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ARTIFICIAL INTELLIGENCE: THE BEGINNING OF A NEW ERA IN PHARMACY PROFESSION

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ABSTRACT
Artificial intelligence (AI) is a field within computer science focused on problem-solving through symbolic programming. It has significantly advanced into a discipline of problem-solving with extensive applications in business, healthcare, and engineering. A key application of AI is the creation of expert systems. With the rise of big data and AI, robots are increasingly becoming reliable partners for doctors, and many institutions are now utilizing robots alongside human oversight to perform tasks that were once handled by humans. The primary benefit of AI is its ability to shorten the time required for drug development, which consequently lowers the associated costs, improves returns on investment, and may even lead to reduced expenses for the end user. Numerous studies are being conducted to enhance the existing AI technologies to make the pharmacy profession more effective. This article provides a brief overview of the significance of AI in drug development and examines the various AI tools available to contemporary pharmacists to facilitate more efficient operations.
KEY WORDS: *Artificial intelligence, Important of AI in pharmacy, drug discovery, tug robots, Watson for oncology, Manufacturing execution system,*

HISTORY

The year 1956 is widely regarded as the birth year of AI, primarily due to the renowned conference organized by Dartmouth College during that time. Nevertheless, the previous year, 1955, marked the introduction of the first AI system known as Logic Theorist, developed by Allen Newell and Herbert A. Simon. This system successfully proved nearly 40 theorems from Alfred N. Whitehead and Bertrand Russell's Principia Mathematica. Unfortunately, the creators of this system were unable to publish their findings.[2] In a BBC interview, theoretical physicist Professor Stephen Hawking expressed that humanity's attempts to create thinking machines pose a significant threat to our existence. He warned that the race to develop comprehensive AI could potentially lead to the extinction of the human race in the future. This cautionary statement was made by Professor Hawking in response to a question about improving the technology he uses for communication, which relies on basic AI.[3] Despite his warning, the global community has largely dismissed Professor Hawking's concerns. Around the world, countless research initiatives are underway in the field of AI, with substantial financial investments aimed at developing systems that can operate more efficiently and in less time than an average human being.

Whether in an educational institution, a manufacturing company, a government agency, or a research organization, AI is applicable across all sectors. It is projected that the revenue from the AI market will increase by as much as ten times between 2017 and 2022. The natural language processing market, which encompasses various applications such as text prediction and speech and voice recognition, is anticipated to grow by 28.5% in 2017. Globally, revenue from big data and business analytics reached US$ 122 billion in 2015, and it is expected that this figure will exceed US$ 200 billion by 2020.[4]

IMPORTANCE OF AI IN PHARMACY

Artificial Intelligence plays a crucial role in the pharmaceutical industry by expediting the processes of drug discovery and development, tailoring treatments for patients, and enhancing the management and safety of medications. It aids in optimizing procedures such as drug discovery, improves the efficiency of supply chain management, minimizes medication errors, and allows pharmacists to concentrate on providing higher-value care to patients.

According to a survey conducted by U.S. News involving 150 professionals, pharmacists rank as the 13th highest-paid profession. The average salary for pharmacists was reported to be $120,950, with an unemployment rate of 1.6%. For many years, pharmacists have been responsible for ensuring that prescriptions received at pharmacies are filled accurately with the correct medication in the appropriate dosage, as well as verifying that multiple medications do not result in adverse drug-drug interactions. However, this landscape has significantly transformed over the last five years. With the rise of big data and artificial intelligence, robots are increasingly gaining the trust of doctors, and many institutions are now integrating robots alongside human oversight to perform tasks that were once solely handled by humans. Numerous compounds with the potential to address various specific diseases are available from pharmaceutical companies. Nevertheless, these companies lack the necessary tools for their identification. The process of drug development and production is complex and can cost a pharmaceutical company up to $2.6 billion, taking as long as 12 to 14 years to complete. This is where AI proves to be invaluable for pharmaceutical firms. AI shortens the time required for drug development, thereby reducing associated costs, improving returns on investment, and potentially lowering costs for the end user. The primary advantage of AI lies in its superior capability to analyze data, allowing it to process vast amounts of information that would typically exceed the capacity of conventional computers. Currently, AI is predominantly utilized in research fields. Its processing power surpasses that of any other tools available, particularly in research related to gene mutation, where it can sift through extensive data sets to extract relevant information.

