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ARTIFICIAL INTELLIGENCE IN PHARMACEUTICAL INDUSTRY

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Abstract:
It has the potential to enhance its use in pharmaceutical research and biotechnology. 3D printing covers a broad range of technical applications in the pharmaceutical field, including new drug delivery systems, developing new excipients, improving drug compatibility, and creating customized dosage forms. In the future, 3D printing could be regulated and used across pharmaceutical and other industries, with proper attention to safety and security. The main potential of AI in the pharmaceutical industry is to cut costs and boost efficiency.A lot of research shows that dynamic learning can create highly accurate AI models that use half or even less information than traditional AI and information subsampling methods. Although the exact reason for this boost in productivity isn't fully clear, it seems that reducing repetition and bias, along with getting more meaningful data to overcome decision limits, play a big role in this improved performance. 3D printing technology can create complex structures in a cost-effective and time-saving way.

Keywords: *Artificial intelligence, History, Technology, Classification, Challenges, Recent Development, Future Scope.*

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INTRODUCTION:

Artificial Intelligence (AI)is a branch of science focused on creating intelligent machines, especially computer programs, that can perform tasks in a way similar to how humans think. In general, AI is used to analyze data and mimic the way people think and make decisions. AI technology helps in doing more accurate analysis and provides useful insights. It combines various statistical models and computational intelligence. The growth and innovation in AI often raise concerns about job loss, but most advancements in AI are celebrated because they bring significant benefits to industries. The first includes traditional computing methods like expert systems, which can simulate human experiences and provide conclusions based on established principles. The second type involves systems that model brain functions using artificial neural networks (ANNs), such as deep neural networks (DNNs) or recurrent neural networks (RNNs). In competitions like Merck Kaggle and NIH Tox21, DNNs have shown better prediction abilities than traditional machine learning methods. Machine learning uses statistical methods to learn either with or without being explicitly programmed. This paper provides an overview of the current state of AI/ML in drug development and highlights new areas where there could be a major impact. We hope this paper offers a balanced view, helps distinguish between hope and hype, and encourages the best use of AI/M.

