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Advances and Challenges in Enhancing Cancer Diagnosis with Green Artificial Intelligence Deep Learning Models: A Comprehensive Study

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Abstract: Cancer is characterized by the proliferation of aberrant cells originating from any organ inside the human body. Fundamentally, the proliferation of cells within these organs is reached a point of saturation. Deep learning (DL) is a subfield within the realm of machine learning and artificial intelligence that has found extensive application across various disciplines, including but not limited to health care and medication creation. The study of cancer prognosis involves the estimation of the eventual outcome for individuals affected by cancer, as well as the estimation of their survival rates. The primary aim of this study is to investigate the advancements and challenges associated with enhancing cancer diagnosis using deep learning models based on green artificial intelligence. The research approach utilised in this study is qualitative in nature. The present review study primarily examined the period spanning from 2018 to 2024. Based on the findings of this study, DL emerges as a versatile model that necessitates few data alterations and demonstrates superior performance when applied to vast quantities of data.
Keywords: *Cancer; Green Artificial Intelligence (AI); DL; Healthcare; Cancer Research; Treatment*.

INTRODUCTION

Cancer is characterised by the proliferation of aberrant cells originating from any organ inside the human body. Fundamentally, the proliferation of cells within these organs is reached a point of saturation [1]. These quiescent and packed cells undergo rapid proliferation until they are either eliminated through a physical intervention such as surgery, medicine, hormonal therapy, or radiation therapy, or they naturally dissipate. The phenomenon of spontaneous apoptosis can occur in malignancies associated with renal or melanomagenesis. The detection of these cells can be accomplished using many diagnostic techniques, including colonoscopy, pap smear test, or mammography [2]. There exists a vast array of over 150 distinct forms of cancer, with a dearth of effective therapeutic approaches available for their early-stage treatment. Cancer stem cells have been identified as a viable approach for the generation of stromal cells, hence offering potential for the effective treatment of cancer. In addition to its role in stem cell function, the WNT16B protein has been found to enhance resistance against cancer in conjunction with chemotherapy [3]. Treatment modalities such as laser therapy and cryotherapy represent highly dynamic and promising methods in the realm of cancer treatment. Lip, oral cavity, breast and cervical, and thyroid cancers are among the most commonly observed forms of cancer on a global scale. In contrast, it is noteworthy that certain types of cancer, namely osteosarcoma, Ewing's sarcoma, male breast cancer, gastrointestinal stromal tumours, chondrosarcoma, mesothelioma, adrenocortical carcinoma, cholangiocarcinoma, kidney chromophobe carcinoma, pheochromocytoma and paraganglioma, sarcoma, and ependymoma, constitute over 20% of cancer cases and are classified as rare forms of malignancies [4].

In recent years, there has been a remarkable expansion in the field of DL within the realm of Green artificial intelligence. This advancement has enabled the development of intricate computer models capable of representing abstract concepts derived from data. DL has found extensive applications in various fields, including speech processing and visual processing. The aforementioned methods operate by identifying intricate patterns within extensive and frequently intricate datasets through the utilisation of a backpropagation algorithm [1]. In contrast to DL, standard methodological approaches, such as machine learning-based methods, exhibit certain limitations when it comes to handling raw natural data without prior preparation. The below diagram elucidates the function of AI in the diagnosis of Cancer.

