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Review of Integration of Machine Learning Techniques in Biomedical Engineering: Enhancing Diagnosis, Treatment, and Healthcare Systems

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ABSTRACT

The extensive influence of biomedical engineering's use of AI and ML on healthcare systems, diagnosis, and therapy are the primary foci of this review. By sifting through mountains of data in search of patterns, machine learning algorithms have utterly transformed biological applications. Medical imaging analysis, illness diagnosis and prognosis, individualized treatment planning, medication development, healthcare administration, and other critical areas where machine learning improves biomedical engineering are scrutinized in this study. It lays forth the revolutionary possibilities of machine learning in healthcare delivery, patient outcomes, and precision medicine (drug development) via an exhaustive literature analysis. In addition, it suggests ways forward for study and application while tackling problems including data quality, interpretability, and ethical concerns.

Keywords: AI, Machine Learning, Biomedical Engineering, Disease Diagnosis And Prognosis, Image Analysis, Drug Discovery, Patient Outcomes

I. Introduction:

Biomedical engineering seeks to address healthcare difficulties via the integration of medicine, biology, and engineering. A significant game-changer in this discipline is the incorporation of machine learning methods. From early illness identification to individualized treatment techniques, machine learning algorithms might completely transform healthcare by using AI and big data analytics [1]. Machine learning has many applications in biomedical engineering, and this study delves into such applications and their potential to enhance healthcare delivery, patient care, and diagnostics.

Clinical laboratory testing, illness diagnosis, and therapy selection might all benefit greatly from AI integration in healthcare. Artificial intelligence systems can outperform humans in several areas of healthcare by mining massive information for trends. While artificial intelligence (AI) reduces the likelihood of human mistake, it increases accuracy, saves money, and saves time. It has the potential to transform the field of customized medicine by creating virtual health assistants, optimizing pharmaceutical doses, improving population health management, establishing recommendations, bolstering mental health care, enhancing patient education, and influencing trust between patients and doctors [2]. To facilitate the easy identification of data patterns, deep learning used data mining methods and Convolutional Neural Networks (CNN) to construct layers. [3].

Artificial intelligence , machine learning and Deep learning in Biomedical engineering:

Machine learning is a branch of artificial intelligence. Machine learning is centered on systems that can learn autonomously from their experiences, without any kind of human involvement or support.
The primary goal of DL algorithms is to process data. In the same way that our brains categorize data based on patterns, patterning mechanisms do the same. DL is able to self-administer the prediction process and operates on bigger data sets than ML.
More precise diagnosis and treatment suggestions may be possible with the help of cutting-edge diagnostic systems that use AI and machine learning algorithms to sift through mountains of patient data.

II. Literature Survey:

Machine learning has many potential uses in biomedical engineering, particularly in the areas of diagnosis, image analysis, and drug development. This study aims to examine these applications. The process's indicated algorithms, their relative efficacy, and the ways in which they failed or shown less resilience.

"Revolutionizing Healthcare: The Role of Artificial Intelligence in Clinical Practice" by Alowais commented on the function of AI in healthcare and how it may be effectively implemented by providing healthcare practitioners the necessary information and resources [4]. In this research, we looked at the possible effects and consequences of using AI in healthcare settings. Author: McKinney SMHe demonstrated in his research that using an AI system to interpret mammograms reduced false positives by 5.7% and false negatives by 9.4%, respectively [5]. Linked difficulties, including those involving human knowledge, ethics, and the law. raises awareness of AI's value in healthcare and helps hospitals and other medical facilities successfully use AI systems[6].
"Evaluation of artifcial intelligence approaches in illness diagnosis and prediction" by Nafseh Ghafar[7] showed that AI systems need enormous amounts of data, which isn't always feasible when dealing with most infections. The fact that data labeling is an expensive and time-consuming process that calls for expertise adds another layer of difficulty [8]. Training state-of-the-art ML models requires high-quality patient datasets, according to another research. Strict privacy and security measures make its acquisition difficult. Preparing data for machine learning analysis requires a lot of work, as shown in another article [9]. Feature extraction from pictures of blood cells infected with malaria was also performed using the CNN model in another work [10].
Acute exacerbations in chronic obstructive pulmonary disease were identified by researchers using several machine learning algorithms as Random Forest, Support Vector Machine, Logistic Regression, K-Nearest Neighbor, and Naïve Bayes. The SVM model was determined to have the highest performance [11]. Another study utilized data from the National Survey on Drug Use and Health from 2015–2017 to forecast opioid use among teenagers using three ML algorithms: artificial neural networks (ANN), distributed random forests (DRF), and gradient boosting.
“Artificial intelligence in medical imaging: moving from radiographic pathological data to clinically useful endpoints” states Ohed's research. Artificial intelligence (AI)-powered mammography screening did not outperform human radiologists in identifying cancer[12].