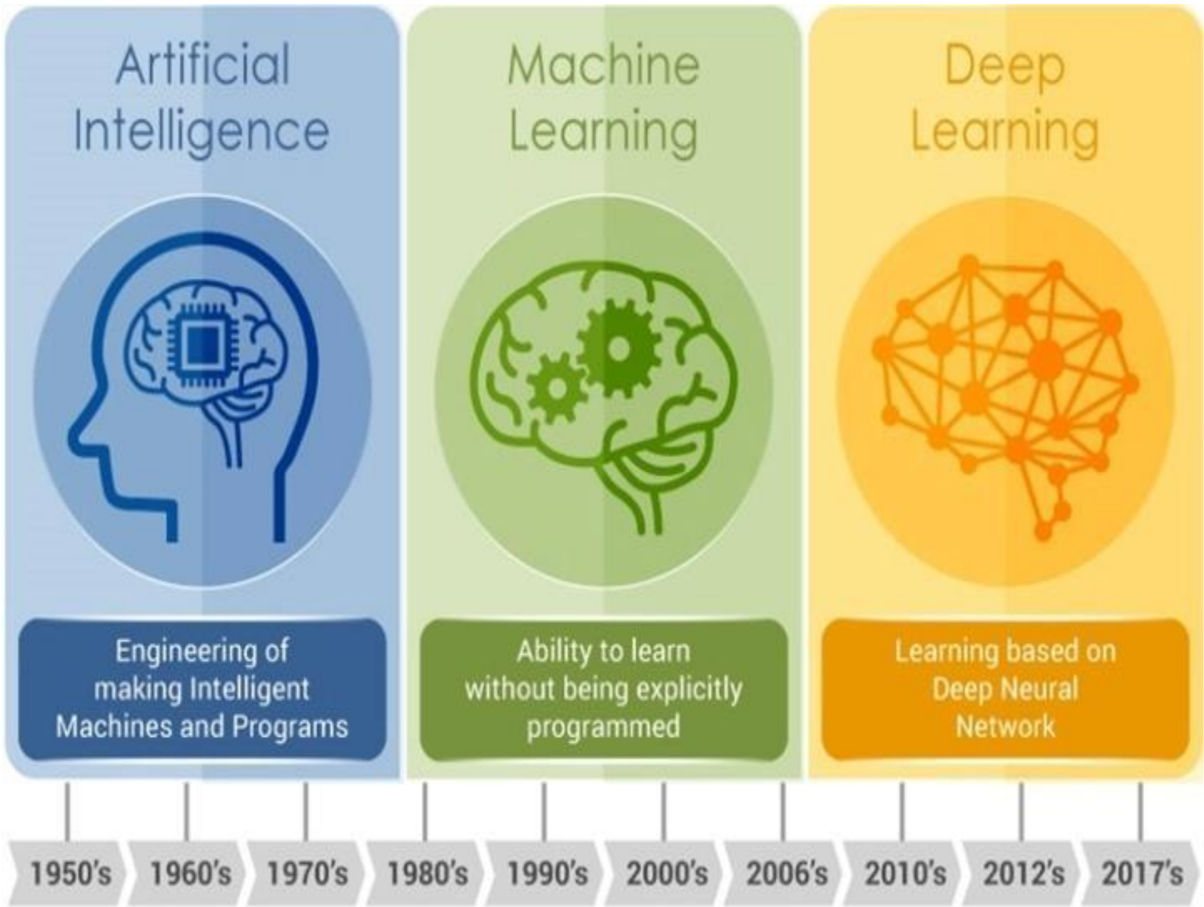


Fig No 1. Chronology of AI and ML

❖ Artificial Intelligence

The goal of AI is to perform tasks, either on its own or together with other systems, in a way that mimics how humans would. AI can use different programming techniques, checks, and ways to recognize patterns to act as expected. The main purpose of AI is to create useful results by analyzing and understanding data deeply. It works by processing information smartly and automatically, with changing parameters. AI aims to imitate human thinking to provide realistic solutions to difficult problems by making better decisions. This includes understanding past experiences and applying new information in a thoughtful way.

HISTORY:

Allen Newell and Herbert A. Simon developed the Logic Theorist, which was created in 1956. That same year, Dartmouth College organized a famous conference. It was predicted that the revenue from the AI market would increase tenfold between 2017 and 2022. The natural language processing market, which has applications like text prediction and speech recognition, was expected to grow by 28.5% in 2017. In 2015, the global revenue from big data and business analytics was $122 billion, and it was anticipated to rise to more than $200 billion by 2020 Artificial intelligence has a history that dates back to the 1950s. For a long time, it was considered a field for dreamers, but this started to change in 1997 when IBM's Deep Blue computer defeated chess champion Garry Kasparov. By 2011, IBM's new Watson supercomputer won the Jeopardy! Game show in the U.S. Since then, Watson has expanded into healthcare and drug discovery, including a partnership with Pfizer in 2016 to speed up drug development in immuno-oncology.

CLASSIFICATION OF AI:

AI can be classified in two different ways: based on its capabilities and based on its presence.
Based on its ability, AI can be categorized as

1. **Artificial Narrow Intelligence (ANI) or Weak AI:**

It is designed to perform specific tasks, such as facial recognition, driving a car, playing chess, managing traffic signals, etc.

2. **Artificial General Intelligence (AGI) or Strong AI:**

It can perform all the tasks that humans can do and is also known as human-level AI.
It can simplify human intellectual abilities and is capable of handling unfamiliar tasks.
Type I: It is used for narrow-purpose applications and cannot use past experiences as it lacks a memory system.
It is known as a reactive machine. Examples of this type include the IBM chess program, which can recognize pieces on a chessboard and make predictions.
Type 2: It has a limited memory system that allows it to use previous experiences to solve different problems.
In self-driving cars, this system makes decisions based on recorded observations, which are used to guide future actions, though these records are not stored permanently.
Type 3: It is based on the "Theory of Mind," meaning that human decisions are influenced by their thoughts, intentions, and desires.
Type 4: It has self-awareness, meaning it has a sense of self and consciousness.
This system also does not currently exist in AI.

TECHNOLOGIES USED IN AI:

Natural language processing (NLP)
This allows computers to process and analyze large amounts of natural language data.
Support vector machine (SVM)
When given labeled training data (supervised learning), the algorithm creates an optimal hyperplane that helps categorize new examples.
Heuristics
These are mental shortcuts that reduce the cognitive effort needed to make decisions.
Examples include using a rule of thumb, making an educated guess, using intuition, making a rough estimate, profiling, or applying common sense.

- **Artificial neural networks (ANN):**

These were first developed back in the 1940s.
They are an information processing model inspired by the way biological nervous systems, such as the brain, process information. An artificial neuron is a mathematical function. ANNs use data samples instead of entire data sets to find solutions, which saves time and money. ANNs consist of three interconnected layers (Python). Neural networks learn in the same way the brain does, usually through a feedback process called back-propagation. Software for artificial neural networks (ANNs) models the pattern recognition capabilities of brain neural networks. Like a single neuron in the brain, an artificial neuron system receives feedback from many external sources, processes it, and makes decisions. Based on their pattern of association, ANNs are classified as supervised associative networks, unsupervised feature-extracting networks, and non-adaptive unsupervised networks. The potential applications of ANN methodology in pharmaceutical sciences range from interpreting analytical data, image recognition, drug and dosage form design through biopharmacy to clinical pharmacy.

