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From Humans to Robots : Machine Learning for Healthcare

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ABSTRACT

Machine learning is a branch of artificial intelligence (AI) through which identification of patterns in data is done and with help of these patterns, useful outcomes or conclusions are predicted. One of the most prominent or frequently studied applications of machine learning is the surgical phase or robotic surgery. This makes machine learning an important part of research in robotics. The implementation of this technology in the field of healthcare aims in improving medical practices resulting in more precise and advanced surgical assessments. This paper aims in outlining the implementation and applications of machine learning related to robotics in the field of healthcare. Machine learning aims in generating positive outcomes with assumptions. The objective of this paper is to bring light on how these technologies have become an important part of providing more effective and comprehensive strategies which eventually add to positive patient outcomes and more advanced healthcare practices.

Keywords : Machine learning; Artificial Learning; healthcare; Robotics; Robotic Surgery; Surgical Phase

I. INTRODUCTION

We are living in an era of algorithms where intelligent software like machine learning will assist doctors and physicians [1] in examining patients in the coming future and machine learning will revolutionize medical research and practice [2] and will also generate better clinical decisions [1]. Machine learning is basically a study of tools and techniques to identify patterns in data [2]. These patterns are then used and studied to broaden our understanding of the current healthcare practices and thus to make crucial predictions and decisions regarding the future [2,3,4] to generate optimistic consequences. Since machine learning runs on algorithms, healthcare specialists are focusing to hold this technology in their field by developing these algorithms and providing information to machines that can help them in imaging and analyzing human bodies for abnormalities [2] and further the information or data collected can be used in bringing out certain predictions which can benefit these healthcare departments.

In today's time, machine learning has emerged as an extraordinary replacement for human expertise and has simplified the optimization functions as well [5]. So, the basic idea behind the implementation of machine learning is to simplify complex problems. A lot of robotics-related problems have been simplified

with the execution of machine learning. Machine learning is a powerful tool that can be very useful for efficient administrative work in hospitals like mapping and treat infectious diseases and personalized medical treatments. Through machine learning, hospitals and health care systems work efficiently, while reducing the cost of care. With the large implementation of Machine learning in various fields, these kinds of technologies have become an essential part of our daily routine and lifestyle. But, the proper usage and implementation of machine learning require a good number of efforts from the human expert as no algorithm can attain good performance on all workable problems [6]. Earlier, a lot of clinical data was ignored or was not collected due to the lack of such techniques for gathering and saving such data. Another reason for this ignorance could be the complexity of the data. This clinical data can be really helpful as it could lead to improved understanding of risk factors of any infectious disease and identification of new patterns to give new outcomes and predictions. At present, machine learning has been a successful approach to data collection and bringing positive outcomes out of it. Despite having good knowledge of clinical data, a lot of health researchers lack proper expertise which is necessary for applying these techniques.

1.1 Traditional Programming Vs Machine Learning

Both traditional programmings, as well as machine learning, aim to resolve the issue or a problem but the main difference between these two is their implementation. Machine learning follows the data-driven approach and on the other hand, traditional programming is heavily dependent on the developer's creativity to create an algorithm that solves the problem [7]. In easier terms, traditional programming is a manual procedure which means the programmer has to create the program whereas, in the case of machine learning, the algorithm spontaneously creates the rules from the data [8]. Figure 1 outlines the difference between traditional approach of programming and machine learning.

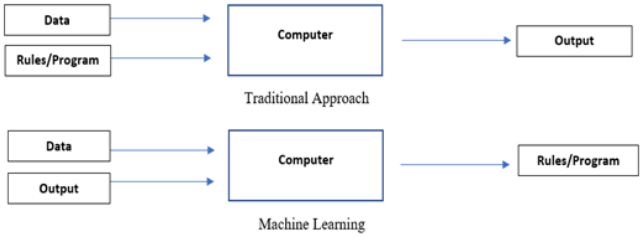

Fig 1. Difference between traditional methods and Machine Learning

1.2 Types of Machine Learning

Machine learning (ML) contains computer algorithms on which we perform our models based on data. It is an integral part of artificial intelligence (AI). With machine learning, we can model based on data with the help of algorithms so that we can make predictions or decisions.

