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Applied Mathematics for Pharmaceutical Problems Using Robotics as Assistive Tools for Learning: A Comprehensive Review

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ABSTRACT

Smart machine endures getting smarter as they are going to access more about the facts and pieces of evidence that make our work even more authentic than before. The term "robot" was created in 1920 by Czechoslovakian playwright Karel Capek and has been a principal point in science fiction ever since. Pharmacy automation involves machine-driven or mechanical processes of distributing, dispensing and managing medications. Pharmaceutical organizations take advantage of robotics to manoeuvre biological or chemical samples around to integrate novel chemical structure or to test the pharmaceutical value of remaining organic material. Pharmaceutical applications with aid of robotic systems are progressively accepted for enhanced throughput and proficiency to satisfy this growing demand, within a rapidly ageing population that directly requires sophisticated medical devices and newer drugs. According to Robot IQ, mathematics is one of the few main robotics attributes that cannot be learned along the way. A good background in many fields of mathematics and science is needed for robotics at the very least. Several studies have shown that robotics is an effective medium for teaching STEM (Science, Technology, Engineering, and Mathematics) skills to students. Thus, Novel methods are under development in machine learning, symbolic reasoning and signal processing which may be utilized in production and packaging concerned to the pharmaceuticals. The target is to review the Planning, Safety, Reliability, Accuracy, Quality, Flexibility, Redeployment, Efficiency and other vital applications of Robotics in Pharmacy.

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A. INTRODUCTION

Robotics has seen substantial advances over the past years leading to its increased applications to numerous real-world complications including automated industrial manufacturing, healthcare and medical robots, and self-driving vehicles (Haidegger, 2019). Within the field of technology, the Robots first commercially workable in the early 1970, and were principally organized and supervised in automotive manufacturing lines. Robotics is that branch of technology that deals with the planning, creation, action, and application of robots to play within the complicated processes of research and development, production, and packaging as well as with the computer systems for their control, sensory feedback, information and material processing (Nie, 2020).

According to The Robotics Institute of America: A robot is a Re-programmable multi-functional manipulator devised to transfer the materials, parts, tools, or specialized devices through mechanized gestures for the execution of a range of tasks. Perhaps the chief assistance is the eradication of wrong dosage, wrong medication, and other errors mainly contingent human mistakes (Brito et al., 2020). Since the mid-1970s, the United States and continental European hospitals equipped with the pharmacy robotic technology, but the United Kingdom hospital networking has traditionally had a mixed dispensing profile. In a very broader sense, emerging actions that are more patient-focused can lift pharmacy expansion and as this succeeds, variation can occur in specialized individuality across a variety of job roles within the pharmacy (West, 2018). Nevertheless, industrial robotics creators face some encounters in their effort to make themselves in pharmaceutical applications. It's believed that in future the robotics would play a significant role in the development and growth of pharmaceutical sciences. Key among these is the incompatibility of their controller software with prevailing fixed equipment (Aoun, 2017).

The term "robot" was coined in 1920 by Czechoslovakian playwright Karel Capek and has been a centre of attention in science fiction ever since. The primary robot was connected with the automotive field around 1974. Subsequently, quite 1,50,000 are installed worldwide including an outsized proportion within the field of medicines (Taulli, 2020). The International Organization for Standardization (ISO) broadens the importance of a robot in ISO 8373: " a precisely controlled, programmable, multipurpose, controller programmable in at least three tomahawks, which can be either consistent in area or cell to be utilized in modern mechanization applications" (ISO 8373, 2012). The inventive electric portable digital tablet counting technology was invented in Manchester, England between 1967 and 1970 with the aid of the brothers" John and Frank Kirby. In 1967, Kirby's apprehended a transportable digital tablet counter to count tablets and capsules (Batson et al., 2021). The widely held recent scientific and high-tech advancements couldn't be possibly accomplished without the assistance of robots. Robotics and Artificial Intelligence (AI) present a huge opportunity to minimise human error and improve operational efficiency. Robots are already active, large-scale components of the workforce in industries as diverse as automobiles and IT and sanitation. Specialists show that scaled-down implantable robots that are controlled from outside with significantly less power and injury to the tissues, helps in the fragile treatment of the careful fields. Sooner rather than later, automated gadgets with remote telemonitoring, littler instrumental measurements and smoothed out stages for multipurpose utilization might be normal. Thus, the rationale of this paper is to analyse major milestones that established a phase for a change and advancement of today's robotic adeptness including sufficient detail to acquaint the reader with the long term of robotics in India (Gomez, 2012).