ACHIEVING AI

a. **Machine Learning (ML)**

This is a method where the goal is set, and the machine learns how to reach that goal on its own through training.
For instance, if the goal is to recognize a simple object like an apple or an orange, it's not done by writing detailed rules or coding them in advance.

b. **Natural Language Processing (NLP)**

Natural Language Processing refers to the way software automatically handles natural languages, such as speech and written text.
A common example of this technology is emailing spam filtering, which has become much better over time in our email systems.

c. **Computer Vision**

This is a field that allows machines to "see."
Machine vision uses cameras, analog-to-digital conversion, and digital signal processing to capture and analyze visual data. It's similar to how humans use their eyes, but it's not limited by human abilities. For instance, machines can "see" through walls, which would be fascinating if humans could have implants that allowed us to do the same. This

capability is mostly achieved through machine learning, making it closely related to NLP.
Robotics is a branch of engineering that deals with the design and creation of robots.
These machines are used for tasks that are either too dangerous, repetitive, or difficult for humans to perform. Examples include working on car assembly lines, assisting in hospitals, cleaning offices, serving food in restaurants, preparing meals in hotels, patrolling farms, and even acting as police officers.

TOOLS OF AI

Robot pharmacy:

The goal is to improve patient safety, so UCSF Medical Center uses robotic technology to prepare and track medications.
According to them, the technology has prepared 350,000 medication doses without any errors. The robot is much better than humans in terms of size and its ability to deliver accurate medications. The robotic technology can prepare both oral and injectable medicines, including chemotherapy drugs that are toxic.

Fig No 2. Robot pharmacy

MEDi Robot;

It's an AI-powered tool designed for pain management. The robot was created as part of a project led by Tanya Beran, a professor of Community Health Sciences at the University of Calgary in Alberta. She came up with the idea after seeing children cry during medical treatments in hospitals. The robot starts by building a friendly connection with the kids and then explains what will happen during a medical procedure. Even though the robot can't think, plan, or reason on its own, it can be programmed to appear as if it has AI.
Erica is a new caregiving robot developed in Japan by Hiroshi Ishiguro, a professor at Osaka University. It was made with the help of the Japan Science and Technology Agency, Kyoto University, and the Advanced Telecommunications Research Institute International (ATR). It is able to speak Japanese.

TUG Robots:

Aethon TUG robots are designed to move on their own through hospitals and deliver medications, meals, specimens, materials, and carry heavy items like linen and trash.
The TUG can handle various types of carts or racks, making it a highly flexible and useful tool.

Automated Control Process System (ACPS):

The components of the ACPS include:
- Sensing the value of process variables.
- Transmitting a signal to the measuring element.
- Measuring the process variable.
- Presenting the measured value.

Berg:

Berg is a Boston-based biotech company that uses AI in various processes.
It has an AI platform for drug discovery, which includes a large patient database. This database is used to identify and validate various biomarkers.
The company identifies diseases and then creates treatment plans based on the information gathered. Their goal is to make the drug discovery process faster and more affordable by using AI, which removes the guesswork involved in developing new medicines.

Manufacturing Execution System (MES)

Using MES helps ensure compliance with legal standards, reduces risks, improves transparency, shortens production time, makes better use of resources, controls and monitors each step of production, and ensures quality up to the final batch release.

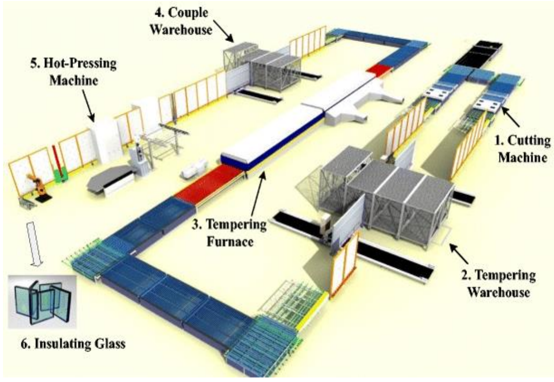


Fig No 3. Manufacturing Execution System

Verge is using automated data collection and analysis to address key challenges in finding new drugs. Basically, they are using algorithms to study hundreds of genes that have complex roles in brain diseases like Alzheimer's, Parkinson's, or ALS. Verge believes that gathering and analyzing gene data can improve the drug discovery process, especially in the early stages before clinical trials begin. Their goal is to use AI to track how specific treatments affect the human brain during the preclinical phase.