In easier terms, machine learning is considered as the extraction of information out of data. The basic idea of machine learning is to recognize patterns or specific trends in the data and make functional conclusions using those patterns.

There are mainly three classifications of machine learning namely:

1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

Figure 2 depicts different classifications of machine learning.

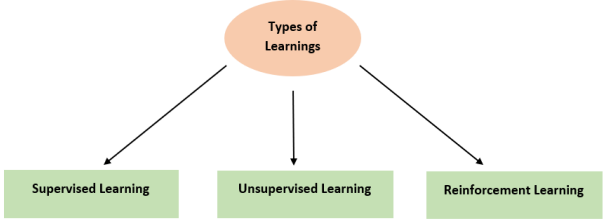

Fig 2. Classifications of Machine Learning

1.2.1 Supervised learning

Supervised learning, as the name suggests involves machine learning algorithms that are learned under the existence of some supervisor. Since, under the supervision of a teacher or a supervisor, this type of learning helps us to gather information or to produce a data output from the earlier occurence. The working of supervised learning can be understood using an example i.e. if we want to reach home on time, we need to consider several factors that include weather condition, distance, our speed, etc. All these details are our inputs whereas the output would be the time taken to reach home on time. Now, the machine needs facts and statistics. A set of training data will be created that will contain details of inputs such as weather etc. And based on these training data, the machine will see that there is a direct relationship between the features and the time it will take to get home on time [9].

1.2.2 Unsupervised learning

On the other hand, in unsupervised learning, we lack such presence of a supervisor which means we have to decide about what to do. Because of the absence of some supervision, it works on its own to collect the data and hence mainly deals with the unlabeled data to find unknown patterns in data. To understand the working of unsupervised learning, let us take an example of a small child and her family dog. Now, the family decides to bring in a new dog and the child still sees it as a dog because it identifies features (two eyes, 2 ears, 4 legs, etc.). This is unsupervised learning, in which we can be taught but learn in detail from the data .

1.2.3 Reinforcement learning

Reinforcement learning varies from both supervised learning and unsupervised learning in such a way that in this type of learning, the reinforcement agent decides what to do to do the given task. In other words, the decision depends on the case for strengthening the learning. This technique helps us learn how to achieve a complex goal or increase a certain size in many steps. Let's take the example of a cat. Now, the cat doesn't know anything about our language, so we plan a plan and if the cat does something, it will get a fish otherwise it won't. Therefore, whenever a cat is exposed to such a situation, the cat will do the same in anticipation of the reward. This is an invigorating study that helps us increase a portion of the collection's income [10].

Table 1. Comparison between Supervised, Unsupervised, and Reinforcement learning

Sno.	Basis of Comparison	Supervised Learning	Unsupervised learning	Reinforcement Learning
1.	Training Data	Requires the supervisor or the expert to recognize or label the data	Unlabeled or unidentified data	Learns from the interaction with the environment
2.	Preference	Routine tasks (input-output mapping)	Clustering, discovering data correlation and new patterns	Artificial intelligence (Behavioral learning)
3.	Area/field	Machine learning	Machine learning	Machine learning
4.	Optimal Strategy	Depends on the data and the algorithm used	Depends on data and its classification	Learns the optimal strategy from experience
5.	Exploration	No exploration	No exploration	Adaptable to changes through exploration

1.3 Why consider Machine Learning for healthcare?

The use of robotic devices in the healthcare system in the medical sector will benefit large numbers of people. Healthcare is the most popular field in which robotics has a good capability to bring change in the traditional methods that were adopted by our medicine industries [11]. Several people with disabilities need care at their homes only but many times their family members are unable to do so because of their own work lives. This is where robotics comes in. Medically designed robots can be really helpful in these cases, where they will take care of the patient.