B. METHODS

In review, we highlighted numerous recent research reports, merits and demerits as well as applications based on market utilization. The data has been retrieved using various websites and web portals based on automation and artificial intelligence to collect comprehensive literature for this article. The best mode to understand the assembly of robots is to partition by their applications

1. Components of a Robotic System in General

The body/ frame, control system, manipulators, and drive train are all parts of a robot shown in **Figure 1.**

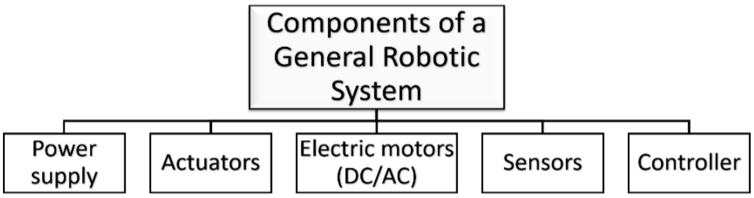

Figure 1. The various components of a general robotic system

Power supply- For the running of any device or machine the main component is the power supply and so a robot needs energy from a power supply to perform a task. It can be generated from various sources such as batteries, hydraulic, solar power or pneumatic power sources. **Actuators-** Converting energy into movement devised as actuators. **Electric motors (DC/AC) -** Used to convert electrical energy into mechanical energy. To provide movements of robotic parts, the use of such motors is required. In portable robots brushless and brushed DC motors are used and AC motors used in industrial robots. **Sensors-** Robots are equipped with various types of sensors to sense the changes in surrounding and produce a signal to respond accordingly. **Controller-** The controller controls and co-ordinate with all segments of the robot and therefore controller is said to be the brain of a robot. Robot achieves all their fixed or prearranged tasks with the help of the controller. The core part of the controller is called Microprocessor, which sequences various signals as Input and generates a corresponding output signal (Takács et al., 2015).

2. Laws related to Robotics in Pharmacy

Originally robots were simple automatic machine built with microprocessors, sensors, controller based on computer technology. The robots are very supportive in every sector such as the pharmaceutical industry, Medical healthcare, etc. The designing and manufacturing are based on laws proposed by "ISSAC ASIMOV" (1940) an American writer. The laws are stated as follows: (1) A robot may not injure or harm a person or well-being. (2) A robot must follow orders given to it except where such instructions would disaccord with the First Law. (3) A robot must shield its presence as long as such defence does not conflict with the First or Second Law (Teja et al., 2014).

3. The arrival of Robotics in the Pharmaceutical Industry

Robots or Pharmacy Automation was first turned into commercially feasible in early 1970 and were principally organized in repetitive obligations such as linking and management in automotive business lines (Rasouli et al., 2020). The foremost robot was connected in 1974 with the automotive arena. Subsequently, more than 150000 have been installed worldwide together with a large share in the pharmaceutical field (Rocha, 2017). Robots were tiny in addition to more programmable liquid handlers that provided a mechanical arm for high-throughput screening (HTS) systems, where the arm stimulated models from one gadget to another. The application of robotics in manufacturing and packaging developments in the industry was slow to adopt (Mejía & Franco, 2019).

a. Robotic Pharmacies

Larger health care clinics and some hospitals employ robotics to dispense medication. "Robotic pharmacies within the clinics and hospitals are developing and expanding rapidly. In local pharmacies, there will be a challenge on the retail level for the robotic advancements. The technology is attainable but the directive will bound the evolution of robotic pharmacies more than the technology and expertise. For the overall system, robotics manufacturing industries must implement alternative deposits of cost reduction to make robots more attractive to the local pharmacies (Isaacs, 2020).

b. Lab Work

FDA now approved the DaVinci surgical system for a variety of general, cardiac, gynecologic, and urologic procedures which are directly or indirectly belongs to the medical lab works**.** In assembling and packaging medical devices, robotics plays a significant role. The manufacturing process is highly structured to play a more integral role in the years to come (Chen et al., 2018)**.**

4. Generations of Robots designed for Pharmaceutical Practices

The first-generation robot devised in the 1960s and typically it was a single purpose and used in some operations such as fusing or welding, painting, and machining. These days such robotic machines are widespread throughout the world, being enlisted in the early phases of research laboratory development and technology as well as commercially feasible in the early 1980s. *Second-generation* robots at a laboratory scale in the 1970s are Sensor-based robots, came into existence that is technical and practically feasible. These are assorted robots with some intellect, but still mostly single function as similar to first-generation robots. *Third generation* robots technologically advanced to work externally. In an extremely structured atmosphere, the industrial robots employed to function the manufacturing operations. (James et al., 2013).

5. Advantages of Robotics in Pharmacy

Robotic machines in pharmacy have improved the way and means, which pharmacies operate. Undertaking operations such as robotic prescription dispensing systems that are capable of storing, loading, directing, filling, capping, covering and labelling prescription medications efficiently & firmly. They are capable to store & manage a large number of medications and patient information (Khader et al., 2016). Robotic systems in the pharmaceutical field have transformed the healthcare landscape by increasing efficiency, improving patient care & enhancing productivity. They can be a major time-saver for the pharmacy, dispensing robots offer faster service, customers do not have to wait as long to receive medication, and the machine can fill a prescription much faster than a human can (Cresswell et al., 2018).

