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Mini Review

A Detailed Review on Artificial Intelligence in Pharmacy

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ABSTRACT

Artificial Intelligence (AI) focuses in producing intelligent modelling, which helps in imagining knowledge, cracking problems and decision making. Recently, AI plays an important role in various fields of pharmacy like drug discovery, drug delivery formulation development, poly pharmacology, hospital pharmacy, etc. In drug discovery and drug delivery formulation development, various Artificial Neural Networks (ANNs) like Deep Neural Networks (DNNs) or Recurrent Neural Networks (RNNs) are being employed. AI technologies are revolutionizing drug discovery, clinical trials, personalized medicine, drug manufacturing, and more. Despite these limitations, AI holds significant promise in transforming the pharmaceutical landscape, enhancing efficiency, and improving patient outcomes. In the current review article, the uses of AI in pharmacy, especially in drug discovery, drug delivery formulation development, poly pharmacology and hospital pharmacy are discussed.

INTRODUCTION

AI is a stream of science related to intelligent machine learning, mainly intelligent computer programs, which provides results in a similar way to the human attention process. Novel pharmaceutical innovations are range from small drug molecules to biologics, with a preference for better stability with high potency to fulfil unmet needs to treat diseases. Artificial intelligence (AI) is being introduced into pharmacy to personalized, efficient, and effective. Recently, AI technology becomes a very fundamental part of the industry for useful applications in many technical and research fields. An introduction to a review article on AI in pharmacy often defines AI as a field that uses intelligent algorithms to solve complex problems, and highlights its growing importance in key pharmacy areas like drug discovery, clinical decision-making, and operational efficiency. It emphasizes that AI, driven by advances in machine learning and large datasets, is transforming the industry by making processes faster and more cost-effective, from identifying drug targets to personalizing patient care. Numerous industries are striving to enhance

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their progress to meet the demands and expectations of their customers, utilizing various methodologies. The pharmaceutical industry is a critical field that plays a vital role in saving lives. It operates based on continuous innovation and the adoption of new technologies to address global healthcare challenges and respond to medical emergencies, such as the recent pandemic. In the pharmaceutical industry, innovation is typically predicated on extensive research and development across various domains, including but not limited to manufacturing technology, packaging considerations, and customer-oriented marketing strategies. Novel pharmaceutical innovations are range from small drug molecules to biologics, with a preference for better stability with high potency to fulfil unmet needs to treat diseases.

History of AI:

The history of Artificial intelligence (AI) in the pharmaceutical industry is one of accelerating integration, moving from early automation to its current role in complex drug discovery, clinical research, and personalized medicine. Initially driven by the need to manage massive data sets and streamline processes, AI has evolved to encompass machine learning, deep learning, and natural language processing to address key industry challenges like high costs and low success rates in drug development. This evolution has enabled AI to impact nearly every stage, from target identification and drug design to clinical trial optimization and supply chain management.

Modern integration in research and development

Drug Discovery:

AI's ability to analyze vast biological data (genomics, proteomics) has become critical for identifying disease targets and predicting interactions with drug candidates, leading to a more efficient and targeted approach.

Drug Design:

AI is used to predict the properties of drug candidates and optimize lead compounds, significantly reducing the time and cost associated with preclinical studies.

Clinical Trials:

AI aids in the design and recruitment for clinical trials by analyzing data from sources like social media and doctor visits to find suitable participants and predict potential issues.

Personalized Medicine:

AI algorithms analyze real-world patient data to tailor treatments, leading to more effective outcomes and better patient adherence.

Table 1: Important milestones in the area of the AI uses.