Development of New Peptides from Natural Foods

The Irish startup Nerites uses AI and other advanced technologies to help find new and stronger food ingredients and health-related compounds.

BASF, a well-known company, is working with Nerites to create new functional peptides from natural sources. In practice, BASF uses Neritas AI and DNA analysis tools to predict, study, and confirm the effectiveness of peptides from natural materials.

Treatment and Management of Rare Diseases

There has been progress in AI technology, and there is renewed focus on developing treatments for rare diseases.

Right now, more than 350 million people worldwide are affected by over 7,000 rare diseases. However, there are positive developments for patients with rare diseases. For example, Heal, a UK-based biotech company, has raised $10 million in Series A funding to use AI in creating new drugs for rare conditions. Similarly, Thera Chon, a Swiss biotech firm that uses AI to develop drugs for rare genetic diseases, has received $60 million in funding.

RECENT DEVELOPMENTS IN AI:

AI in Healthcare:

A study of 10 promising AI applications found that they could save up to $150 billion annually in the U.S. healthcare system by 2026. These savings come from reducing healthcare costs through image processing, protecting patients' personal records from cybercriminals, and assisting during surgeries. AI-powered workflow assistants are helping doctors save time and reduce costs. AI also supports pathologists in analyzing tissue samples, leading to more accurate diagnoses. According to Harvard Business Review and Accenture, there are 10 potential applications of AI that could significantly change the healthcare industry.

AI in Drug Discovery:

Machine learning and artificial intelligence are changing the way scientific discoveries are made by helping scientists explore large amounts of research data and improve their scientific insights. Benevolent AI used this technology to find several compounds, including compound A, which could have therapeutic potential. Potential in (Amyotrophic Lateral Sclerosis) ALS. In December 2017, BenchSci and The Science Academy conducted a survey that found the stages where AI is used in the drug discovery process include: target identification and validation, safety tests, compound discovery, lead optimization, preclinical studies, formulation, clinical studies which include clinical trial recruitment, approval, marketing, and post-marketing surveillance. Based on the importance and growing popularity of AI in drug discovery, the Journal of Medicinal Chemistry, published by ACS, is planning to publish a special issue on "Artificial Intelligence in Drug Discovery." The roadmap includes moving from clinical data generation to natural language processing data enrichment, to machine learning data analysis, and then to clinical decision-making.

Advantages of 3D Printed Drug Delivery:

High drug loading capacity compared to traditional dosage forms.

Reduced production costs due to less material waste.

Medication can be customized for each patient based on age, gender, genetic differences, ethnic background, and environment.

Treatment can be tailored to improve patient compliance, especially in cases where multiple drugs are used with different dosing schedules.

Avoids batch-to-batch variations that occur in the mass production of traditional dosage forms

3D printers take up little space and are affordable.

Techniques in 3D Printing:

There is many different manufacturing methods used in 3D printing, all of which are based on digitally controlled layer-by-layer deposition of materials to create complex shapes.

Thermal Inkjet Printing

In thermal inkjet printing, an aqueous ink fluid is heated to become vapor, which expands and pushes the ink out of a nozzle.

It is used in making drug-loaded biodegradable microspheres, drug-loaded liposomes, microelectrode arrays, coatings, and drug-eluting stents. It is also an effective method for creating films of biological materials without affecting protein activity.

Inkjet Printing

This technique deposits ink onto a substrate either through Continuous Inkjet printing or Drop-on-Demand printing. It allows for high-resolution printing and has a low cost, fast processing rate, and generates minimal waste. It provides CAD data in a 'direct write' way and can process materials over large areas with very little contamination.

Fused Deposition Modeling (FDM)

Fused Deposition Modeling (FDM) is a common method used in 3D printing.

In this process, materials are softened or melted by heat to create objects. FDM 3D printing is useful for making delayed-release tablets without the need for an outer enteric coating and also enables personalized medicine doses.

Extrusion 3D Printing

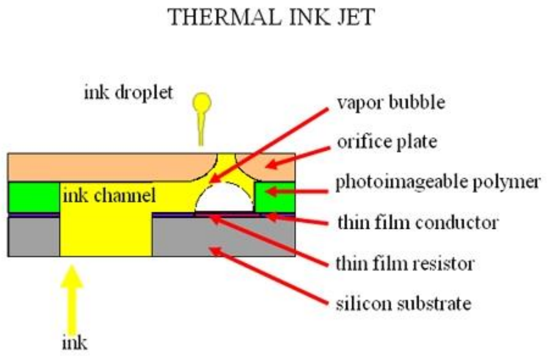
In this method, the material is extruded from an automated nozzle onto the substrate without the need for any additional support material.