According to an additional research, the models undergo thorough evaluation. DenseNet121 achieved the best validation accuracy with 99.94%, the lowest loss with 0.0017, and the lowest Root Mean Square Error (RMSE) values with 0.036056 for training and 0.045826 for validation. The findings showed that AI-based approaches may improve the accuracy of cancer diagnosis, with DenseNet121 being the most successful model [13].

A realistic dataset, which can be obtained via the use of an ETL tool and a large dataset, is necessary to generate reliable findings when using AI for illness detection, according to the literature review. [14]

III. AI Role in Bio medicals :

1)Medical Imaging Analysis by machine learning:

When it comes to biomedical engineering, medical image analysis is where machine learning really shines. Human error and lengthy processing times characterize conventional approaches to medical image interpretation using X-rays, MRIs, and CT scans. In contrast, machine learning algorithms may automate the interpretation of images, extract relevant information, and aid doctors in the detection of anomalies with remarkable precision. For example, convolutional neural networks (CNNs) have shown outstanding results in the early detection and improvement of patient outcomes for imaging-based diagnoses of cancer, neurological illnesses, and cardiovascular diseases.

Fig 1: Imaging Analysis by machine learning

2).Disease Diagnosis and Prognosis:

By evaluating various biological data sources, such as genomes, proteomics, and electronic health records (EHRs)[15], machine learning is important in illness diagnosis and prediction. Using this information, machine learning algorithms may categorize people according to their risk profiles, forecast how patients will fare, and detect disease biomarkers. Case in point: the use of support vector machines (SVMs) and random forest classifiers in the diagnosis of diabetes, cancer, and infectious illnesses has allowed for prompt interventions and individualized treatment programs based on patient traits. For deep learning models to perform as well as human doctors when it comes to making diagnoses.

3).Personalized Treatment Planning by Machine Learning:

A promising approach to enhancing therapeutic results while avoiding side effects is personalized medicine, which tailors' treatment procedures to each patient's unique traits. Predictive models that take into consideration genetic variables, treatment response, and patient variability may be created using machine learning methods. Machine learning algorithms improve therapeutic monitoring, dose optimization, and therapy selection by evaluating large datasets including patient demographics, clinical factors, and molecular profiles. More successful and less dangerous cancer treatment regimens have been achieved, for example, by the use of deep reinforcement learning algorithms to improve medication combinations. Targeted medicines that are more successful and less likely to have adverse effects may be available via this customized healthcare strategy, which has the ability to change treatment paradigms.

4).Healthcare Management:

Machine learning has several uses in healthcare beyond only clinical settings; it helps with resource allocation, operational efficiency, and overall patient outcomes. Healthcare practitioners may use predictive analytics technologies to anticipate patient admission rates, distribute staffing resources, and implement early intervention techniques to avoid hospital readmissions. To aid in evidence-based decision-making and quality improvement efforts, natural language processing (NLP) algorithms[16] extract useful insights from unstructured patient data and clinical notes. Wearables powered by machine learning and remote monitoring systems enable patients to take an active role in their healthcare management, encouraging a change in focus from reactive to proactive and preventative therapy. [17]

5). AI in Diagnosis :

When it comes to understanding medical pictures, finding abnormalities, and aiding in diagnosis, artificial intelligence systems have shown exceptional adeptness. Algorithms that can detect patterns in medical photos [18]with more accuracy and speed than people have been developed by using the capabilities of machine learning, especially deep learning. Consequently, this leads to quicker and more precise diagnoses, which in turn improve patient outcomes while reducing healthcare costs.