Year	Events
1943	Walter Pitts and Warren McCulloch proved that logical operations like "and", "or" or "not" can be done by neurons connected in a network
1956	The term 'artificial intelligence' was first appeared.
1958	Frank Rosenblatt created neuronal networks called Perceptrons which can transmit information in one direction.
1974	Initiation of "First AI Winter".
1986	Georey Hinton promoted Back propagation algorithm design which is widely used in deep learning.
1987	Initiation of "AI winter".
1997	Garry Kasparov (Russian grandmaster) was defeated by IBM Deep blue.
2013	Google carried out efficient research on pictures by utilizing the British technology.
2016	In this year, the Go Champion Lee Sedol was defeated by Google DeepMind, software AlphaGo.

Key milestones

2014: The invention of Generative Adversarial Networks (GANs) provided a breakthrough in generative AI, allowing for the creation of new molecular structures.

Late 2010s: The first AI-designed drugs entered preclinical and early-stage clinical trials. Notable examples include In silico Medicine's drug candidate for idiopathic pulmonary fibrosis and Deep Genomics' therapeutic candidate for Wilson disease.

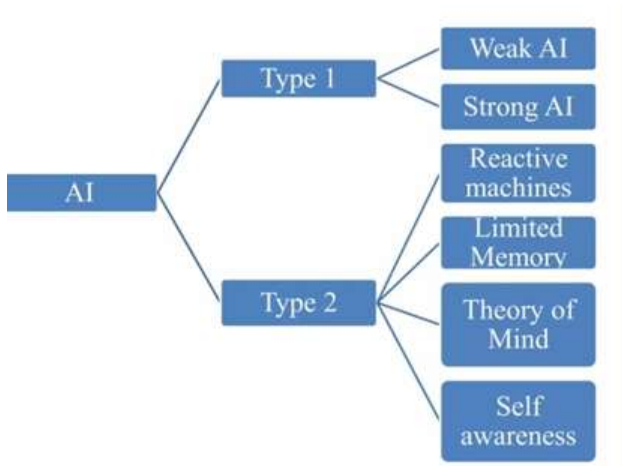
Drug repurposing: AI algorithms demonstrated success in repurposing existing drugs for new therapeutic uses. For instance, AI helped identify new indications for existing drugs during the COVID-19 pandemic and is being used to find treatments for rare diseases.

Manufacturing and supply chain: AI applications extended beyond R&D to optimize pharmaceutical manufacturing. AI now supports quality control, predictive maintenance, and supply chain management.

2025 and beyond: Projections indicate that AI will be central to the pharmaceutical industry. The World Economic Forum estimates that by 2025, 30% of new drug discoveries will be driven by AI, leading to significant reductions in cost and time.

Classification of AI:

AI in pharmacy can be classified by its function, such as drug discovery, clinical decision support, and operational optimization. It can also be classified by its technical capabilities, including machine learning, Natural language processing (NLP), and Robotics.



Types of AI

AI can be classified into two different ways: according to calibre and their presence.

Artificial Narrow Intelligence (ANI) (Weak AI):

Systems designed to perform a specific, narrow task, such as facial recognition or playing chess. This is the type of AI currently used in most pharmacy applications, like specific software for prescription verification or medication adherence.

Artificial General Intelligence (AGI) (Strong AI):

A hypothetical AI with human-level intellectual abilities that can understand and perform any intellectual task a human can. This level of AI is not yet present but represents a future goal for AI in pharmacy.

Artificial Super Intelligence (ASI):

A hypothetical AI that is smarter than the smartest humans. This is also a future concept with no current presence in the field.

Reactive Machines: These are the most basic AI systems. They do not have memory and cannot use past experiences to inform future decisions. They perceive the world directly and react to it based on a pre-defined set of rules.

Example: IBM's Deep Blue, which famously beat a chess grandmaster, could identify pieces on a chessboard and predict moves but had no memory of past games.

Limited Memory AI: Most modern AI systems fall into this category. They can store some past information for a short period to make informed decisions. This memory is temporary and not stored permanently.