AI IN DRUG DISCOVERY

Klopman launched a new initiative aimed at investigating the structure-activity relationship (SAR) of organic compounds. This program, designed for structural assessment, is automated by computer technology, enabling it to recognize molecular structures from the KLN code, which is a linear coding system for molecules. It subsequently identifies, organizes, and statistically analyzes biophores—substructures that are crucial for the biological activity of these molecules. This method has been utilized to examine the carcinogenic potential of polycyclic aromatic hydrocarbons, the pesticide activity of ketoxime carbamates, and the carcinogenicity of N-nitrosamines in rats.[8] Cherkasov and colleagues proposed the synthesis of small peptides with broad-spectrum antibiotic properties by leveraging the extensive knowledge in chemical biology. By employing peptide array technology and focusing on the amino acid composition of the more active peptides, they randomly generated two extensive libraries of 9-amino-acid peptides. The resulting data were integrated with Artificial Neural Networks—electronic models mimicking the brain's neural architecture—to create in silico models that simulated antibiotic activity. Through random sampling, these models proved highly effective in predicting the activity of 100,000 virtual peptides. The peptides identified as top candidates demonstrated significant efficacy against numerous multidrug-resistant “Superbugs,” exhibiting activities comparable to or surpassing those of four commonly used antibiotics. They even outperformed the most advanced clinical candidate antimicrobial peptide and showed effectiveness against Staphylococcus aureus infections in animal testing.[9,10]

Aliper et al. have recently introduced an innovative method that employs deep neural networks (DNNs) to forecast the pharmacological activities of various drugs. This team of researchers trained DNNs to enable the prediction of therapeutic applications for multiple drugs based on gene expression data. The data were obtained from experiments conducted on human cell lines. A total of 678 drug samples were included in the study, utilizing the A549, PC-3, and MCF7 cell lines. The DNN demonstrated a high level of accuracy in categorizing drugs into distinct therapeutic groups. For the first time, it was revealed that DNN could be applied to identify the pharmacological properties of several drugs.[11]

TOOLS OF AI

AI technologies in the pharmaceutical field are utilized for various purposes, including drug discovery and development, clinical decision support, and administrative automation. These tools enhance processes such as prescription analysis and medication management, elevate patient care by offering personalized treatment plans and adherence monitoring, and aid in automating routine tasks like dispensing and quality control.

IBM Watson for Oncology

IBM has created a supercomputer called Watson, which integrates AI with advanced analytical software primarily aimed at answering questions.[12] Watson for oncology is specifically designed to help oncologists make improved decisions regarding cancer treatment. It functions by examining a patient's medical information sourced from an extensive network of data and expertise, subsequently offering treatment options based on the evidence gathered. Watson for oncology can interpret both the meaning and context of any data found in clinical notes or reports, regardless of whether they are well-structured or unstructured. It can efficiently gather essential information about the patient and articulate it in plain English, which can be a crucial step in formulating the appropriate treatment plan for the patient. It merges vital details from a patient's file with external research, clinical studies, and data to determine the most effective treatment strategies that can be applied to a patient. Watson boasts an extensive collection of information from literature and rationales curated by MSK, including over 200 textbooks, 12 million text pages, and more than 290 medical journals.[13]

Recently, a 37-year-old Indian software engineer was diagnosed with a rare form of breast cancer that was rapidly spreading across both breasts, threatening the possibility of bilateral mastectomy. Dr. Somashekhar, an oncologist in Bengaluru, input her medical records along with her genomic data into Watson, which generated viable treatment options in just 60 seconds.[14]