The robotic system reduces dispensing errors and chances of contamination, leading to effectiveness in dispensary throughput, evolving ward-based medication management services and decentralizing the clinical pharmacy services. Photo verification feature and barcoding systems in pharmacy robots increase patient safety, reducing the risk of obligations and dispensing error for the pharmacies (Dalton & Byrne, 2017). As seen in Figure 2, robots can improve the production, reliability, durability, and accuracy of goods in a variety of cases.

6. Disadvantages of Robotics in Pharmacy

Robotic pharmacies still have a lack of solutions for some types of products such as blood derivatives, flammables, and cytotoxic drugs. So, some robotic pharmacies still need conventional static shelving, and considering the high capital investment required, these disadvantages make robotic pharmacist an unattractive option for many health services **(Figure 2)**.

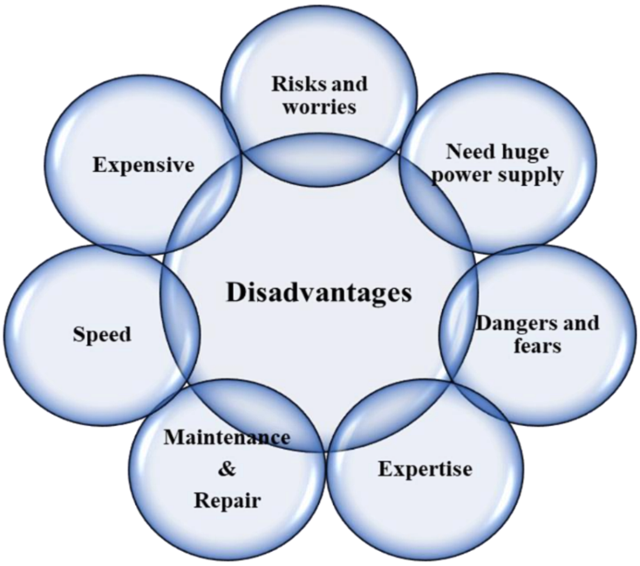

Figure 2. Disadvantages of robotics in pharmacy

Robotic pharmacy technologies are expensive, although the addition of robotics can improve efficiency & productivity. Pharmacy automation systems can't replace pharmacists if you implement a new technology that limits human interaction. The patients may be reluctant to frequent your pharmacy (Colquhoun, 2010).

A robotic pharmacy can enhance precision & accuracy but robotics isn't trained to explain medication interactions or give advice about adding a vitamin to the patient's medication regimen, robotics can cause disaster in the case of malfunction. If the pharmacy heavily relies on automation, the system breakdown could lead to less work productivity. Elimination of a whole labour class would presumably occur a bit of a way down the road, but the implications of this point are too large not to consider. Bringing in robots to take unskilled labour jobs will place more pressure on the economy, education system, and financial market, just to name a few. The United States has always been associated with the grit and work ethic of its blue-collar workers, and robots are threatening to eliminate this aspect of the human population, with a takeover of production jobs (Patel et al., 2017).

7. World's Top-10 Industrial Robots and Manufacturers

Globally, in the industrial market of robotics Japanese and European companies are largely dominated. ABB, The Yaskawa Electric Corporation, Midea Group (KUKA, The Fanuc Corporation, and Kawasaki Heavy Industries are leading companies in this sector (Estolatan et al., 2018). The global Industrial robotics market is probable to reach USD 42.29 billion in terms of robotic machines and USD 138.03 billion in terms of robotic systems by 2026, representing 2019-2026 CAGRs of 11.57% and 12.59% respectively. The annual shipment is expected to exhibit a CAGR of 17.09% during the same period, advancing to over 1.15 million units in 2026. Table 1 lists the top ten industrial robots and manufacturers in the world.

Table 1. World's Top-10 Industrial Robots and Manufacturers

No.	Robotic Company	Company's Headquarter	About Robot
1	ABB	Zurich, Switzerland	**ABB** (ASEA Brown Boveri) a leading supplier of industrial robots and robotic software.

No.	Robotic Company	Company's Headquarter	About Robot
2	YASKAWA ELECTRIC CORP.	Kitakyushu, Japan	Motion controllers, AC motor drives, switches and industrial robots.
3	MIDEA GROUP (KUKA)	Bavaria, Germany	**KUKA** (Keller und Knappich Augsburg) manufactures industrial robots and solutions for factory automation.
4	THE FANUC CORPORATION	Yamanashi prefecture, Japan	The company provides automation products and services such as robotics and wireless system.
5	KAWASAKI HEAVY INDUSTRIES	Tokyo, Japan	The company is a leading manufacturer of motorcycles, heavy equipment, aerospace and defence equipment.
6	EPSON ROBOTS	Tokyo, Japan	Leading manufacturers of computer printers & imaging related equipment.
7	STÄUBLI	Pfaffikon, Switzerland	The company manufactures textile machinery and connectors.
8	NACHI FUJIKOSHI CORPORATION	Toyama, Japan	The company manufactures industrial robots, machining tools and systems and machine components.
9	COMAU	Turin, Italy	The company is a subsidiary of automaker Fiat Chrysler Automobiles.
10	OMRON ADEPT TECHNOLOGY INC.	California, US	The company provides a solution (product and services) for industrial automation and robotics, including software and vision guidance.