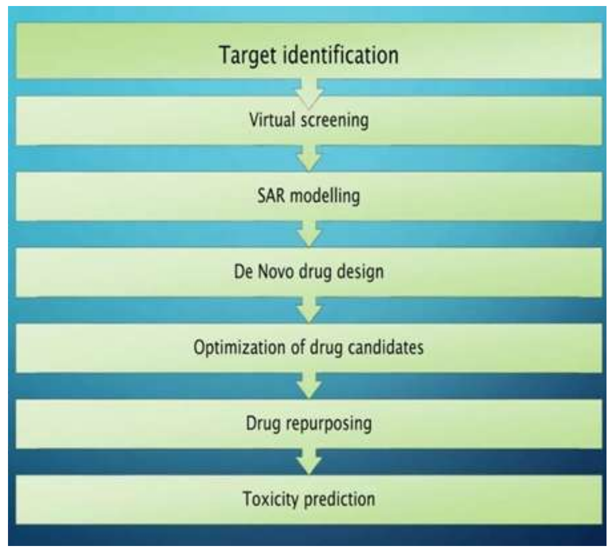
Example: Self-driving cars, which use recent observations of other cars' speed and direction to make navigational decisions.

Theory of Mind AI: This is a theoretical and more advanced AI that would understand the concept of a "mind," recognizing that people, creatures, and objects have beliefs, desires, intentions, and emotions that can influence their own behavior.

Self-Aware AI: A hypothetical AI with consciousness and a sense of self, able to understand its own internal states and existence. This is the final stage of AI development, which has yet to be achieved.

Drug discovery cycle:

AI is transforming the drug discovery cycle by using machine learning and deep learning to analyze vast datasets, identify potential drug candidates, predict efficacy and toxicity, and optimize lead compounds. These techniques accelerate the process, reduce costs, and improve success rates by analyzing compound libraries more quickly and providing more accurate predictions than traditional methods. Review articles highlight that AI applications span the entire discovery pipeline, from initial target identification to preclinical testing and clinical trial design, although challenges like data quality and regulatory concerns remain.



AI in drug discovery

Target Identification:

AI analyzes large datasets, including genomic and proteomic data, to identify novel disease targets and validate them more efficiently.

Drug Candidate Identification:

AI models can perform virtual screening of millions of compounds to identify those with the highest likelihood of binding to a target, drastically reducing the time and cost of experimental screening.

Hit and Lead Optimization:

AI can help optimize drug structures by predicting their properties, such as efficacy, toxicity, and pharmacokinetics, allowing for more efficient selection of promising leads.

Preclinical and Clinical Trials:

AI can predict drug efficacy and toxicity, potentially reducing the number of compounds that fail in later stages. It also aids in optimizing clinical trial designs by analyzing patient data, improving recruitment, and automating data collection and analysis to potentially shorten trial durations.

AI techniques in drug discovery

Machine Learning (ML):

Includes supervised learning (e.g., for toxicity prediction), unsupervised learning (e.g., for grouping compounds), and reinforcement learning (e.g., for generating novel molecules).

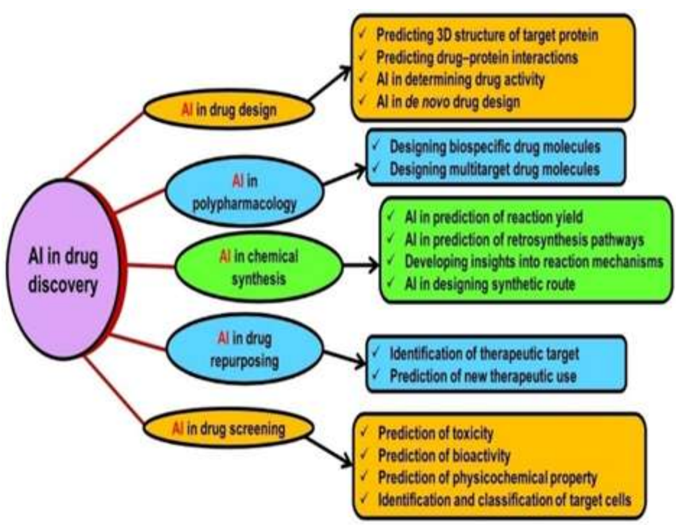
Deep Learning (DL):

A subfield of ML that uses artificial neural networks, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), to analyze complex data patterns.

