Of India 2020). The main objective to launch the app is to help government improve its response system. It complements the Aarogya Setu app in attainment of three objectives – contact tracing, public awareness and self-assessment. It helps community workers in carrying out door to door surveys, public awareness campaigns, contact tracing and delivery of essential items. Through this app users will contribute towards preparation of national database of the country. The app will collate data at the state level and geo-tag it for further analysis by Survey of India (SOI).

Source:(Mitter 2020; Anand 2020; ET Wing, Govt of Telangana 2020; Mizoram State e-Governance Society 2020; Press Trust of India 2020c; Nag 2020; ETGovernment 2020)
Source: Survey Of India. 2020. "Sahyog." 2020.
https://play.google.com/store/apps/details?id=in.gov.surveyofindia.sahyog&hl=en

Enforcing quarantine and social distancing

AI based tools such as drones and mobile applications have also helped in enforcing quarantine and maintaining social distancing. Drones are being used to monitor the movement of COVID-19 suspects in quarantine centers. They are being leveraged for video surveillance and enforcing social distancing purposes. These are particularly helpful in the red alert and containment zones and in public places where people gather in large numbers like banks, ration shops etc. Table 5 enlists few of the geofencing mobile applications running in various states in India[4].

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[4] Geofencing technology is being used for enforcing strict vigilance on COVID-19 suspects in quarantine. It uses location based service like GPS to set up a virtual boundary around the quarantine center. Mobile app is installed in the COVID-19 suspect's mobile device and this app

Table 5: Geofencing mobile applications

State	Name of the mobile application	Purpose
Maharashtra	MahaKavach	Geofencing app: Helps track movement of COVID-19 suspect in quarantine
Tamil Nadu	Quarantine Monitor	Geofencing app: Helps track movement of COVID-19 suspect in quarantine
Karnataka	Corona Watch	Geofencing app: Helps track movement of COVID-19 suspect in quarantine
Himachal Pradesh	Corona Mukt Himachal	Geofencing app: Helps track movement of COVID-19 suspect in quarantine
Gujarat	SMC COVID-19 Tracker App	Geofencing app: Helps track movement of COVID-19 suspect in quarantine
Maharashtra	Coviguard	The Coviguard app is helpful in monitoring the people who are in home quarantine. The Coviguard app also has a built-in facility for personalized chats that helps the quarantined person to communicate with the authorities.
Tamil Nadu	CoBuddy	CoBuddy is an android based mobile application being used by Police authorities in Tiruvallur district of Tamil Nadu(Barik 2020). CoBuddy is a geofencing app and helps in monitoring the movement of COVID-19 suspects under home quarantine. The app uses face verification as an added layer of authentication. Random messages are sent to the user throughout the day to upload his/her photograph to verify their current location.
Mizorum	mCOVID-19	Provides access to COVID-19 updates, government advisories, task force and volunteer registration, volunteer mPASS (pass to permit movement of goods, vehicles and people); a geofencing app
Punjab	COVA Punjab	Provides access to real time dashboard for COVID-19 statistics, helpline numbers, prevention measures, government advisories, travel instructions; a geofencing app; a platform for self-screening for COVID-19 and locates nearest COVID-19 hospital

Source:(Mitter 2020; Anand 2020; ET Wing, Govt of Telangana 2020; Mizoram State e-Governance Society 2020; Press Trust of India 2020c; Nag 2020; ETGovernment 2020)

AI for treatment and remote monitoring of patients

- The Kerala Government has initiated the use of robots 'KARMI-Bot' and 'Nightingale-19'(Bhatia 2020; Zachariah 2020). These robots serve food and medicines to the COVID-19 patients, collect trash used by the patients, enable video call between patients and doctors or

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uses GPS to trigger an alert whenever the suspect's mobile device enters or exits the virtual boundary.

relatives and perform disinfection of the isolation ward. Other states like Tamil Nadu and Jaipur have also explored the use of robots.

- For monitoring COVID-19 patients, states are exploring the use of remote monitoring systems. These include Indore 311 mobile app by state of Madhya Pradesh, Monal 2020 by the state of Uttarakhand, Milagrow Humanoid ELF in AIIMS,New Delhi, LiFi (Light Fidelity) technology in Ahmadabad(Press Trust of India 2020f; Vora 2020; Express News Service 2020). These remote monitoring systems enables remote monitoring of patient's vital parameters like pulse rate, blood oxygen level, body temperature, respiration rate, heart rate etc.

- The Indraprastha Institute of Information Technology (IIIT-Delhi) has developed an AI model to repurpose existing drugs for treatment of Covid-19[5] . The AI model would help identify the drugs which have the highest probability of success against COVID-19. This model eliminates the need of trying all of the drugs in clinical trials and thus save time and money.