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Robot Pharmacy
In order to enhance patient safety, UCSF Medical Center employs robotic technology for the preparation and monitoring of medications. They report that the technology has successfully prepared 350,000 medication doses without any errors. The robot has demonstrated superior performance compared to humans, both in size and in its capacity to deliver precise medications. The capabilities of this robotic technology encompass the preparation of both oral and injectable medicines, including toxic chemotherapy drugs. This advancement has allowed UCSF's pharmacists and nurses to focus on direct patient care and collaborate more effectively with physicians.[15] Within the pharmacy's automated system, computers first receive medication orders electronically from UCSF's physicians and pharmacists. Subsequently, the robotics pick, package, and dispense individual doses of pills. Following this, machines assemble the doses onto a bar-coded plastic ring. This thin plastic ring contains all medications that a patient needs to take within a 12-hour period. Enhancing the automated system's capabilities is its ability to prepare sterile preparations for chemotherapy, as well as to fill intravascular syringes with the appropriate medications.[15]

The automated facility also features an inventory management system that monitors every product, along with a refrigerated and two non-refrigerated pharmacy warehouses to provide storage and withdrawal of supplies and medications. All these facilities are fully automated.[15]

MEDi Robot
MEDi stands for Medicine and Engineering Designing Intelligence. The pain management robot was created as part of a project spearheaded by Tanya Beran, a professor of Community Health Sciences at the University of Calgary in Alberta. She conceived the idea after her experiences in hospitals where children often scream during medical procedures.[16] The robot first establishes a connection with the children and then explains what to expect during a medical procedure. Throughout the medical procedure, it instructs them on what actions to take, how to breathe, and how to manage their emotions.[17] While the robot lacks the ability to think, plan, or reason, it can be programmed to exhibit characteristics of AI.[18]

MEDi, produced by Aldebaran Robotics, features integrated facial recognition technology, can communicate in 20 different languages, and is highly versatile in various situations. The retail price of the robot is $9000; however, the cost increases to $15000–$30000 when the necessary applications for the robot to assist in medical procedures are installed.[17] Initially designed for pain management, the robot's applications have since broadened to include comfort during procedures, physical rehabilitation, and fundraising.[18]

Erica Robot
Erica is a newly developed care robot from Japan by Hiroshi Ishiguro, a professor at Osaka University. It was created in partnership with the Japan Science and Technology Agency, Kyoto University, and the Advanced Telecommunications Research Institute International (ATR). The robot can communicate in Japanese and possesses a mix of European and Asian facial characteristics.[7] Similar to an ordinary human, it enjoys animated films, has a desire to explore south-east Asia, and seeks a life partner for conversation. Although the robot cannot walk on its own, it has been designed to comprehend and respond to questions with human-like facial expressions. Ishiguro has crafted Erica to be the "most beautiful and intelligent" android by averaging the features of 30 attractive women to design the robot’s nose, eyes, and other attributes.[19]

TUG Robots
Aethon TUG robots are engineered to autonomously navigate through hospitals, delivering medications, meals, specimens, materials, and transporting heavy loads like linen and trash. They come in two configurations: fixed and secured carts, along with an exchange base platform that can accommodate racks, bins, and carts. Fixed carts are designated for delivering medications, sensitive materials, and laboratory specimens, while the exchange platform is utilized for transporting materials that can be loaded onto various racks.