In the years to come, machine learning will take over the healthcare departments around the world. The adoption and utilization of machine learning (ML) and artificial intelligence (AI) will transform the field of medical science and health care. Proper utilization and implementation of machine learning and in the health care ad medical region ensures a better diagnosis and treatment of a particular disease.

1.4Role of Machine Learning in Health departments

Machine learning provides stronger results when it comes to healthcare departments. This is because of its better efficiency and fast decision-making qualities. Mechanical Learning Programs can be developed for health care services, which can change the diagnosis and treatment of diseases, which ensures that patients receive the right treatment at the right time.

The implementation of Machine learning in healthcare departments have brought many positive changes like:

1. Imaging and diagnosis are possible by scanning the body.
2. Operating on a body becomes easier and more comfortable with help of surgical robots.
3. Treating cancer has become much easier as these machines depict the after-effects of radiation on the body.
4. These machines work with more precision and accuracy and hence fewer complications are expected.
5. Detecting drugs and medicines become easier as machines can suggest how an individual can behave under certain medications and cases.

1.5Applications of Machine Learning in Healthcare departments

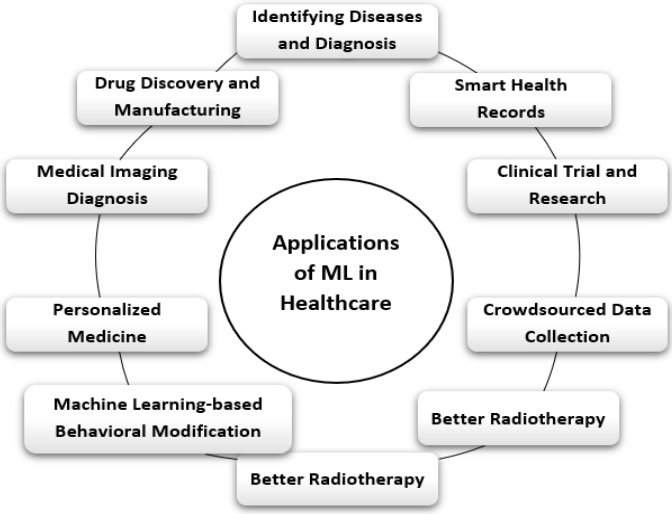

Fig 3. Some well-known applications of Machine learning in healthcare

1) Identifying Diseases and Diagnosis: This is one of the most important applications of machine learning when it comes to healthcare. With machine learning, diseases like cancers that are tough to identify during their elementary stage are identified which can help in early diagnosis. [12]

2) Drug Discovery and Manufacturing: This is a primary application of machine learning where early-stage drug discovery task. Research and development (R&D) technologies are also included in this which are very useful in searching for proper medications and therapy.

3) Medical Imaging Diagnosis: Both machine learning, as well as deep learning, are considered to be equally accountable for the advanced technology called Computer vision. With help of this, image analysis has been made possible .

4) Personalized Medicine: Personalized medicines are more likely to transform healthcare standards when the selection of certain treatments as per the standard guidelines seldom fails [13]. It uses special data about a person's health condition which can be useful in making a diagnosis and finding out if the treatment is working properly or not.

5) Machine Learning-based Behavioral Modification: To create a specific profile or a type of description about an individual and examining its behavior is known as Machine Learning-based Behavioral Modification [14]. The purpose of using behavioral analysis is to make us realize our unconscious behavior in our daily lives and making necessary changes.

6) Smart Health Records: Smart health records refer to a maintained health record of an individual and thus keeping it up-to-date can be a hectic task. But, with help of machine learning, the data entry process has been made easy and simpler.

7) Clinical Trial and Research: Machine learning is a promising technology in the area of clinical trials and research. Machine learning plays an important role in recognizing promising candidates for clinical trials that can benefit many researchers in fetching out different varieties of data.