8. World's Top-10 Healthcare/Surgical Robots & Manufacturers

Best recognized robotics applications in healthcare, medicines and surgical. Everything from organ transplants and gastrointestinal procedures to spine surgery and urological operations is performed using robots of one type or another. Robots also assist in transporting medical supplies, prescription drug dispensing, sanitation and clinical management so human healthcare workers who normally do those tasks can focus more on their patients. As innovative progressions constantly rise throughout the decades, the medical procedure has substantiated itself as a refined control fit for rewarding plenty of ailments and conditions. Therefore, as computer hardware, software and programming become progressively refined, these advances have been actualized in the working room also (Dwivedi, 2012). Top-10 Healthcare/Surgical Robots & Manufacturers in the world, shown in Table 2.

Table 2. World's Top-10 Healthcare/Surgical Robots & Manufacturers

No.	Robotic Company	Company's Headquarter	About Robot
1	DILIGENT ROBOTICS	Austin, Texas	Capable of navigating hospital hallways and other tight spaces, imbued with social intelligence
2	REWALK ROBOTICS	Marlborough, Massachusetts	Exoskeletons for personal and commercial rehab use
3	MYOMO	Cambridge, Massachusetts	Reads nerve signals, recently introduced a MyoPro model for adolescents.
4	BARRETT TECHNOLOGY	Newton, Massachusetts	Designed for upper-extremity rehabilitation training and robotics research

No.	Robotic Company	Company's Headquarter	About Robot
5	ENERGID TECHNOLOGIES	Cambridge, Massachusetts	"Affordable, modular robotic surgical system capable of complex motion control"
6	INTUITIVE SURGICAL	Sunnyvale, California	Used for minimally invasive surgery and peripheral lung biopsies.
7	TRANSENTERIX	Morrisville, North Carolina	System for laparoscopic procedures, integrated with existing technology
8	SOFTBANK ROBOTICS	Tokyo, Japan	SoftBank's robots Pepper, Nao and Romeo are empathetic humanoids programmed to be proactive and expressive, Entertaining, educational and engaging.
9	EMBODIED	Pasadena, California	Exhibit human-like care and compassion to enhance individual wellness and quality of life.
10	HARVARD BIO-DESIGN LAB	Marlborough, Massachusetts	"Soft wearable robots", improve walking efficiency.

9. Robotics play a significant role in pharmaceutical mathematics

With the variety of robotics platforms on the market, educational researchers would continue to investigate the suitability of such devices for different age groups. Robotics applications are currently in their development, but they can be improved and strengthened by the demographic climate. According to Robot IQ, mathematics is one of the few main robotics capabilities that cannot be learned along the way: (1) Calculus and algebra will assist you in writing the calculations and formulas that describe the abstract ideas that a robot manipulates. (2) Geometry and mechanics can help you understand the many ways a robot can travel so that you can eliminate movement, mitigate wear and tear, and extend the life of your machinery. (3) Applied mathematics, or the use of math to solve problems in science and engineering, would allow you to deal with problems successfully.

10. The Future of The Robotics in Pharmacy

There are the following areas where robotics can be used vastly in future: (1) Robotics can be used for e-commerce. (2) Robotics can be raised with cloud-based software which will define new skills in the robots. (3) Robotics can be used more than the industries. (4) Robotics can be used in the medical field (Mourtzis et al., 2015)

A comprehensive pharmacist workforce analysis should also incorporate consumer health outcomes. There is some evidence that automated dispensing lower the rates of dispensing errors. In terms of the next steps in pharmacy workforce planning, a more comprehensive analysis is warranted. From the data gathered, it would be prudent to build simulation models using updated estimates of demand and supply under different practice models to test the effects before implementation. As these models are being built, assumptions will need to be made as to what the role of the pharmacist entails if the mechanical part of dispensing is removed. This is where community pharmacy needs to be ready to provide alternatives (Spinks et al., 2017).

11. Types of Robotic System in the Pharmaceutical Industry

The robotic system mainly works for manufacturing, production and packaging in the pharmaceutical industries. Robots play a very significant role in establishing process parameters or steps (Taylor et al., 2016). To automate or mechanise a process using a robot the process parameter includes: (1) the use of required type End-Of-Arm Tooling (EOAT), (2) cycle time, (3) repeatability, (4) reach and (5) payload capacity.