It is mainly used to fabricate tablets containing guaifenesin, which helps with expectoration. The materials that can be extruded include molten polymers, suspensions, semisolids, and pastes.

Zip Dose

Zip dose is the world's first and only FDA-approved, commercial-scale 3D printing (3DP) method

currently used in therapeutic areas for pharmaceutical manufacturing.
It features distinctive digitally coded layering and



zero compression practices, making it suitable for tablets with large dosages and rapid disintegration.

Hot Melt Extrusion (HME)

Hot melt extrusion (HME) is a process where the polymer and drug are melted at a high temperature.
Hot melt extrusion is a continuous manufacturing method that includes feeding, heating, mixing, and shaping materials. In recent years, it has shown its ability to improve the solubility and bioavailability of drugs that are only moderately soluble.

3D Printer

The 3D printer is a special tool used to create medications that have customized release patterns and are more comfortable for patients.

Stereo lithography

Stereo lithography is a method that uses a computer-controlled laser beam to turn liquid polymer resin into a solid, thereby creating a 3D structure.
Compared to earlier types of 3D printing, stereo lithography offers better resolution and avoids the use of heat, which can be harmful to certain drug molecules.

Selective Laser Sintering

Selective laser sintering (SLS) works by melting particles in a powder bed to bond them together.
During the printing process, a laser is used to draw a specific pattern on the surface of the powder bed, forming a 3D structure. For example, Paracetamol in the form of an or dispersible tablet is made using this method.

Laser-Based Writing System

Based on the principle of photo polymerization, this system releases free radicals that can contribute to various diseases through interactions between the photo initiator and ultraviolet light.

Continuous Layer Interface Production

This is an improvement in printing technology related to printing speed.
However, the method creates 3D structures without layer-by-layer processes. The speed is increased by an oxygen-enriched zone, which helps and ensures successful photo-polymerization. Inkjet printing is used to create free-form structures by hardening materials drop by drop.

Powder-Based 3D Printing

This technique uses a powder bed and jetting method to create thin layers of powder.
A liquid binder, which can include binders or active pharmaceutical ingredients (APIs), is applied using inkjet printers.

Fig No 4. Tharmal Ink Jet

ADVANTAGES OF AI TECHNOLOGY:

1) Error minimization: AI helps to reduce errors and increase accuracy with more precision.
2) Difficult exploration: AI is very useful in the mining industry.
3) Daily application: AI is very helpful for our everyday activities.

APPLICATION:

(1) In Formulation:

Controlled release tablets: The first work using neural networks to model pharmaceutical formulations was done by Hussain and their team at the University of Cincinnati (OH, USA).

(2) In Product Development:

The process of developing pharmaceutical products is a multivariate optimization problem.It involves optimizing both formulation and process variables. One of the most useful features of artificial neural networks is their ability to generalize.

CHALLENGES IN ADOPTING AI IN PHARMA COMPANIES:

1.Lack of familiarity with the technology - for many pharma companies, AI still feels like a "black box" because it's new and complicated to understand.

Fig No 5. Challenges in adopting AI in pharma

FUTURE SCOPE:

Machine learning techniques can handle complex analysis of large, varied, and high-dimensional data sets without needing manual input, which has already proven helpful in writing business applications. Combining machine learning, especially deep learning, with human skills and experience could be the best way to manage vast data stores. The powerful information-mining ability of AI innovations has added new essential value to computer-supported medical plans that take into account multiple clinical factors. As more clinical data is collected and AI continues to improve, these benefits will likely grow even further.AI is expected to help in many areas of drug discovery and development, and eventually become the standard way to create medication plans with computer support. This will be important for making drug development faster, cheaper, and more successful: this is the main goal of using AI in this area.

CONCLUSION:

The main potential of AI in the pharmaceutical industry is to cut costs and boost efficiency.A lot of research shows that dynamic learning can create highly accurate AI models that use half or even less information than traditional AI and information subsampling methods. Although the exact reason for this boost in productivity isn't fully clear, it seems that reducing repetition and bias, along with getting more meaningful data to overcome decision limits, play a big role in this improved performance. 3D printing technology can create complex structures in a cost-effective and time-saving way. It has the potential to enhance its use in pharmaceutical research and biotechnology. 3D printing covers a broad range of technical applications in the pharmaceutical field, including new drug delivery systems, developing new excipients, improving drug compatibility, and creating customized dosage forms. In the future, 3D printing could be regulated and used across pharmaceutical and other industries, with proper attention to safety and security.

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