6).AI Contribution in Diagnosis the Cancer :

Cancer is an umbrella term for a group of illnesses defined by the uncontrolled growth and metastasis of aberrant cells that may invade and damage healthy tissue. There are cancer detection software options accessible right now. Figure 1: Example.

Fig 2 : AI Cancer Detection Software

Because cancer is the biggest killer in the world, finding ways to detect it has become a major problem for scientists and doctors. There is a need for more effective and efficient solutions in the field of artificial intelligence (AI), particularly in the area of deep learning models, since existing cancer detection approaches often depend on invasive procedures and time-consuming investigations, despite the critical importance of early diagnosis. Some examples of CNNs include DenseNet121, DenseNet201, Xception, InceptionV3, MobileNetV2, NASNetLarge, NASNetMobile, InceptionResNetV2, VGG19, and ResNet152V2.The following seven cancer types are tested using picture datasets: cervical, Acute Lymphocytic Leukemia, brain, oral, breast, kidney, lung, and colon cancers. [19].

7).AI in Detecting Leukemia:

The sensitivity and specificity of leukemia diagnosis have been enhanced by the objective decision-making capabilities of artificial intelligence (AI)[20]. Using blood and bone marrow samples, AI-based algorithms have shown to be very accurate in detecting subtypes of leukemia, including chronic myeloid leukemia (CML). As an example, consider the research of Huang et al. [21] Demonstrated that CNNs were able to classify CML cells from microscopy pictures with an accuracy of well over 95%. This impressive degree of precision highlights the promise of AI in enhancing the accuracy and efficiency of diagnostics.

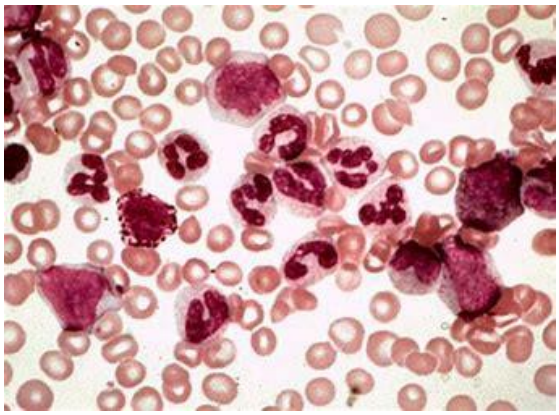

Fig 3: AI proves Leukemia cancer.

8).AI in Detecting Breast Cancer:

Researchers, doctors, regulatory agencies, and others must work together to realize artificial intelligence's great promise in improving breast cancer screening [8]. By using the appropriate methodology and framework, artificial intelligence has the potential to enhance breast cancer screening, leading to better health outcomes for patients. [22][23][24][25].

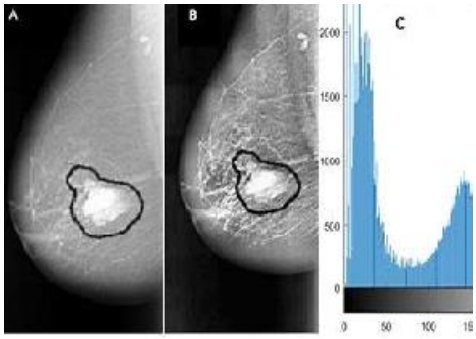

Fig 4: Detecting Breast Cancer:

9).AI in Detecting Lung Cancer:

In order to combat the scarcity of radiologists, AI may be used to aid in the early detection of lung cancer [26]. Traditional ML-based CAD systems for pulmonary nodules have achieved impressive strides in recent years [27].Artificial intelligence (AI) technology outperforms radiologists in recognizing GGNs larger than 5 mm and screening nodules between 0 and 3 mm in pulmonary nodule imaging, according to recent research. Having said that, CAD technologies cannot replace human clinicians. By blocking normal lung structures, particularly blood arteries, the Vasopressors (VS)-CAD system, formerly known as the ClearRead CT software, which received FDA approval in 2016, might enhance the detectability of tiny pulmonary nodules. As artificial intelligence (AI) has progressed, deep learning (DL) neural networks (NNs)[28] have shown great promise in pulmonary nodule identification, segmentation, and classification.

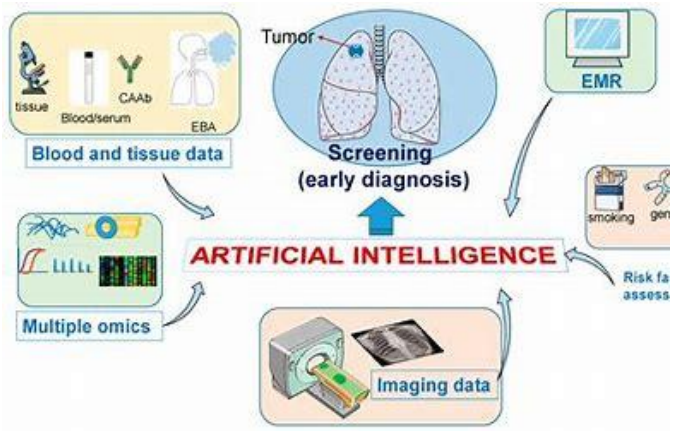

Fig 5: Lung Cancer

10).AI in Advanced blood testing:

Biomarkers, which may be proteins or DNA, can indicate the presence of illness or track its course; advanced diagnostic testing may include blood analysis to identify these markers.

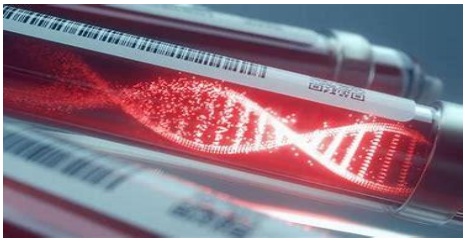

Fig 6: AI Blood Test proves Lung cancer detection

11).AI role in drug discovery :

With the advent of AI and the deluge of clinical data, powerful new tools have become available to drug developers, offering the potential to greatly enhance the efficiency of drug-development processes.

From identifying targets to designing clinical trials, pharmaceutical firms began incorporating AI into many aspects of drug development. There has been a transition toward more efficient, data-driven pharmaceutical R&D in recent years, and artificial intelligence (AI) has become an essential tool in this process, speeding up drug discovery, improving clinical trials, and customizing therapies. [29].

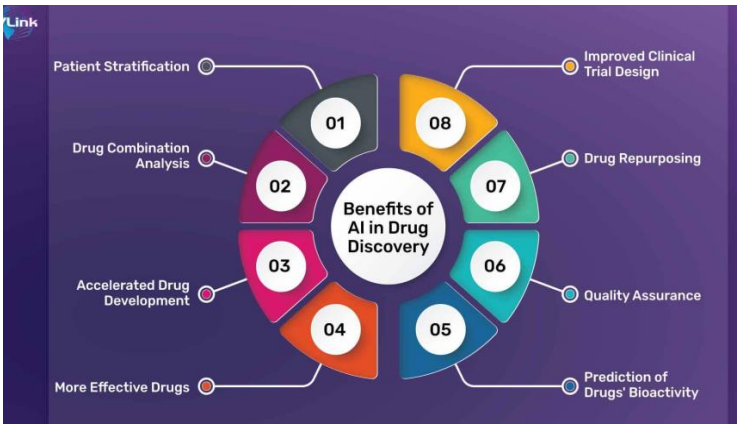

Fig 7: Drug Discovery through AI

12).Patient outcomes:

Through the application of machine learning, deep learning, and natural language processing methods to massive amounts of healthcare data, AI has enabled the detection of illnesses at an early stage, the creation of personalized treatment regimens, and the identification of complicated patterns. medical picture interpretation, which aids in the analysis of diagnostic imaging, including X-rays, CT scans, and MRIs, to detect abnormalities that human radiologists can miss[31][32][33][34]. Artificial intelligence is crucial for making medical image analysis more accurate and efficient, which aids in the early diagnosis of sickness, the planning of treatments, and the improvement of patient care [35].
Improving patient outcomes may decrease healthcare costs associated with hospital readmissions. The new businesses like "Reveal ®" were born out of the need to develop prediction models that could account for social health issues, medical history, and patient demographics. [36].

IV. Advantages of AI in Bio Medical Engineering:

- Artificial intelligence can help us identify potentially deadly cancer cells and other types of cell damage.
- With the help of AI, early treatment may be feasible.
- It allows for the best decision-making while reducing costs.
- Rapid drug development is within reach.
- The health industry saw a dramatic transformation with the introduction of AI.
- Because of advancements in blood testing, it becomes more precise.
- An all-encompassing picture of a patient's health is available with many MLs' round-the-clock monitoring.
- Efficiency gains in healthcare are possible via the automation of mundane operations and the quick processing of data.
- Surgical robots driven by artificial intelligence are helping surgeons with complicated surgeries and making minimally invasive treatments more precise.
- In the field of regenerative medicine, artificial intelligence is helping with things like designing and developing synthetic tissues and organs, optimizing growing conditions, and forecasting results.
- Reduced downtime and increased patient safety may be achieved via the use of AI algorithms that can forecast when medical equipment will need repair or replacement.
- Automated decision assistance from intelligent medical devices may help with patient management, treatment planning, and diagnosis.
- Researchers may now test hypotheses and make predictions using AI-powered models and simulations, all without subjecting their ideas to rigorous physical testing.
- AI technologies are making it easier for academics to work together by streamlining data sharing, analysis, and communication across different fields and institutions.
- There is less room for human mistake and more precise outcomes in shorter amounts of time when using AI techniques.
- ETL tools clean and prepare data for ML analysis, reducing the amount of labor needed to analyze the raw data.

V. Future challenges:

- Although there have been some successes in using AI to better understand and treat lung cancer, there are still many challenges to be solved.
- Artificial intelligence (AI) in healthcare settings should adhere to unified planning and complete aim, as well as standardized and defined principles that give fine-grained information for easy application in real-world situations.
- Regulatory clearance procedures may become more difficult due to the complex nature of AI-enabled products.
- Obtaining and transmitting personal health information is fraught with security and privacy risks.
- Maintaining backwards compatibility with preexisting healthcare IT systems is no easy feat.
- Implementation success depends on overcoming skeptics and making sure health care professionals get the training they need.
- There are ethical concerns about patients' rights to autonomy and decision-making transparency brought up by the use of AI in healthcare.
- A lot of money and risk goes into making sure that healthcare apps, services, and processes that use AI and big data are safe and efficient. [37].

VI. Conclusion:

Huge changes are coming to healthcare delivery and patient care as a result of AI's profound effects on biomedical engineering. Artificial intelligence (AI) offers unprecedented opportunity to improve results and expedite operations throughout the whole healthcare continuum, from individualized treatment and sophisticated diagnostics to simplified drug development and remote monitoring. To ensure that innovation is in line with values of openness, justice, and patient-centered care, as well as to fully realize the promise of AI in biomedical engineering, it is necessary to address ethical, regulatory, and social problems. Combining artificial intelligence with biomedical engineering is an exciting new frontier that might dramatically improve people's health and well-being throughout the globe. When data privacy, availability, and security are ensured, the data and analyses created by AI have the potential to be compelling and realistic. Because AI results could be skewed due to a lack of high-quality medical data. As a result, ML requires realistic datasets.

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