Taken together, these will usually determine whether a cartesian, SCARA or articulated robot is necessary. Another essential consideration is the environment in which the robot will be operating. Robot models are available for use in cleanrooms, and in applications where bio-contamination control is required, aseptic models have special seals, outer coatings and other construction features that allow them to be cleaned with hydrogen peroxide (Ji & Wang, 2019). There are various types of robots which are being used in multiple areas depending on their work, and the following are the description of some industrial robots:

a. *Cartesian: Cartesian robot applies the Cartesian coordinate system (X, Y, and Z). These types of robots have three linear joints. They also may have a wrist that can provide a rotational movement* (Weiß, 2018).
b. *Polar: A type of robot which can consist of a rotatory base with an elevation pivot. The polar robot has only one arm which can perform the various task* (Vaidyanathan et al., 2021).
c. *SCARA: SCARA stands for "Selective Compliance Assembly Robot Arm." Sacra robot can do three linear movements with a vertical motion. It is fixed at the Z-axis and flexible in XY axes* (Junia Santillo Costa et al., 2020).
d. *Delta: These robots are the shape of a spider that has parallel arms connected to the universal joints* (Mokled et al., 2019).
e. *Cylindrical: Cylindrical robot has a rotary joint for the rotational transaction and a prismatic joint for performing a linear movement* (Shah & Pandey, 2018).
f. *Articulated: Articulated robots have rotary joints which can range from a simple two joints structure to a complex structure with 10 or more joints* (Bhavsar et al., 2021).

C. RESULT AND DISCUSSION

Robotics in the Pharmaceuticals' world, play a dynamic role in the complex processes of research and development, production, and packaging and the reason behind the development of robots' ranges from better worker safety to improved quality. Another benefit of robotics is to speed up the drug discovery processes. At present, various types of functions and activities performed by the robots in numerous fields by carrying out several tasks organized as per the needs (Kulkarni et al., 2020).

Mechanical advancements bolster the rebuilding of pharma experts' work from beginning periods of professionalization and preparing to proceed with the proficient turn of events and work connections. This incorporates issues of information sharing and preparing in virtual learning networks, work multifaceted nature and correspondence, just as reconfiguring word related limits. Existing exploration has would, in general, utilize a dyadic concentration in understanding limited work, at the same time, given the expanded accentuation on multidisciplinary cooperation, contemporary work environments are probably going to incorporate numerous gatherings of on-screen characters with a decent variety of interests, qualities, skills, and practices. A future examination is currently expected to check and expound on them, just as to look at how to limit relations that are reconfigured in different settings and with other advanced developments (Barrett et al., 2012).

Pharmaceutical applications with aid of robotic systems are progressively accepted for enhanced throughput and proficiency to satisfy this growing demand, within a rapidly ageing population that directly requires sophisticated medical devices and newer drugs.

1. Automated prescription filling device

To discover community pharmacy specialist workflow, change after implementation of an automated robotic prescription-filling device, shown in **figure 4.** Today robotic devices integrated with pharmacy computer software and hence the most inclusive forms of automated dispensing systems used in community pharmacies; the devices are capable of counting, packaging, and labelling dosage forms which can increase expert prescription-filling proficiency based on overall time but rise complexity as well. However, these aptitudes allow for increased prescription filling efficiency, automation surprises and errors in the workflow possibly introduced in the presence of pharmacy robotics (Disler et al., 2019).

2. Research and Development (R&D) Robotics

In the development of novel drugs, robots play a crucial role. For instance, thousands to millions of complex mixtures are tested in High Throughput Screening (H.T.S.) and hence to test these millions of compounds, the use of robots is more noteworthy. Robot replaces an individual's repetitive task as robots can easily speed up the process significantly [(41)]. AstraZeneca, the Pharmaceutical giant industry is a leader in the ultrahigh-throughput screening and its innovation led the initiative to modernise next-generation medicines and types of machinery. This initiative has granted AstraZeneca's academic and industry associates' access and retrieve more than 250,000 compounds for screening and assessing for other use. AstraZeneca anticipates screening 40 million potential drugs for dozens of illnesses causing each year (Girasa, 2020).

3. Laboratory *Robotics*

Using robots for laboratory purposes, directed at specific laboratory functions, new experimental procedures, centrifugation and aliquoting. Revolution in laboratory robotics eliminating human tediousness, inaccuracy and miscalculation in washing and transferring, comprises experiments in radioactive, fluorescent, and luminescent analysis, which helps to meet the needs of increasing collective productivity, decreasing drug development time and reducing costs. Three of the most common geometries for laboratory robots are Cartesian (three mutually perpendicular axes); cylindrical (parallel action arm pivoted about a central point); and anthropomorphic (multijointed, human-like configuration) (Bogue, 2012).