AI with Pharma:

Artificial intelligence (AI) is transforming the pharmaceutical industry by enhancing nearly every stage of the drug lifecycle, from initial research and development (R&D) to post-market surveillance. By analyzing massive datasets, AI accelerates timelines, improves accuracy, and drives innovation, with McKinsey estimating it could generate $60 to $110 billion in annual value for the sector.

Transforming the drug discovery cycle process:



AI in drug development process

Target Identification:

AI analyzes large datasets to identify novel drug targets and understand complex biological pathways.

Compound Screening and Design:

AI helps find "hit" compounds by sifting through vast libraries and even designs entirely new molecules with desired properties.

Lead Optimization:

AI optimizes lead compounds by predicting their properties and improving their efficacy and safety profiles, often more efficiently than traditional methods.

Toxicity Prediction:

AI models can predict the potential toxicity of a drug candidate early in the development process, reducing later-stage failures.

Drug Repurposing:

AI can identify new uses for existing drugs by analyzing their effects and interactions with different targets.

Clinical Trials:

AI helps in optimizing clinical trial design, patient recruitment, and analyzing trial data, which can lead to faster and more successful trials.

Artificial intelligence (AI) accelerates and enhances the drug discovery cycle across all stages, from identifying initial targets to post-market surveillance. By leveraging Machine learning (ML) and vast datasets, AI reduces the cost, time, and high failure rates associated with traditional, manual methods.

1. **Target identification and validation**

AI analyzes genetic, proteomic, and clinical data to identify and validate potential biological targets, such as specific proteins or pathways that cause disease.

Traditional method: Relied on existing knowledge and complex manual analysis.

AI advantage: AI can find targets not easily addressed by traditional methods, including "undruggable" proteins, by processing enormous datasets and identifying intricate patterns.

AI techniques: Deep learning models, like graph-convolutional networks, analyze protein structures from microscopy data to predict function.

2. **Compound screening and lead optimization**

AI speeds up the process of finding and refining lead compounds, the most promising potential drug candidates.

Traditional method: High-through put screening is used to test millions of compounds, which is time-consuming and expensive.

AI advantage: Virtual screening uses AI algorithms to simulate interactions and predict the binding affinity between compounds and targets, significantly narrowing the pool of molecules for lab testing.

3**. Preclinical studies**

AI helps predict a drug candidate's toxicity and pharmacokinetics early in the development process. This reduces the need for extensive animal testing and minimizes the risk of failures in later stages.

Traditional method: Extensive and time-consuming laboratory safety and efficacy assessments.

AI advantage: Predictive models, such as the Deep Tox algorithm, predict the toxicity of compounds based on their chemical structures and characteristics.

AI techniques:

Wearable devices and sensors provide real-time data collection for continuous patient monitoring, allowing for adaptive trials.

Predictive modeling can analyze historical trial data to optimize design and improve outcomes.

5. FDA approval and post-market surveillance

AI continues to provide valuable insights after a drug has been approved for market.

Traditional method: Primarily relied on voluntary reports from healthcare professionals and manual data review.

AI advantage: AI systems can monitor drug safety in real time by analyzing electronic health records, social media, and other data to detect signals of adverse events.

AI techniques:

NLP helps analyze large volumes of literature and reports for adverse drug reactions.

Risk prediction algorithms forecast the likelihood of side effects based on a patient's individual characteristics.

