Artificial Intelligence in Healthcare and Pharmacy: A Review

Shilpa P. Bhilegaonkar

shilpabhilegaonkar@gmail.com

Abstract:

With the advent of Industry 5.0, the fifth industrial revolution, and the ongoing paradigm shift of Industry 4.0, artificial intelligence aims to reshape the landscape of the healthcare and pharmaceutical sectors by delivering smarter and more effective solutions in the field of medicine across the globe. Within the healthcare environment, AI is driving future advancements by predicting clinical outcomes, enhancing diagnostic accuracy, and enabling personalized treatment plans. In the pharmaceutical sector, AI has been implemented at almost every stage, driving innovation from the initial phases of drug discovery through manufacturing and commercial distribution. This review briefly explores the pivotal role of AI-based systems in healthcare and pharmacy. Furthermore, the critical challenges and potential solutions are examined within the context of the evolving frameworks of these industrial revolutions.

Keywords: Drug discovery, Machine learning, Clinical pharmacy.

INTRODUCTION

Traditionally, the healthcare and pharmaceutical industries relied upon manual procedures, clinical intuition, and time-intensive research processes to diagnose, prevent, manage and alleviate symptoms of a disease as well as discover and develop medicinal compounds to improve the quality of life. Over time, the growing complexity of healthcare data, combined with the demand for more efficient, and cost-effective solutions, led to the rapid adoption of several advanced digital technologies (particularly artificial intelligence, robotics, and automation) within the healthcare and pharmaceutical domain. This transition from manual to digital operations is not merely a trend; it represents part of a broader continuum of evolution within the industry, essentially altering the way industries function. The integration of AI into the healthcare and pharmaceutical sectors marks the latest chapter in the continuous evolution of industrial innovations. In Industry 1.0, the focus shifted from manual labour to large-scale machinery that enhanced medicine processing. Industry 2.0 introduced electricity and basic automation, revolutionizing manufacturing capabilities. The advent of computers and the internet marked Industry 3.0, allowing for greater automation of processes. Industry 4.0 features autonomous production systems with little to no human involvement. It employs the powerful fusion of AI-driven systems, Internet of Things with vast data landscapes, automation and adaptive robotics. [1] Finally, Industry 5.0 is essentially built upon three core values that shape the future: prioritizing human well-being, embracing sustainability, and resilience. This is the path toward a more inclusive and eco-conscious industrial landscape. [2, 3]

WHAT IS ARTIFICIAL INTELLIGENCE?

Intelligence refers to the intellectual ability of an individual that enables oneself to acquire knowledge, understand, think creatively, and solve problems related to the complex situations.[4] Artificial Intelligence refers to the automation of cognitive functions. [5] It refers to ability of machines to mimic or simulate intelligence.

THE EVOLUTION OF AI

The origins of artificial intelligence can be traced back to the early 1950s, when English mathematician and computer scientist, Alan Turing introduced the concept of machine intelligence through a paper titled "*Computer Machinery and Intelligence*" and devised the Turing test, originally a deception game, to determine whether a machine is truly capable of simulating human intelligence. In his thought-provoking paper, he raised a question: Could a device created by humans truly possess the ability to function and make decisions in a manner indistinguishable from that of a human being? [6]

The term "artificial intelligence" was established during the influential Dartmouth conference in the summer of 1956 by mathematics professor John McCarthy. In 1957, the first artificial neural network capable of recognizing patterns, *perceptrons*, was developed by Frank Rosenblatt. [7] In 1966, ELIZA, the first chat bot program simulating a human psychotherapist was created by Joseph Weizenbaum. In 1971, INTERNIST-1, the first artificial medical consultant, was developed. [8] At Stanford University in the year 1976, Shortliffe and Buchanan developed MYCIN to diagnose infectious diseases. In 2006, Geoffrey Hinton and his colleagues demonstrated how deep learning architectures can be trained efficiently. In 2011. [9] IBM created Watson, a deep learning system, which was able to outperform human champions in the quiz show *Jeopardy*.

