

Artificial intelligence in the sector of Ayurveda: Scope and opportunities

The importance of digital infrastructure, technology, and innovation in achieving the 17 Sustainable Development Goals (SDGs) is critical and important in making progress toward them. The strategic and innovative use of digital and information and communications technologies is an essential factor for ensuring the Triple Billion Targets, i.e., 1 billion more people benefit from universal health coverage, that 1 billion more people are better protected from health emergencies, and that 1 billion more people enjoy better health and well-being. Digital transformation and technologies in health care such as virtual care, remote monitoring, Artificial Intelligence (AI), big data analytics, blockchain, smart wearables, platforms, tools enabling data exchange and storage, remote data capture, and the exchange of data and sharing of relevant information across the health ecosystem have enhanced the health outcomes by improving medical diagnosis, data-based treatment decisions, digital therapeutics, clinical trials, self-management of care, and person-centered care as well as creating more evidence-based knowledge, skills, and competence for professionals to support health care.^[1]

The World Health Organization's (WHO's) "Global Strategy on digital health 2020–2025" has emphasized the use of AI to strengthen health systems with its varied range of applications, specifically focusing on the needs of consumers, health professionals, health-care providers, and industry toward empowering the patients and achieving the vision of health for all.^[1] Although the concept of AI began in the 1950s, in recent times, it has shown enormous potential in enhancing health-care delivery worldwide with its significant impact in disciplines such as drug discovery, genomics, radiography, pathology, prevention, detecting outbreaks of early epidemics, and health research.^[2]

The Council on AI of the Organization for Economic Cooperation and Development (OECD) defines an AI system as "A machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments." AI systems are designed to operate with varying levels of autonomy.^[3] AI is any software technology with at least one of the following capabilities: perception – including audio, visual, textual, and tactile (e.g., face recognition), decision-making (e.g., medical diagnosis systems),

prediction (e.g., weather forecast), automatic knowledge extraction and pattern recognition from data (e.g., the discovery of fake news circles in social media), interactive communication (e.g., social robots or chatbots), and logical reasoning (e.g., theory development from premises).^[4]

ARTIFICIAL INTELLIGENCE AND HEALTH SECTOR

Various world's largest technology companies are spending heavily on data collection (including health data), algorithm development, and AI deployment. There are several distinct areas for increasing the efficiency and improving the utility of AI, which include search and optimization capacity, natural language processing, Machine Learning (ML) and probabilistic reasoning, neural networks, and planning and decision-making; of which ML, natural language processing, and neural networks are increasingly being used to evaluate enormous amounts of data.^[5] AI, as a virtual human body, augments the drug discovery and development process through computer-aided drug-designing methods, which could serve as an efficient tool for the discovery of novel drug compounds. Nowadays, high-throughput AI-assisted approaches are being employed in conjunction with bioinformatics to understand in-depth biology and pathophysiology. With the advent of AI systems, clinical studies can be altered and conducted dynamically with the usage of supercomputing AI systems, algorithms, and high-throughput techniques, enabling in-depth analyses of the studies, reducing the fluctuation in results, minimizing errors, and enhancing the output of clinical trials. AI integration can also aid in the selection of the study participants based on the patient's eligibility, and suitability, efficient sorting of medical records, and identification of illness phenotype with optimal patient monitoring to ensure timely identification of predictive signs of any drug-induced toxicities.^[6]

Owing to the potential of AI in the health sector, it could play a crucial role in bridging gaps in health-care delivery and services, particularly in low- and middle-income nations. The use of AI-based tools promises a significant role in extending health-care services to neglected groups, improving public health surveillance, and assisting health-care providers in better responding

and providing complex care. This allows health-care providers to focus on addressing the challenges and complexities of the health-care system. AI, as an enabler for long-term health security and universal health coverage, needs to be integrated into the larger digital health ecosystem, guided by a robust strategy, and should be more people-centered, efficient, sustainable, and inclusive in nature.