4. Robotic *Vision Systems*

For determining the accuracy of text and illustrations in pharmaceutical and medical packaging carried by a valuable tool provided by a vision system. A robotic system proposed by the various investigations attempted as the framework was created for the visual arrangement of drug store automated innovation. The principal benefit accessed by adding a robot to the vision system is *speed*. A device devised in the robotic vision system for determining the location of items from the image received by the recording device. A vision system is capable of reading and determining whether the matter present within the medication is opaque or foreign by employing a type of sensors in a vision system.

Programmed solution acknowledgement framework can assist drug specialist in identifying clinical data in the medication. It empowers the acknowledgement stream to perceive the data in the solution. By this framework, one can perceive medications and their utilization, courses of medication, concentration, dose and day.

5. Robotic *for Sterilization and Clean Rooms*

Robots are adaptive to work in aseptic and sterilised environments and featured to protect from potential contamination. Robots in the aseptic environment are cost-effective by automating the inspection, picking and placing, or loading and unloading of process tools. "Clean Room" robotic system, designed specifically to inhibit microbial as well as particulate contamination. Laminar Flow patterns in concurrence with distinct resources and aseptic devices have been adjusted to prevent the introduction of particulate matter into the process. The cleanroom/ aseptic system employs the USP-preferred membrane filtration method and practices the Millipore Sterile filtration chambers as its "output" for incubation.

The Fanuc M-430iA/2PV can withstand hydrogen peroxide fume cleansing and has a waterproof rating; all wiring and cabling are steered through the robot's empty arm. Robots intended for use in cleanrooms must limit particulate age to keep up cleanroom arrangements, commonly ISO Class 5 or 6. Cleanability, including limiting cleft and guaranteeing the robot is impervious to cleaning and disinfecting operators, is additionally a prerequisite, notes Grant (Nikolov et al., 2020).

6. Role *of Robots in Packaging Operations*

Automation brings speed and repeatability in packaging operations by effortless product transfer and loading contributing flexibility and accuracy during the process. Robotics achieves more efficient dedicated machines, in some packaging applications such as carton loading. Understanding and awareness of the statistic that design packages can help older patients to cope with their treatment represents a small, but yet significant contribution for future ageing societies. Packaging of tablets may affect the release generated during the packaging of medicines. Therefore, the selection of an appropriate packaging of medicine also impacts the emission added to the environment. Opportunities in incorporating different packaging sizes, substituting aluminium foil lidding with paper lidding, using various modes of transportation, and different choice of the impact assessment method (Raju et al., 2016).

7. Robotics *in Biopharma and Diagnostic Approaches*

At present biopharma and diagnostic companies are exploring the practice of robotic technology and its applications to optimise their clinical trials as well as improving trial design and patient recruitment, scrutiny of both trial results and real-world evidence, and automation to increase the speed and efficiency of results publication. Positive implementation could result in reduced development costs, increased adherence and improved outcomes (Shukla et al., 2018). It delivers uniform solutions that offer high throughput and ensure reproducible, accurate results in areas such as cells, genomics and forensics. Biopharma applications, supplying pharmaceutical laboratories with automated solutions for cell culture, nucleic acid extraction, normalization, genotyping protein purification and analysis, hit-picking, ADME screening, PCR applications and protein crystallography. End-to-end commercialisation could have substantial aids to biopharma companies. Over the next few coming years, using robotic technologies can help companies coordinate product launches better, improve patient compliance, help with physician decision support and marketing operations, and predict market access and pricing decisions. Automation, including computerized investigation and packaging, is turning into a progressively significant role in the pharmaceutical industries. The numerous advantages of computerization incorporate proficiency, sparing personnel from dangerous situations or redundant assignments, diminishing preparing overhead, disposing of human blunder, expanding repeatability and reproducibility, and in cleanrooms, expelling the potential for human infection (Leinbach, 2014).

A mechanical framework (robot) is a kind of robotization that has numerous degrees of freedom for movement and can be modified to play out a capacity. Robot types incorporate explained, cartesian (i.e., gantry), parallel (i.e., delta), and selective compliance assembly robot arm (SCARA), shown in figure 5. Basic applications incorporated "pick and spot" activities that frequently use SCARA robots. There is additionally another, developing utilization of delta-type robots for fast picking and packaging, noted Chris Sumner, overseeing chief of Fanuc Robotics UK and Vice President of Fanuc Europe Corporation, in an official statement. Merck, for instance, is utilizing a Fanuc delta robot on a packaging line to put allocator tops onto packaged sensitivity meds (Kabra et al., 2011).

"Ten variations of the container can be run on the framework, and the main robot line-change prerequisite is to choose the fitting project on the robot controller," clarified Sumner. An investigation by the Association for Packaging and Processing Technologies (PMMI) found that robots are relied upon to deal with 34% of essential pharmaceutical packaging tasks in North America by 2018, contrasted and 21% in 2013. An expansion in the utilization of robots is seen in administering, arranging, unit get together and light machine-tending just as in increasingly conventional applications related with packaging, notes Jonathan Ferrell, a packaging market chief at ABB Robotics" (Jain et al., 2019). The benefits of mechanical technology are genuinely basic: more noteworthy speed and precision, more prominent adaptability and dependability than hard robotization and they are getting perpetually reasonable," says Ferrell (Landers, 2019).