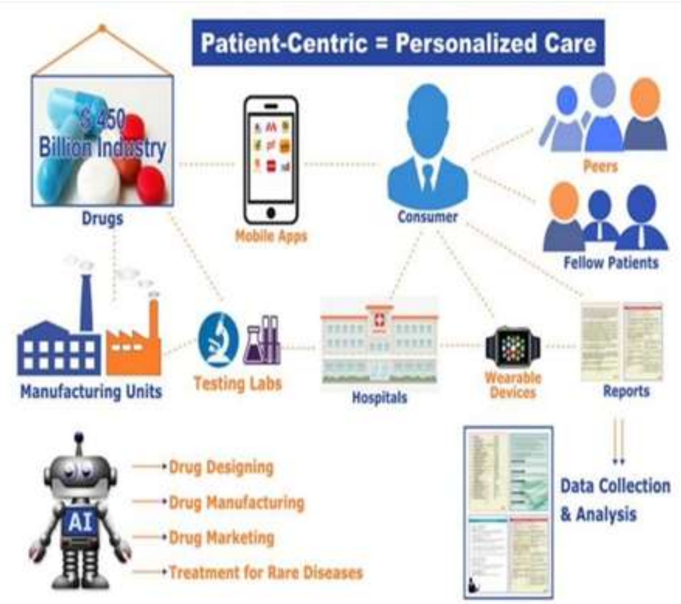
Applications:

There are several applications of AI in hospital-based health care systems in organizing dosage forms for individualized patients and selecting suitable or available administration routes or treatment policies.

- **Maintaining of medical records**
- **Treatment plan designing**
- **Assisting in repetitive tasks**
- **Health support and medication assistance**
- **Accuracy of medicine**
- **Drug creation**
- **AI helps people in the health care system**

Healthcare system analysis

Review articles on the application of AI in pharmacy on SlideShare highlight its use in areas like drug discovery and development, clinical decision support, and personalized medicine. These presentations, often available as PowerPoint files, detail how AI, particularly machine learning and neural networks, can accelerate processes like drug formulation, predict drug interactions, and improve medication management.



Benefits of using Artificial Intelligence in drug development

- Increased efficiency and reduced costs in drug development.

- Improved patient outcomes through personalized medicine and better medication management.
- Enhanced safety through features like drug interaction alerts.

Challenges:

- Data privacy concerns.
- High implementation costs.
- The need for domain expertise to train algorithms and interpret results.
- Ethical considerations, such as algorithmic bias and accountability in case of errors.

AI in the future of pharmacy education:

AI with pharmacy education

As the healthcare sector continues to evolve, the demand for well-prepared pharmacists is greater than ever. Pharmacy education must adapt to meet these changing needs, and AI presents numerous opportunities for enhancement. From personalized learning experiences to automated administrative tasks, AI has the potential to revolutionize the educational landscape.

1. Current State of Pharmacy Education

Pharmacy education traditionally involves a mix of theoretical knowledge and practical experience. With a curriculum that emphasizes pharmacology, therapeutics, and patient care, the challenge lies in keeping this content relevant and engaging. The increasing complexity of drug therapy management necessitates innovative teaching strategies.

Traditional Methods Current pedagogical methods often include lectures, laboratory work, and experiential learning. While these methods provide foundational knowledge, they can be limited in addressing individual student needs and adapting to different learning styles.

Challenges in Pharmacy Education

- **Curriculum Relevance**: Ensuring that the curriculum reflects the latest advances in pharmacotherapy.
- **Student Engagement**: Maintaining student interest and motivation in a challenging field.
- **Workforce Preparation**: Equipping students with skills relevant to modern pharmacy practice.

2. The Emergence of AI in Education:

AI has rapidly emerged as a tool to address these challenges across various fields, including pharmacy education. Its ability to process large datasets, analyze learning patterns, and provide personalized feedback offers exciting possibilities for educators and students alike.

Defining AI in Education

AI in education encompasses a variety of technologies, including machine learning, natural language processing, and data analytics. These technologies can be applied in numerous ways to enhance learning and teaching.