AI-enabled COVID-19 sero survey platform

Thalamus Irwine, India based IT start-up has developed an AI and IoT (Internet of Things)-based sero survey platform named 'Garuda' which claims to conduct a seroprevalence study with 1 crore COVID-19 samples in just one week time (Press Trust of India 2020b; The Weather Company 2020). This technology could be helpful in identification of the vulnerable groups, community and geographical pockets where least or no immunity has been developed against COVID-19. This would be helpful in vaccine prioritisation and putting brakes on the spread of the COVID-19 infection.

"We have developed an Artificial Intelligence (AI) based system to analyse samples tested for COVID-19 within a few microseconds. We connect our AI-Internet of Things (IoT) platform, Garuda, with our partner device that analyses data in real time. Through our technology, we can conduct sero survey with 1 crore actual samples in a week."(Thalamus Irwine chairman Rishabh Sharma)(Press Trust of India 2020b)

"To achieve the scale of 1 crore tests, we need to operate 12,000 nodes or devices for 7 hours per day. The technology can separately detect around more health conditions of individuals. This can help the government understand the health map of the country by one-time investment. The test also detects virus load in individuals and helps prepare a database of potential donors for plasma therapy. All data will be safely hosted at ITI datacentres." (Thalamus Irwine chairman Rishabh Sharma)(Press Trust of India 2020b)

Challenges and Barriers

Challenges related to working with Big Data

The unstructured data sets, interoperability issues, lack of open sets of medical data, inadequate analytics solutions which could work with big data are some of the challenges for AI-driven healthcare(Gujral, J, and M 2020). In resource poor settings like India, there is dearth of high quality datasets related to diseases and conditions prevalent in these settings, which makes it

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[5] https://health.economictimes.indiatimes.com/news/medical-devices/iiit-delhi-develops-ai-model-to-repurpose-existing-drugs-to-treat-covid-19/76939010

difficult to train AI algorithms for identification of risk factors or diagnosis of diseases. Further, in many healthcare settings in India, health records are hand-written in local languages, which makes the process even more challenging. Also, because the Indian population is so diverse, there is a possibility that datasets may have cultural biases like caste, sexuality etc. It is therefore important that input datasets which are used to train AI algorithms should be derived from a large and diverse population(Paul et al. 2018). In one of the workshops on AI in India, AI and healthcare professionals, start-ups and think tanks identified issues related to data entry, tabulation, lack of guidelines on data collection in healthcare as some of the key problems in AI and healthcare in India(Mohandas and Ranganathan 2017). In India, healthcare data remains fragmented spreading across various organizations including hospitals, clinics, pharmacies, testing laboratories etc. Another obstacle in India is the lack of open (publicly available) medical datasets which forces start-ups to use data from other countries that results in AI algorithms that does not cater to Indian demographics. However, there are certain examples of open source data in India , for instance, the National Cancer registry but they are insufficient (Mohandas and Ranganathan 2017).

Infrastructure
One of the key barriers to implement AI in Healthcare in India is the lack of adequate infrastructure. Cloud-computing infrastructure is majorly available in servers located outside India which has led many Indian start-ups to establish themselves outside India(Haider 2020). Further, many equipment which are used in healthcare for diagnostic or therapeutic purposes are imported from countries outside India, which raises the issue of software compatibility for adoption of AI driven healthcare(Haider 2020).

Liability and Accountability
In India, in cases of medical negligence, medical professionals are liable to be taken to the court. However, it is not clear how the accountability and liability will be determined if wrong decision is taken by the doctor due to the glitch in the AI-based system. It is needed to establish laws related to liability and accountability for AI in healthcare and develop guidance defining the boundaries of healthcare system where AI would not be allowed to take over(Mohandas and Ranganathan 2017; Haider 2020).

Training Issues
Lack of AI trained professionals is another challenge to use AI in Healthcare in India.
The workforce which is readily available do not have the necessary skills to use the AI systems effectively. Careful handling of sensitive health information, protection against data theft and to use AI systems effectively with optimal results requires specially trained workforce, which is currently a big challenge for India to adopt AI in the healthcare sector.

Cost
Implementation of AI in healthcare requires substantial initial investment which is one of the major concerns for a low resource setting like India. Investment by the government of India in the domains like AI and research remains limited (Paul et al. 2018).

Trust issues

One of the issues with the adoption of AI in Healthcare in India is the acceptability of the results achieved from AI algorithms(Paul et al. 2018). The decisions made by doctors based on AI solutions must be explainable especially in the Indian scenario where doctor-patient relationship is given complete trust. Further, there is still lack of understanding about AI, its application areas and benefits, not only among the medical and healthcare professionals but also in the general population.

Inequality concerns
There are also concerns related to inequality. For instance, data which is used to develop AI algorithms may have minority groups under-representation which could produce unfair results(Panch et al. 2019). AI algorithms can generate unfair results based on skewed data (such as belonging to specific race, gender, age, and religion) which might be suitable for some demographics in India than others(Pinninti and Rajappa 2020). It is also perceived that higher income populations would be benefitted more because they have better access to technologies. Also, because of the prominence of males in the software industry, there are concerns that AI solutions that are intended to be utilized by the entire population will be produced with a strong male bias(Kalyanakrishnan et al. 2018).