In 2020, DeepMind's AlphaFold was used to predict three-dimensional structures of proteins and BlueDot was able to predict the outbreak of COVID-19 in Wuhan, China, days before the official news alert. [10]

BRANCHES OF AI

- **Natural Language Processing (NLP):** It plays a role in comprehending and translating unstructured input into structured, actionable information.
- **Machine learning (ML):** It uses large amounts of data and algorithms (a set of instructions) to devise predictions without being explicitly programmed. It may be further classified as follows:
    1. **<u>Supervised Learning:</u>** Labeled input data is provided to the AI model. Outputs are specific to the input provided. It does not produce responses beyond the training data.
    2. **<u>Unsupervised Learning:</u>** Models are subjected to unlabeled training data and are allowed to find connections between the input and the output.
    3. **<u>Semi-supervised Learning:</u>** It is a combination of supervised and unsupervised learning used when unlabeled data is sufficiently available and amount of labeled data is insufficient.
    4. **<u>Reinforcement Learning:</u>** Models are trained by repeatedly adjusting and testing their performance, i.e., through a trial and error mechanism.
- **Deep Learning (DL):** It is a subtype of ML based on deep layers of neural networks that uses connections between layers to analyze complicated structures of data. [11]
- **Artificial Neural Networks (ANN):** It is a DL-based algorithmic framework influenced by the intellectual capacity of the human brain. It consists of a network of artificial neurons. [12]

- **Computer vision:** Branch of AI that enables computers to process visual data from videos and images. It isolates objects and captures meaningful information from the given data input.
- **Robotics:** It refers to a system of components capable of analyzing, interpreting, and physically interacting with its environment.
- **Expert systems:** These refer to systems that simulate the decision-making ability of an expert human. [13]

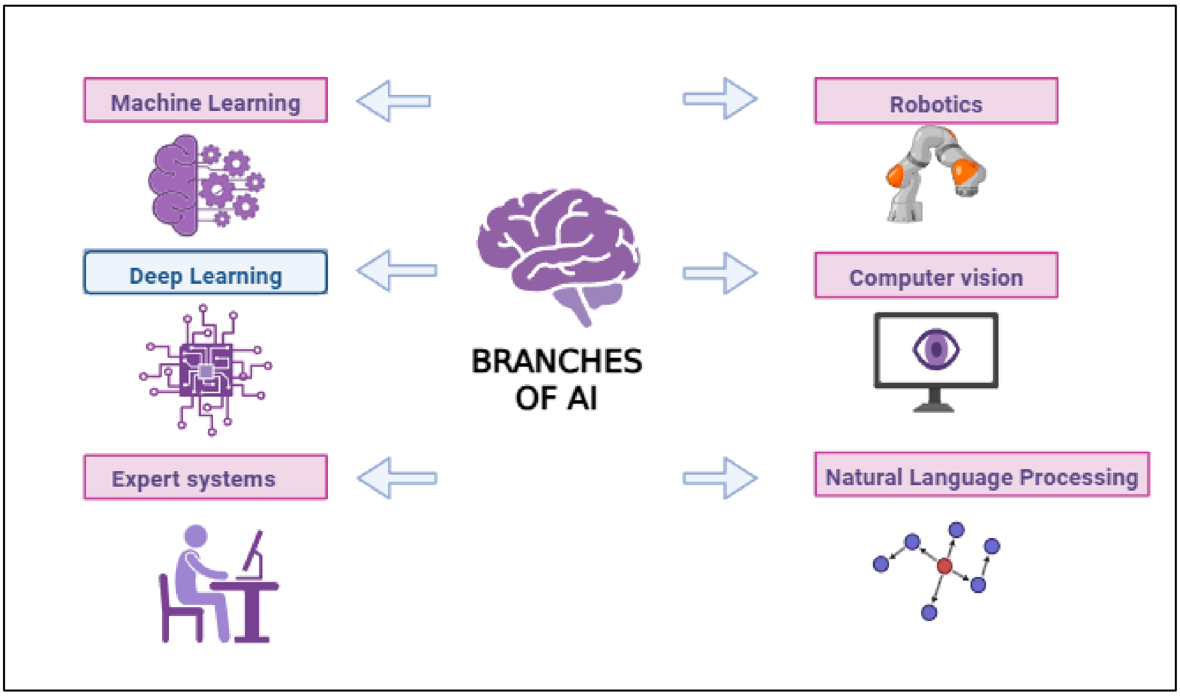

Figure 1: The six main branches of artificial intelligence

CLASSIFICATION OF AI

Artificial intelligence can be categorized based on capability as either weak (narrow); strong (general), or super systems.