8. Robotics *for filling, assessment, and packaging in pharmaceuticals*

Innovation in the robots is being utilized for vial-filling applications on more slow speed applications. "Robotic vial control move parts from station to station both when filling and pack-off," says Walt Langosch, chief of deals and showcasing at ESS Technologies. The organization additionally has involvement in taking care of plastic and glass prefilled syringes in pre-process, buffering, and introductory and end-of-line packaging. "Robotic syringe manufacturing, investigation, and groundwork for packaging is a perfect application for apply autonomy," says Langosch. "The essential favourable position in sterile conditions is the decrease of hazard because of natural tainting and pollution created from human intercession during a part move". Programmed examination, as a component of an automated framework (a robot), has the benefit of empowering 100%-part assessment. Vision-detecting innovation can be utilized in pharmaceutical packaging to check serialization numbers for consistency with track-and-follow guidelines. "Robotic adroitness and exactness joined with present and future optical innovation and serialization programming is the perfect innovation for a computerized arrangement," says Langosch (Basu et al., 2011). A development in vision sensors is shading imaging, which, for instance, permits frameworks to recognize bottle tops of various hues, noted PMMI in a pattern report. Vision sensors have likewise prompted progress in the end-of-arm tooling plan that improve the capacity of robots to precisely distinguish and put objects (Liu & Huang, 2015).

9. Robotics creating Personallized medicine in Pharmaceuticals

Custom mechanization and agreement fabricating organization Invetech as of late joined forces with biopharmaceutical organization Argos Therapeutics to create robotic manufacturing systems dependent on Argos' Arcelis innovation stage for customized immunotherapies. "The Arcelis stage utilizes two, five-pivot mechanical arms in the creation of the mRNA from a patient's tumour, which is utilized as the antigen for stacking into the dendritic cells delivered in the cell preparing gear," clarifies Richard Grant, chief of cell treatment at Invetech. "The battery-operated equipment utilizes robotization to control the white blood cells all through the assembling procedure to control their turn of events and development into dendritic cells. These cells express the ideal antigens, which when conveyed to a patient, will trigger the patient's insusceptible framework to create executioner T-cells that will focus on the metastatic tumours" (Lee Ventola, 2014). "The RNA robots control shut disposables to play out the procedure inside the basic Class 100,000 cleanroom space," says Grant. The utilization of the shut disposables permits different patients' materials to be handled in a similar assembling space, driving the official capital and working expenses down essentially (Terra Univesral Inc., 2012). Argos' lead competitor is presently in Phase III clinical preliminaries, and the mechanized innovation is intended to be secluded and effectively adaptable.

10. Robots in the laboratory

Robotics has come a long way in the pharmaceutical laboratory, notes Mike Ouren, Life Sciences manager at Precise Automation. In the laboratory, robots are used, for example, to transport microtiter plates between instruments. "Although the instruments can be loaded manually, a robot tied to a scheduling software system eliminates human error, maintains the quality of the experiment, and allows scientists to focus on the content of the experiment, instead of how they will execute it," explains Ouren (Joiner, 2018).

Laboratories differ from industrial applications in that, although tasks are repetitive, they are not as consistent and may change depending on the experiment, says Precise Automation's Ouren. The need to access equipment near the robot quickly and the space limitations of a laboratory can be met with new collaborative robots that do not require safety guarding. In 2012, Precise Automation introduced a collaborative SCARA robot (or "cobot"), the PreciseFlex (PF)400, which handles less than 1-kg loads and is designed to allow

operators to work safely next to the robot without barriers. The smaller footprint of the robot reduces cost, and the space savings is useful in benchtop laboratory applications (Joiner, 2018).
The robot is user friendly, and the Precise Guidance Controller inside the PF400 allows laboratory personnel to "teach" the robot using only their hands. "Because there are no barriers, instead of using a complex remote-control pendant to teach the robot, the operator can show the robot what to do by simply grasping the end of the robot arm. This accessibility is unheard of in industrial automation," explains Ouren. Other laboratory applications for robots include vial handling. A Fanuc robot is being used in a laboratory, for example, as a single-point handling solution for vial processing (Amandeep Kaur et al., 2020).

"A handling tool was designed and attached to the end of the robot to enable it to handle ten vials at a time. A variety of components were also placed around the robot cell—including indexing tables for full rack staging, a thermostatically controlled water bath for precise sample temperature, a retrieval system for dumped vials, a washing-brushing-rinsing-drying station, a preservative spray station, and a recapping station," explained Sumner in a press release. In the laboratory and on the manufacturing floor, robots are increasingly used to improve quality and efficiency (Roshanianfard & Noguchi, 2018).