ETHICAL CONSIDERATION FOR THE USE OF ARTIFICIAL INTELLIGENCE IN HEALTH SERVICES

Since all the new technologies not only come up with a pool of benefits and advantages, there are serious concerns regarding their misuse and harm to society. It necessitates obligations toward prioritizing ethics and human rights in the design, development, deployment, and usage of AI in the sector of health and medical care. The proliferation of AI results in the provision of health-care services in unregulated contexts and by unregulated providers, raising challenges for the Government Health-care Regulation. As a result, appropriate regulatory oversight mechanisms must be developed to hold the private sector accountable and responsive to those who can benefit from AI goods and services, as well as to ensure the openness of private sector decision-making and operations. A consultation between the WHO's Health Ethics and Governance Unit in the Department of Research for Health and the Department of Digital Health and Innovation observed and assessed the collective opinions on the various prospects and problems of AI, in the health sector. There were severe ethical questions related to monitoring, invasions of privacy and autonomy, health and social inequalities, and appropriate use of data-intensive applications in the health sector. Thus, to fully assess the benefits of AI and address the ethical challenges for health-care systems, practitioners, and beneficiaries of medical and public health services, the WHO published a guidance report on the "Ethics and Governance of AI for Health" to promote the ethical use of AI for health, so that all populations can benefit equally from the great promise of these technologies in the future. The expert group endorsed a set of six key ethical principles focusing on protecting human autonomy, promoting human well-being and safety and the public interest, ensuring transparency, explaining ability and intelligibility, fostering responsibility and accountability, ensuring inclusiveness and equity, and promoting AI that is responsive and sustainable.^[7]

ARTIFICIAL INTELLIGENCE FOR AYURVEDA

AI integration is accelerating in the mainstream medical industry, and attempts are now being made to include AI in traditional medicines (TMs). In other words, AI opens up

new avenues for exploring the ancient works of the literature of TM, allowing the screening of herbs or components of traditional formulae, which could disclose the mechanism of action. The search for alternative options for effective and safer lead compound discovery and plant-based TM could open an immense knowledge base for the exploration of AI in the TM sector.^[8] The extensive usage of plant-based TM suggests that medicinal plant extracts, when combined with modern technologies and concepts, could serve as potential reservoirs for innovative drug development. Each plant extract is a complex mixture of chemical substances with different forms of ancient medical scripts defining their use; a sophisticated self-learning capable automated machine, like an AI system, will be required to comprehend all available data.^[9] Assistive AI-based diagnostic models are also expanding in the areas of decision-making models, symptom classification based on varied clinical data, and the generation of pharmacological databases that can be utilized in ethnopharmacology.^[10]

With the present global trend, there is a growing need for the digital integration of Ayurveda with AI technologies with an advanced vision to focus and explore its scope in the global competitive market. Various research has been conducted for Ayurveda-based disease diagnosis using ML. There is a vivid range of applications in the market for *Dosha* evaluation, *Prakriti* assessment, etc. for assisting Ayurveda physicians in appropriate evaluation of clinical information to make accurate diagnosis and treatment, with an ample amount of journals, e-books, and indexing units such as Digital Helpline for Ayurveda Research Articles (DHARA), AYUSH Research portal, Traditional Knowledge Digital Library (TKDL), Random Uninterrupted Documentation for Retrospective Analysis (RUDRA) Program, AyuSoft, *Prakriti Vichaya*, and *Triskandha Kosha* to strengthen the position of Ayurveda in the digital era of AI.^[11]

Data mining, a computational technique involving AI, and database systems have a promising role in the field of Ayurveda. This tool allows for precise knowledge searches utilizing any number of search string combinations to hunt for information related to diseases, causative factors, symptoms, treatment protocols, therapeutic interventions, lifestyle changes, and different treatment modalities. AI and ML can assist to usher in a new era of efficient, rational, and competent drug development in the sector of Ayurveda pharmaceutics. A cloud-based representation of several known and yet-to-be-discovered relationships between various biological factors such as genes, symptoms, sickness problems, tissues, animals, and potential treatments can be made to build knowledge graphs.^[11]