8) Crowdsourced Data Collection: Crowdsourced in healthcare allows researchers in getting access to a huge amount of data that is uploaded by the people with their own agreement and consent.

9) Better Radiotherapy: This is one of the most sought after uses of machine learning as image analysis can be very beneficial in detecting the difference between healthy and unhealthy tissues and therefore it can help in improving the therapy or treatment for the same.

10) Outbreak Prediction: Machine learning and other AI-based technologies are used in today's time in predicting several outbreaks as well as epidemics around the globe. This is because, scientists have access to a variety of data which is collected from satellites, website information, etc.

1.6 Robotic Surgery using Machine learning & Artificial intelligence

Machine learning is a major part of research in robotics because, with the presence of a large number of datasets, the robot educates itself accordingly as mentioned in , there is a wide range of robots where machine learning has become very popular which includes Robot vision, Robot navigation, field robotics, humanoid robots, legged locomotion, off-road rough-terrain mobile Robot navigation, modeling vehicle dynamics, medical and surgery Robotics. The Da Vinci robot's system is the most widely used robot system in the world [15].

Fig 4. Artificial intelligence surgery (Robotic Surgery) [16]

Figure 3 represents the actual implementation of robotics in a surgery where the surgeon is holding a robotic arm [16]. Robots are "interconnected systems capable of making physical changes in the world" [17]. Surgery is considered as a highly sensitive procedure that requires correct instructions as well as correct implementation. The robotic Surgery process consists of the robotic surgical system and the surgeon or surgeons who are involved in the operation. Every decision depends upon the surgeon about how effectively he/she can operate the surgical

system to yield better results. These surgical systems are mechanical systems that are powered by microprocessors and are also provided with motors and sensors [18].

Specific computer algorithms are used to analyze the surrounding information and with help of this, certain inputs are processed by the sensors which are being used to perform the given task.

Surgeons in many domains of medical sciences like urology and gynecology are getting more and more familiar with this advanced technology. In this perspective, robotic surgeries ensure flexibility, stability, and an enhanced vision for the professionals in executing surgeries. The use of robotic surgery helps in replacing limited human movement both in time as well as in space to make complex processes possible making them more reliable and safer [19]. 3D-HD visualization on systems such as The da Vinci system is the most commonly used system for robots worldwide [20]. The computer also filters the most common seizures that used to occur with traditional surgical procedures. Along with the proper functioning of the robots, the software also plays an important role while carrying out any surgical task [21].

1.6.1 Components in a robotic surgery

The Da Vinci program contains three key elements namely, a surgeon console, a patient cart, and a vision cart. All of these components work together to allow the surgeon to perform the surgical task carefully and then operate the moments to move the instruments with more flexibility. The surgeon's console is the spot where the surgeon sits and keeps an eye on every movement of the instrument that is working on the patient. It controls the robotic system remotely. Through a surgeon's console, a surgeon can have a high-definition real-time 3D view which helps them in better performance of the surgical task. A surgical console can help surgeons in extracting valuable information during complex cases.

The second component of a surgical robotic system is the vision cart. The camera and other instruments required for the surgery are placed on the patient's cart and through these cameras, a three-dimensional (3D) view is established. A High-definition vision is also there in this component which provides a higher resolution with improved clarity and details and about six to ten times the magnification of the operating area. The digital zoom reduces the interference between the endoscope and instruments. This component takes the charge of the establishment of proper working and communication between all three components of this surgical system.

The third component i.e., the patient cart which is kept next to the patient's bed where he/she is supposed to be operated holds the camera and the instruments that are required for the surgery. A patient cart also consists of robotic arms which are used by the surgeon to make flexible movements with more accuracy. Figure 4 depicts different components of a surgical robotic system [22].

Fig 5. Components of Da Vinci System: Surgeons Console (left), Patients Cart (Centre), Vision Cart (Left) [22].