AI in the future pharmacy

3. Applications of AI in Pharmacy Education:

1. Personalized Learning

AI algorithms can analyze individual learning styles, preferences, and performance data to tailor educational experiences. This personalization can enhance student engagement and improve learning outcomes.

2. Virtual Simulations

AI-driven simulations provide students with realistic patient care scenarios, allowing them to practice clinical decision-making in a risk-free environment.

3. Intelligent Tutoring Systems

These systems use AI to provide immediate feedback and support to students, mimicking the one-on-one interaction of a tutor.

4. Administrative Efficiency

AI can streamline administrative tasks such as grading, scheduling, and student assessments, allowing faculty to focus more on teaching and mentoring.

4. Benefits of AI Integration in Pharmacy Education:

1. Enhanced Learning Outcomes

Research suggests that personalized learning through AI can lead to improved academic performance. Students who receive tailored educational experiences are often more engaged and motivated.

2. Increased Accessibility

AI tools can provide resources and support to students who may struggle with traditional learning methods, ensuring that all students have the opportunity to succeed.

3. Improved Preparedness for Practice

By integrating AI into the curriculum, students can become familiar with the technologies they will encounter in their professional lives, better preparing them for the workforce.

5. Future Directions

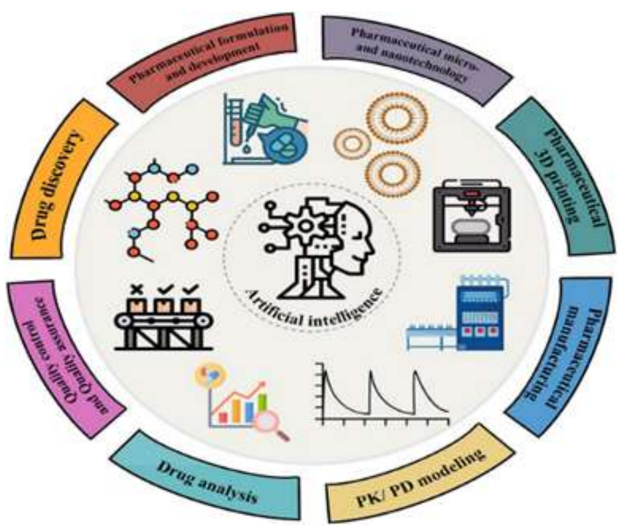
Research Opportunities: Further research is needed to evaluate the long-term impact of AI on pharmacy education. Studies focusing on student outcomes, faculty experiences, and curriculum development.

Policy Development: As AI continues to evolve, educational institutions must develop policies that guide its ethical use. Establishing standards will help ensure that AI technologies are implemented responsibly.

Collaboration with Industry: Partnerships between educational institutions and technology companies can facilitate the development and implementation of AI tools tailored to pharmacy education.

AI in pharmacy research:

Artificial intelligence (AI) is rapidly transforming pharmacy research and practice by enhancing drug discovery, personalized medicine, operational efficiency, and patient safety, among other areas. As artificial intelligence (AI) becomes more powerful, it can make our lives more convenient and solve challenging problems for large organizations. By using large amounts of data to solve problems and identify patterns. This can be particularly valuable in health care research and practice, where challenges are vast, and resources are often limited. While many AI technologies are still new, the Leslie Dan Faculty of Pharmacy recognizes the importance this technology will play in health care in the future. That's why it has embedded use of emerging digital technologies as a pillar of its academic plan. AI improves drug discovery processes in pharmacy research primarily by accelerating and enhancing various stages of drug development with greater precision and efficiency. And members throughout the faculty are using and preparing to use AI in various ways for research, practice and education. AI in pharmacy drug research accelerates drug discovery, enhances accuracy in target identification and compound optimization, reduces costs and timelines, and supports personalized treatments, marking a significant evolution in pharmaceutical innovation and patient care. Artificial intelligence (AI) plays a transformative role in pharmacy drug research, particularly in drug discovery and development. AI techniques, including machine learning, deep learning, and neural networks, enable the analysis of large-scale biological and chemical data to identify disease-associated targets and predict interactions with potential drug candidates more efficiently than traditional methods. This accelerates the drug discovery process, optimizing lead compounds and reducing the time and cost traditionally required for drug development, which can take up to 12-14 years and billions of dollars. Pharmaceutical companies leverage AI platforms to screen vast chemical libraries at unprecedented scale and speed, enabling discovery of novel drug candidates for complex diseases like cancer and immune-mediated disorders. Regulatory agencies like the FDA acknowledge AI's growing role, promoting frameworks to ensure safe, effective, and innovative AI-driven drug development.