Several computer-based Ayurvedic practices are available to assist Ayurvedic doctors in detecting, communicating,

and interpreting data for appropriate diagnosis and treatment. The automatic recognition and classification of plant leaves using an Artificial Neural Network, K-Nearest Network, Probabilistic Neural Network, Support Vector Machine, and Decision Tree and identification of indigenous Ayurvedic medicinal plant species using deep learning techniques, image processing, and AI will be beneficial in the sectors of medical area and botanical research.^[12] The use of robotics in the sector of patient monitoring and diagnostics, robust networking facilities in a rural area and providing consultation services, the use of DNA fingerprinting methods to assess the *Prakriti*, and use of wearable gadgets coupled with AI technologies to get real-time health-related data, all can be used for the early detection of diseases, offering health-care services, and to predict the outbreak of epidemics. There is also a need for experienced researchers and scholars, equipped with knowledge of modern technologies, different data collection methods, and documentation processes. Hence, the curriculum offered to young fellows should be more of computer-aided learning with different visualization technologies, and hospitals, clinics, medical colleges, and universities should be well digitally equipped.

WAY FORWARD

Integration and utilization of AI in the Ayurveda sector have emerged as a potent solution for enhancing the ability and capability of the patients and communities to take charge of their own health care and better comprehend their changing requirements. All stakeholders, including designers and programmers, developers, providers, and various government organizations from the sector of Health Information Technology, and not very least, the patients, must collaborate to include ethical rules at every level of a technology's design, development, and implementation of AI in the Ayurveda health infrastructure. The technology should not only be used to maximize the potential of Ayurveda but also to respect and preserve physicians' integrity and ability, as the core principles of Ayurveda give utmost importance to *Bhishaka* (~physician) in the ethical principle for treatment protocol. The government, various corporations, private partners, and other stakeholders in the sector should participate in the development of technologies, create new standards and approaches for Ayurveda diagnostics, treatment, drug development, and research innovations, and seek transparency to meet the needs of their communities and significantly impacting the needs of the health systems globally. AI systems must be designed, developed, and deployed in a trustworthy manner, respecting human rights and privacy.

The integrative initiatives for AI in Ayurveda must be guided by a solid strategy collaborating with efficient leadership and financial, organizational, human, and

technological resources to serve as the foundation for a standard action plan allowing coordination among multiple stakeholders. It should be guided by strong governance frameworks and should address a method for integrating multiple health priorities supported by an architecture that allows for efficient integration. The action plan should ensure that all end-user communities, beneficiary groups, as well as institutions, decision-makers, and personnel of health-care services are sufficiently engaged in the design and development phases.

A significant amount of research and assessment of the health outcomes from AI-assisted technologies in Ayurveda is also required at the same time to support its safe implementation, promote accountability, and justify financial investments. The agenda should promote and facilitate digital health and AI competencies in the education and training curricula of all health professionals and allied workers. There should be provisions for capacity-building inclusive of multidisciplinary and interdisciplinary fields, entailing and instilling capabilities, attitudes, and skills in various subsectors such as computer sciences, strategic planning, finance, management, health sciences, and health-care delivery, depending on the AI application, also including timely workforce assessment.

AI for health is a rapidly expanding domain and has emerged as an intrinsic part of a variety of fields, including finance, education, business, modern medicine, and TM as well. Many AI techniques, such as algorithms, image processing techniques, pattern recognition, and data mining, can significantly add value to the exploration of Ayurveda. Many studies are needed to critically assess the generalizability, effectiveness, and dependability of this newer AI technique in the industry for the advancement and promotion of Ayurveda globally. The Ministry of Ayush and its dedicated research councils are taking steps to fully leverage the technology. There is a critical need to improve connectivity between technological innovation and research in Ayurvedic health care while addressing the challenges and issues such as accessibility, skilling, consumer behavioral change, technological acceptability, and supply chain efficiency related to it.

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