II. Methodology

Surgical operations include a variety of factors that depend on a variety of factors such as smoothness, comprehension, or direction of response, which determines the ability while relying solely on the movement of the metal [23]. Apart from this, it is very important to follow a systematic approach

because any kind of error can lead to a waste of energy and effort [24]. The growth of this discipline has increased dramatically. Without such growth, the effective implementation of this technology is rare. This is due to the high financial costs associated with these programs. The mechanism of action of any robotic surgical system evaluates six methods namely, clinical need, clinical performance, safety, cost, compatibility, and use. Each situation can be considered as part of three-line top management as shown in Fig. 4. The lower part has the heaviest weight and the lower part is the lowest.

The bottom tier i.e., the clinical need is the most important criterion to be considered as it defines the whole purpose and framing of the robotic system. The middle tier consists of clinical effectiveness and safety which must be fulfilled once a functional purpose has been established. The top layer has robotic features such as compatibility, cost, and usability and none of these points in this layer can prevent the surgical system from being left unattended. The boundary between the middle and upper class can be considered as the difference between the model and the product.

Clinical need: The clinical need in any robotic surgical system describes the whole requirement and aim behind a specific project [25].

Safety: To get approval for its safety, a surgical system has to undergo various rigorous assessments. Other common security measures include redundant sensors, emergency brakes, watchdog time control software, limitations of kinematics- and software, etc.

Clinical Effectiveness: Clinical effectiveness is related to the improvement or development in any state or condition e.g., decreasing cholesterol or blood pressure in a patient having heart disease, etc.

Usability: Usability here means that the surgical system should be easy to use and easy to learn as well. If the system is very complex to understand and use, then it would increase the chances of human error and would become time taking for the surgeon.

Cost: It refers to the total fare of the surgical system. A surgical robotic system is highly expensive and hence it is considered in the top tier. Besides the cost, the maintenance of such systems is also very costly.

Compatibility: The compatibility of a surgical robotic system is considered as to how much compatible the system is with its environment and the surgeon. If the space available is small, then the system should be able to operate in that environment.

Figure 5utlines the Hierarchal structure of criteria for surgical robotic systems.

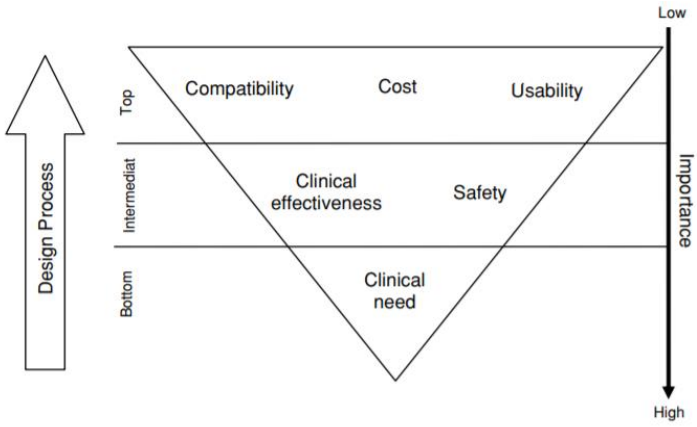

Fig 6. The hierarchal structure of criteria for a surgical robotic system [24]

2.1 Use of Machine Learning in various surgeries

There is no doubt that health care has transcended traditional medicine, and new inventions have led to customized medicine and technology-approved care in this way, medical science has developed various robotic systems in various medical fields. The use of robotic surgery is growing exponentially in the field of gynecology. This adoption of artificial intelligence is because it promises an improved vision, used instruments, and advanced ergonomics associated with such systems, encouraging many surgeons to perform invasive procedures that were earlier banned by laparoscopic surgeons [26].

Compared with traditional treatments for previous gynecology, the use of robotic machine learning in

this domain ensures minimal blood loss, minimal surgical pain, short hospital stay, and recovery of high levels of lymph node, although it may be costly. In traditional methods, there is severe pain involved in any surgery for women and often there is physical trauma associated with such surgery.