AI in Pharmacy Research and Drug Development

Applications in Pharmacy Research

Drug discovery and development:

AI algorithms analyze large datasets to identify potential drug candidates, predict their interactions, and optimize formulations, significantly reducing time and costs compared to traditional methods. Advanced models like neural networks and generative adversarial networks are used for virtual screening and de novo molecule generation, accelerating early-stage research.

Personalized treatment: AI supports precision medicine by analyzing individual genetic, lifestyle, and medical data to customize treatment plans, reduce adverse effects, and improve outcomes.

Clinical decision support: AI helps pharmacists and healthcare providers make evidence-based decisions, assess drug interactions, monitor adverse drug events, and enhance medication safety and efficacy.

Automation and operational efficiency: From automating dispensing processes to streamlining workflows, AI improves accuracy, reduces manual effort, and minimizes errors in pharmacy practice.

AI in the future of pharmacy research

AI in drug research include target identification, virtual screening of chemical structures, molecular modeling, and prediction of pharmacokinetics and toxicity, which helps prioritize promising compounds for further testing.

AI-powered tools, such as generative adversarial networks (GANs), convolutional neural networks (CNNs), and reinforcement learning, are widely used to optimize molecular design and drug efficacy prediction.

Future pharmacy development with AI

These models also contribute to personalized medicine by analyzing patient data to tailor treatments.

AI in Dispensing of Pharmacy:

Artificial intelligence (AI) in pharmacy dispensing is revolutionizing the way medications are managed and delivered, enhancing safety, efficiency, and patient outcomes. AI technologies like machine learning and natural language processing analyze patient data (medical history, allergies, and drug interactions) to aid pharmacists in making accurate and informed decisions regarding drug dosages, delivery, and medication reconciliation. This reduces dispensing errors and improves treatment outcomes.

AI in the pharmacy development

AI powered automation streamlines pharmacy workflow by managing inventory, predicting drug demand, automating prescription refills, and minimizing stock wastage. Robotic dispensing systems equipped with AI accurately package and label medications, reducing human error and freeing pharmacists to focus on patient care.

Benefits of AI in pharmacy dispensing:

- **Streamlined Workflow and Efficiency:** AI automates routine tasks such as medication packaging, labeling, prescription reordering, and inventory management, reducing administrative burden and freeing pharmacists to focus on patient care. It optimizes stock levels by predicting drug demand and minimizing wastage.

- **Enhanced Patient Safety:** AI helps detect medication errors, adverse drug reactions, and potential drug interactions, reducing risks and hospital readmissions. AI-powered systems can monitor patient compliance with medication regimens, reminding patients and improving adherence.

- **Personalized Medicine and Improved Outcomes:** By analyzing patient data including medical history, allergies, and genetic information.AI supports pharmacists in tailoring treatments and identifying patients at risk of complications, enabling early interventions.

- **Decision Support:** AI provides pharmacists with intelligent decision-making tools that categorize prescriptions by urgency, prioritize pharmacist workload, and streamline approval processes. This improves efficiency and safety in dispensing.

- **Administrative Efficiency:** AI reduces paperwork and simplifies communication with health insurers and patients, lessening the time spent on non-clinical tasks.

AI dispensing the medications in pharmacy

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