✓ **Artificial Narrow Intelligence (ANI):** Narrow AI systems are crafted to perform a specific task. These systems lack the understanding and adaptability that humans possess to navigate complex problems and situations. Examples include applications such as gaming, speech recognition, language translation, and tracking weather updates.

- ✓ **Artificial General Intelligence (AGI):** These systems are actually capable of exhibiting human-level intelligence. These possess the flexibility to think like humans and have a sense of self-awareness. AGI is currently under development.
- ✓ **Artificial Super Intelligence (ASI):** Super AI refers to systems capable of simulating as well as surpassing the human mind in terms of decision-making, creative-thinking, problem-solving and overall performance. Currently, it is purely a theoretical concept. [14]

Depending on their functionality, AI can be classified as either Reactive machines, Limited Memory systems, Theory of mind AI or Self-aware AI.

- ✓ **Reactive Machines:** It refers to the primitive form of AI used for specific applications. It does not have the capability to store memories. Hence, it cannot learn from past experiences and improve its performance over time. Examples include IBM's Deep Blue, the groundbreaking ML model that made history by beating the world chess champion Garry Kasparov in 1997.
- ✓ **Limited Memory AI:** This system has the ability to store limited observations and can use its past experiences to solve complex problems. Limited memory AI can be seen in autonomous vehicles.

- ✓ **<u>Theory of Mind AI:</u>** It is a theoretical concept. It refers to systems that possess beliefs, desires, and emotions similar to humans.
- ✓ **<u>Self-aware AI:</u>** It possesses a sense of self and has consciousness. This type of system does not exist yet. [15]

APPLICATIONS OF AI IN HEALTHCARE

AI in Patient Monitoring:

Real-time patient monitoring guarantees interventions in a timely manner. This can help predict adverse drug reactions quicker and ensure the safety and quality of life of patients. Recent advancements include wireless, data-driven, wearable devices equipped with sensors capable of detecting minor changes in physiological as well as pathological parameters. Remote monitoring can help registered medical practitioners in making sound decisions based on evidence. This is particularly useful in rural areas (telehealth). It is beneficial for geriatric and mobility-limited populations. [16]

AI in Diagnostics and Medical Imaging:

AI can be used to analyze and interpret CT scans, X-rays, ultrasounds and MRI analysis for early detection of abnormalities. AI can quickly make observations and draft reports with minimal human intervention. Due to reduction in handling, long-term exposure of personnel to harmful levels of radiation is also minimized.

AI in Patient Flow and Record Management:

AI can be used to manage waiting times in an efficient manner. By monitoring patient movements and identifying possible delays the hospital personnel can take proper action to streamline the flow. AI can be utilized to plan and optimize appointments or schedules and improve patient experience overall. Records can be maintained, processed, and organized through algorithms. [17]

AI in Surgery:

Virtual reality platforms and robotics play a significant role in this domain in training and assisting the healthcare professionals. The application of artificial intelligence in surgical procedures is particularly beneficial when operations require a high degree of precision and a reduced margin for human error. AI-powered automated systems have been used to conduct minor surgical sutures. [18]

AI in Personalized Medicine:

In personalized medicine, specific treatment plans are generated based on the genetic-makeup, lifestyle, and unique characteristics of the patient. By uncovering the complex relationships between genetic factors and drug responses, AI can help boost the identification of relevant genetic markers and consequently tailor personalized interventions as per the needs of the patients. [19]

APPLICATIONS OF AI IN PHARMACY

AI in Drug Discovery:

Drug discovery includes target identification and validation, hit identification and lead optimization. Manually, these operations require years of extensive, laborious efforts. The end result is often unpredictable. Target identification refers to the determination of specific biological molecules involved in the process of a disease. Once a target is determined, it needs to be validated. ML algorithms have been employed to analyze large amount of omics data to find out possible targets, and disease pathways. AI-based high-throughput screening techniques are used to identify hit molecules, predict the efficacy of lead molecules, and simulate drug-protein binding to predict its affinity to the target. [20]