11. Robots in the research facility

Robotics in pharmacy has made some amazing progress in the pharmaceutical lab, notes Mike Ouren, Life Sciences Director at Precise Automation. In the research facility, robots are utilized, for instance, to ship microtiter plates between instruments. Research centres contrast from robotic applications in that, although errands are monotonous, they are not as steady and may change contingent upon the investigation, says Precise Automation's Ouren. The need to get to hardware close to the robot rapidly and the space restrictions of a research centre can be met with new synergistic robots that don't require security guarding. In 2012, Precise Automation presented a community-oriented SCARA robot (or "cobot"), the PreciseFlex (PF)400, which handles under 1-kg stacks and is intended to permit administrators to work securely close to the robot without hindrances. The little impression of the robot decreases cost, and the space reserve funds are valuable in benchtop research centre applications (Cole et al., 2017). Other research facility applications for robots incorporate vial dealing with. A Fanuc robot is being utilized in a lab, for instance, as a solitary point taking care of answer for vial handling. "A taking care of hardware was planned and appended as far as possible of the robot to empower it to deal with ten vials one after another. An assortment of segments was additionally positioned around the robot cell—including ordering tables for full rack organizing, a thermostatically controlled water shower for exact example temperature, a recovery framework for dumped vials, a washing-brushing-flushing drying station, an additive splash station, and a recapping station," clarified Sumner in a public statement. In the research centre and on the assembling floor, robots are progressively used to improve quality and proficiency (Grau et al., 2017).

12. Robotic role in the Pharmaceutical and Life Sciences Industry

Robots in the lab, life science and pharmaceutical applications perform assignments at rates past human capacity. These robots work in possibly unsafe settings in the vicinity to organic risks, the danger of radioactive tainting, and poisonous chemotherapy mixes (Gbadegeshin, 2019). Robotics are called upon to amass and bundle an assortment of clinical devices and embeds just as getting ready remedies for mail-request drug stores or emergency clinics. "Robots are doing to examine investigation and mechanizing the development of test tubes to explore research centres. On account of the high number of tests that need investigation and the measure of information assortment required, the procedure and expenses are handily approved with apply robotics," says Chetan Kapoor, Chief Executive Officer of Agile Planet Inc. (Austin, Texas) "In pharmaceutical applications, medical clinics use robots to blend possibly risky malignant growth drugs and those related with radiation" (Gbadegeshin, 2019).

13. Robotics Use in Pharmaceutical Manufacturing

The following are some of the commercially available robots used in the pharmaceutical manufacturing process:

a. *High Throughput Screening Cylindrical Robot* - ST Robotics developed a new 4-axis cylindrical robot for drug discovery and toxicology applications. It serves as a simple 2-axis plate mover mounted on a track. Based on the protocol designed by a user, the robot moves samples from one instrument to another by creating a swift & smooth motion (Bhatnagar, 2020).
b. *C3-V Robots* – Developed by EPSON Robots, C3-V Robots were created to increase the throughput of aseptic manufacturing and assembly at reduced costs. These robots are used in barrier isolator systems employed in pharmaceutical industries. They are designed to prevent contamination of pharmaceutical products and protect human operators from exposure to harmful toxic drugs.
c. *M-430iA Robot Arms* – FANUC's M-430i A robot arms features a pair of multi-axis robot arms and a visual tracking system. The robot arms have been designed to successfully lift 120 items per minute whilst moving along the conveyor belt during the manufacturing process. M-430i A robot arms reduce the manufacturing cost of the pharmaceutical product and improve the quality of the product.

D. CONCLUSION AND SUGGESTIONS

The utilization of mechanical autonomy in drug store will give advantages, will also decrease administering blunders, and improve the proficiency of existing administrations, streamlining the space in a clinical drug store. Due to the potential hazards and high volumes of drugs products, some hospitals and larger health care clinics utilize robotics to dispense medication. Robotic pharmacies are expanding rapidly within hospitals and clinics. Pharmaceutical applications with help of mechanical frameworks are increasingly more acknowledged for upgraded through put to fulfil this developing need, inside a quickly maturing populace that legitimately requires complex clinical gadgets and fresher medications. Along these lines, Novel strategies can be successfully utilized with robots with the greatest exactness of portion and precision.

In the realm of pharmaceuticals, there is a fundamental job to apply autonomy to play in the confusing procedures of innovative work, creation, and bundling. Support for robots' ranges from improved labourer security to improved quality. Accelerating the medication revelation process is another advantage of mechanical autonomy. Medication Production Robotics assumes a significant job in the assembling of pharmaceutical medications because, in contrast to different enterprises, pharmaceuticals request higher speed and precision. Gadgets, for example, syringes, inhalers, IV packs and diabetes testing units are made with the assistance of apply autonomy.

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