Inadequate framework and Regulatory weaknesses
Currently, India does not have any regulatory structure or framework to guide the development of AI solutions and ensure their quality, privacy and security. This is one of the biggest challenge for India to adopt AI-based Healthcare on a large scale.

Data protection and privacy
Privacy of information is one of the big concern for adoption of AI in Healthcare(NITI Aayog, Government of India 2018; Jagdev and Singh 2015). Particularly in Indian context where data is usually government owned, access of such data by private players for their own use raises a lot of concerns. Cybersecurity is also a major concern. Lot of confidential health information available online across the cloud computing environment poses a risk of data security. The leakage of more than 35,000 patients' medical records from a diagnostic lab in Maharashtra, India in the year 2016 is one such example(Outlook 2016).

Way Forward

It is recommended that government should support companies to invest in AI; encourage public private partnerships in the domain of AI and Health; enact and effectively enforce laws and legislation related to AI and Health; frame policies addressing issues related to confidentiality and privacy in the AI-driven healthcare; and establish a certification system for AI-based healthcare solutions. To adopt AI-based healthcare, it is important to train workforce in AI so that they can carefully handle sensitive health information, protect data against theft and use AI systems effectively. It is also crucial that healthcare decisions based on the AI solutions should have a rationale and are explainable.

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innovation-protect-health-workers-india-ser106/.

Annexure 1

Name of the Organization	Description
SigTuple Technologies Private Limited	Founded in Bangalore in April 2015, Sigtuple is working on data-driven, machine learning and cloud-based solutions to identify abnormalities and patterns in medical data for disease diagnosis. The organization is using AI to create hardware and software tools to digitize test results for hospitals and clinics for pathological analysis. Its AI-powered continuous learning platform, Manthana, enables five major capabilities for them – data management, observations, model development, continuous learning, and analysis / reporting.
Qure.ai	Qure.ai was founded in 2016. Qure.ai basically provides solutions to physicians which are related to routine diagnosis and treatment . In addition to their deep learning solutions, they transcend the field of research in their respective area of interest.
Tricog Healthcare Services Private Limited	Tricog, a healthcare analytics organizations based in Bengaluru was founded in 2015. For easier diagnosis and treatment of heart attacks, Tricog has revolutionized not only the way ECG(Electrocardiogram) analysis is performed in India but also in remote healthcare centers throughout India. For heart patients, technology , artificial intelligence and a 24-hour medical team, Tricog provides the most reliable and quickest real-time diagnosis. Tricog uses multiple AI algorithms to control each ECG received, after which an expert medical team assesses the absolutism of each ECG diagnosis, who are directly available around the clock at the Tricog hub in central location.
Oncostem Diagnostics	Established in Bangalore in 2011, Oncostem is designing measures to help detect patterns in the risk of cancer recurrence. OncoStem seeks to create innovative tests designed to personalize cancer patients' care. Their flagship product Can Assist Breast was launched for breast cancer CanAssist Breast digitizes historical patient medical records, feeds into an AI-algorithm that then analyzes the data to generate actionable knowledge for doctors. The study reads and analyzes tissue abnormality and identifies cancer-growing tumors-which benefits from technologies that may not be comparable to human experience. They are currently working on similar tests for other types of cancer including oral and ovaries cancer. Development to identify and describe novel drug targets for breast and oral cancer is under way.
Niramai Health Analytix Private Limited	Niramai was founded in July 2016, Bangalore. Niramai is the pioneer of a patented technology called Thermalytix which is a novel fusion of AI and thermography for Breast Cancer Screening. Niramai's early stage breast cancer screening solution is a non-contact, non-invasive, portable, safe, automated solution that works for women of all ages.
Predible Health	Predible health is a Bangalore based organization which was founded by Mr Abhijit Chunduru and Mr Suthirth Vaidya in 2016. It basically utilizes AI for radiology for diagnosis of liver and lung cancers. The organization had done a major part of its research upon the application of deep learning components of AI for radiological aspects such as detection of lung cancer, radiology level malignancy detection on chest computerized tomography scans.

CARING	CARING refers to the Centre for Advanced Research in Imaging, Neuroscience and Genomics. CARING is evolving as one of the top most AI organizations in healthcare by research point of view. They are carrying out extensive research in artificial intelligence based imaging, neuroscience and genomics. They are also involved in developing collaborative research projects.

Source: InnoHEALTH Magazine. 2020. "India's Top Artificial Intelligence Organizations in Healthcare." 2020. India's top Artificial Intelligence Organizations in Healthcare. https://innohealthmagazine.com/2020/trends/top-artificial-intelligence-organizations-in-healthcare-in-india/