AI in Drug Development:

This includes pre-clinical trials, clinical trials and post-marketing surveillance. The aim of pre-clinical trials is to evaluate the safety and efficacy of a drug candidate before it is tested in humans. Experiments are conducted *in-vitro* and *in-vivo* during pre-clinical trials. AI, coupled with ML and DL, can be used to predict the success rate of trial. Clinical trials are conducted on human volunteers to confirm the safety and efficacy of the drug. AI can be used to select appropriate candidates depending on inclusion or exclusion criteria. It is used to streamline experimental designs, identify trial endpoints, etc. [21]

AI in Supply Chain Optimization:

AI is used in key areas of supply-chain optimization such as logistics optimization, demand forecasting, supplier selection, managing risks, and inventory management. [22]

AI in Drug Safety:

In drug safety, AI is employed in managing medication adherence, monitoring dosages, and detecting fraudulent prescriptions.

AI in Research:

AI can be utilized summarize key insights and identify gaps in research. AI tools are available for detecting plagiarism, grammatical errors, and other anomalies.

AI in predicting drug-drug interactions:

AI tools can be used to deduce drug-drug interactions and improve clinical outcome. [23]

BENEFITS

1. *Improved speed and efficiency:* Vast amounts of data can be thoroughly analyzed rapidly and efficiently through AI.
2. *Personalization:* AI can be used to customize or tailor services based on user preferences and behavior.

3. *Data-driven insights;* AI can be used to reveal hidden patterns and trends normally not visible to humans.
4. *24/7 availability*: AI can never get tired unlike its human counterparts when it comes to tedious work. Virtual assistants are ideal for round the clock tasks.
5. *Automation:* Incorporation of AI in automated dispensing systems, automated scheduling programs, etc., can significantly reduce the possibility for human error in repetitive and calculation-driven tasks. [24]

CHALLENGES

1. *Lack of abstract thinking and common sense:* It fails to understand context beyond the training data. This can lead to undesirable responses. This issue can be controlled by employing hybrid models that blend abstract reasoning with ML.
2. *Security and privacy concerns:* The information fed to AI models is very sensitive. Therefore, it is important to utilize encryption and ensure strict compliance to privacy protocols. There is a strong need for privacy laws to be implemented with respect to the ethical use of personal information by AI systems.
3. *Data dependency and bias:* Models trained using biased data are only capable of producing biased outputs. To reduce data dependency, it is imperative to use diverse datasets to train the models.
4. *High cost and resource requirement:* AI uses an overwhelming amount of resources for its functioning and maintenance. To curb its impact on the environment and reduce overall costs, the use of readily available pre-trained models should be promoted.
5. *Job displacement:* The integration of AI may result in massive lay-offs. This may potentially lead to the collapse of socio-economic structure. Hence, AI should be designed with a goal of

assisting humans, and should not be able replace them completely.

6. *Over-reliance and misuse:* AI should not be trusted blindly until proper regulations are established as it can be risky. It is necessary to train users on what AI can do and what it cannot do to prevent the misuse of AI. Multidisciplinary teams can be formed to approve and monitor its use in high-risk areas. [25]

CONCLUSION

In conclusion, the field of healthcare and pharmacy has transformed tremendously by harnessing AI-driven technologies within the Industry 4.0 landscape. AI possesses numerous benefits in terms of productivity and time-management. Despite the advantages it provides, the limitations pose a barrier to its implementation in a broad sense. Many researchers and professionals are hesitant and do not trust AI due to the lack of proper regulatory framework and security concerns. Ethics regarding its use and its impact on the environment must be addressed to ensure smooth shift to a sustainable future, one of the primary goals of Industry 5.0. Collaboration between experts belonging to various scientific disciplines may help in speed-running and identifying strong remedies to overcome these problems. AI will continue to advance until the concept of general intelligence is achieved. Hence, it is crucial to stay updated with the dynamic changes taking place in our surroundings, whether we want to or not, in order to avoid falling behind in understanding of current events.

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