The TUG is capable of delivering multiple types of carts or racks, making it a highly flexible and versatile resource.[20] During operation, a user-friendly touchscreen enables users to specify delivery locations or pickup points for supplies or materials. When faced with multiple destinations, the TUG automatically calculates the optimal route. It is equipped with overlapping sensors that provide 180° coverage for navigation and obstacle detection. An array of sonar and infrared sensors, referred to as the "Light whisker," can identify low-lying obstacles. The advantages of utilizing TUG include enhanced productivity around the clock, improved patient experience, increased worker safety, higher employee satisfaction, and enhanced patient safety.[20]

MANUFACTURING EXECUTION SYSTEM (MES)
A Manufacturing Execution System (MES) is a control mechanism designed to oversee, monitor, and track various manufacturing data in real-time by collecting minute-by-minute information from multiple sources, including robots, personnel, and machine monitors. In

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the current landscape, MES is increasingly being integrated with enterprise resource planning (ERP) systems.[21] This system aids in adhering to regulatory standards while ensuring that pharmaceutical manufacturers produce high-quality products throughout their production processes.[22] The advantages of implementing MES encompass compliance with established legal regulations, reduced risks, enhanced transparency, shortened production timelines, optimized resource use, controlled and monitored production phases, and improved efficiency up to the point of batch release.[23]

AUTOMATED CONTROL PROCESS SYSTEM (ACPS)

The aim of an ACPS is to guarantee that a process is conducted safely and profitably. This is accomplished by consistently monitoring various process variables, including temperature, pressure, flow, vacuum, and concentration, and when necessary, taking appropriate actions such as reducing pump speed, opening valves, and increasing heater output to ensure that the process variables remain within the required parameters. The benefits of ACPS include achieving high quality at a low cost, material savings, guaranteed safety for personnel, plants, and processes, enhanced yield, and lower labor costs.[24] The components of ACPS consist of (1) sensing the value of process variables, (2) transmitting signals to the measuring element, (3) measuring the process variable, (4) displaying the value of the measured variable, (5) setting the desired variable value, (6) comparing the desired and measured values, (7) transmitting control signals to the final control element, and (8) controlling the manipulated value.

Berg

Berg is a Boston-based biotechnology company and a significant player in the application of AI across its various processes. It operates an AI-driven platform for drug discovery, which boasts an extensive database of patients. This resource is utilized to identify and validate the different biomarkers linked to diseases, subsequently determining therapies based on the data collected. The company's mission is to accelerate the drug discovery process while reducing costs through the use of AI, which eliminates the guesswork typically associated with drug development. The procedures followed by Berg involve acquiring sequencing data from human tissue samples, gathering information on metabolites and protein synthesis, and employing AI algorithms to accurately identify the underlying causes of diseases.[25]

CONCLUSION AND FUTURE PERSPECTIVES

It is often stated that a human being is the most advanced machine that can ever be developed. A few decades ago, this statement would have been widely accepted. However, the current situation has changed significantly. Humans are no longer viewed as the most advanced machines. The human brain, regarded as the most intricate network of knowledge, is diligently working to create something that surpasses human efficiency in performing tasks, and it has made substantial progress in this regard. AI is gradually becoming an essential component of the pharmaceutical industry and the healthcare team. With countless research initiatives being conducted globally to enhance the efficiency of manufacturing and other healthcare-related activities, researchers are exploring the potential of utilizing AI for all tasks performed. AI tools such as Watson for oncology, tug robots, and robotic pharmacies have significantly transformed the profession. These tools operate at a much quicker pace, and the likelihood of errors associated with their use is minimal. As the healthcare sector expands, it will require increasingly sophisticated and technologically advanced infrastructure. This indicates that the sector will heavily depend on AI for most of its future endeavors. This development is promising in terms of productivity and efficiency.

AI not only enhances efficiency but also reduces errors that are significantly more common when tasks are performed by humans. Consequently, this leads to less waste, improved product quality, and increased profit margins for businesses. This is a key reason why the industry is becoming increasingly technologically advanced each day. However, when considering the impact on human employment, one might conclude that replacing humans with machines could result in widespread unemployment, with all tasks previously performed by humans becoming the responsibility of AI. As Stephen Hawking remarked, "this could signify the end of the human race." Therefore, while AI should be integrated into healthcare, it is essential that it is designed to work in collaboration with humans.

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