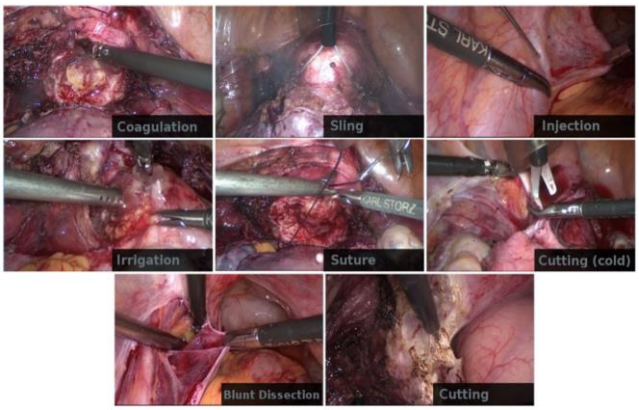

Fig 7. Laparoscopic view of a gynecology surgery with the help of machine learning [27]

Kidney transplant surgery is only necessary when one or more of the kidneys will be removed. Traditional methods of kidney surgery involved large incisions of up to eight inches. When robotic kidney surgery occurs, cuts are very short and recovery time is also short due to which the patient can resume his or her daily life activities immediately.

Gallbladder surgery involves cholecystectomy which means removal of the gallbladder. With the help of robotic gallbladder surgery, surgery can be performed on a single skin resulting in fewer scars and the recovery time is also shorter due to less bleeding as compared to open surgery. Gallbladder surgery with help of robotic surgical procedures is very helpful for the patient as it can return to work much faster compared to traditional surgical procedures.

2.2 Why Robotic surgery has an edge over the traditional methods of surgery?

Robotic surgeries are far more precise and accurate as compared to traditional surgical methods. This surgical method allows complex surgeries to be performed which were not possible in the case of earlier traditional methods. From a patient's view, such surgeries cause minimal pain and scarring [20]. It also promises a short recovery time. The surgeon also enjoys more flexible movements and enhanced visibility of the operated area. Such surgeries promise fewer complications and there is no need of staying for a longer period in hospitals. With the help of robotic arms, surgeries can be performed with more delicacy and precise effective movements, and hence they can make better decisions.

2.3 Risks Involved in Robot-Assisted Surgeries

While performing any robot-assisted surgery, there is not only the possibility or chances of human error but there is also a potential risk for mechanical failure. Such surgeries can be a cause of nerve palsies because of extreme body positioning or direct nerve pressure that may take place while using robotic components. A patient may experience some breathing problems and small infections due to the surgery.

III. Conclusion

Machin learning has shown its crucial importance and role in various departments. With proper use of mechanical and robotic learning in a particular area, there will be a better understanding and predictability of infectious disease transmission and transmission mechanisms, improving targeted interventions, and reducing health-related diseases. The safety and subsequent results of robotic surgery depend on what the surgeon does because it is not the robots that perform all the surgical operations but the surgeon who uses those surgical procedures. In newer robotic systems, the surgeon is free to measure movement. That is to say, he can set the scale on a one-to-one scale where the arm of the robotic system will move two inches by one inch of the surgeon's hand.

With the development of this new technology, a systematic training or instruction program is essential to improve to guarantee more enhanced surgical outcomes and products for patients. Such training programs should not be disrupted by any learning process. A well-trained and systematic module is needed to ensure the secure and effective use of these emerging technologies. To be precise, the number of these formal training programs is very small. Such programs should include good knowledge, skills, real-time case recognition at the training center, bedside help, and counseling console. Apart from this, a certificate of completion of the surgical training program module must be issued to define a robotic surgeon. Along with the certificate of completion, the operating license for the operating system should also be provided for additional security. These steps are very important from a patient's viewpoint so that they can have faith and trust in the surgeon. We hope that the proper use of these modern technologies brings efficiency to the surgeon and patient safety.

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