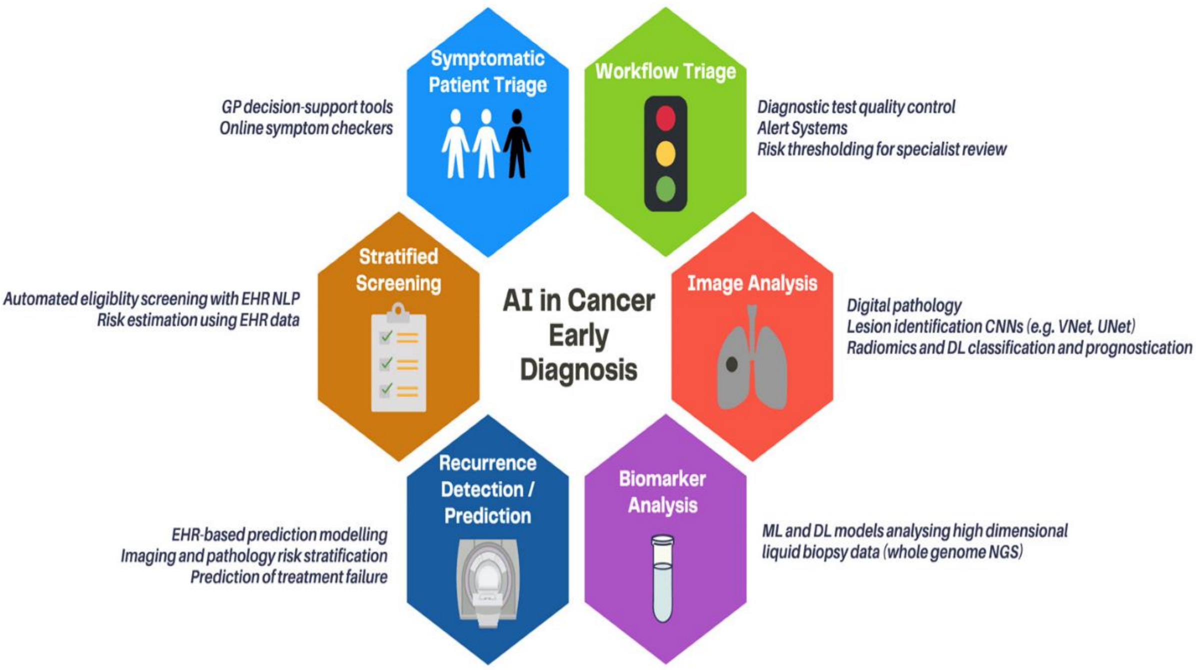

Fig. 1. An Overview of Cost Estimation Process

The primary objective of this study is to investigate the advancements and challenges associated with enhancing cancer diagnosis using deep learning models based on green artificial intelligence. This following section provides an overview of the previous literature that is pertinent to the present research.

LITERATURE REVIEW

The subsequent table provides a comprehensive overview of previous scholarly works pertaining to the advancements and challenges encountered in the enhancement of cancer diagnosis through the utilisation of green artificial intelligence deep learning models.

Tab. 1. Comprehensive review of research on green artificial intelligence deep learning models for cancer diagnosis.

AUTHORS AND YEAR	METHODOLOGY	FINDINGS
[6]	Investigated how AI aids cancer diagnosis and prognosis, particularly its exceptional accuracy, which exceeds ordinary statistical applications in oncology.	Provided a new viewpoint on how AI might improve cancer detection and prognosis and future human health.
[7]	AI-based Machine Learning (ML) and DL techniques for COVID-19 diagnosis and treatment were reviewed. This cited study also review AI-based ML and DL approaches, datasets, tools, and performance in the COVID-19 battle.	Unbalanced datasets due to poor medical imaging and protracted COVID-19 training period make it difficult to explain the findings.
[8]	This cited paper discussed cancer research AI trends, difficulties, and future directions.	Regulatory limitations on data security and privacy, non-labelled data, data bias, imbalanced data, etc. limit AI use for cancer research. Because AI is predictive and probabilistic, it will make bad decisions in some scenarios.
[9]	This review discusses using AI to diagnose and treat OC early in cancer. Additionally, numerous DL and ML models have been evaluated to show that the DL model may	To prevent or reduce oral cancer, reduce tobacco and alcohol usage and immunise against HPV. Oral disease prevention also involves clinician and patient training and screening high-risk populations for early detection.

	overcome the tough obstacles of early mouth malignant tumours.	
[10]	This comprehensive research revealed AI and ML's remarkable impact on oncology and their many applications. AI and ML give cancer doctors unmatched precision and efficiency.	Despite challenges, these technologies could transform patient care, improve outcomes, and combat cancer. AI and ML in oncology must be explored and responsibly implemented to maximise their potential and improve cancer patients' lives.

Research Gap

Considering the notable progress made in the field of lung cancer diagnosis through the utilisation of deep learning models, there remains a crucial research void in effectively reconciling the need for precise diagnostic accuracy with the constraints of energy efficiency and processing requirements. Traditional deep learning models utilised in cancer diagnosis frequently exhibit resource-intensive characteristics, resulting in elevated energy usage and consequential environmental ramifications. The existence of this gap highlights the necessity of creating green AI models that effectively employ computational resources and energy consumption while maintaining diagnostic performance at an optimal level. Furthermore, it is evident that there exists a dearth of both accessible and sustainable solutions that effectively utilise green AI for precise diagnosis of lung cancer. This underscores the imperative for research endeavours that prioritise the development of environmentally friendly, efficient, and widely available deep learning models within the realm of medicine.

METHODOLOGY

A qualitative methodology was utilised in this study, utilising secondary data obtained from peer-reviewed articles, conference papers, and academic journals published between the timeframe of 2018 to 2024. The primary objective of this study is to identify and analyse the significant developments in green AI deep learning models for cancer diagnosis, while also examining the obstacles that arise during their application. The collected data undergone a systematic review and synthesis process in order to offer a full comprehension of the present state of research within this scholarly field.

RESULTS AND DISUSSION

Since the inception of the profession, specialists have made predictions regarding the potential of utilising AI technologies to provide highly personalised oncology care. The realisation of this promise is an outcome of the collective progress in the sciences, which includes the enhancement of ML and DL algorithms, the broadening and diversification of databases, including multiomics, and the decrease in the cost of highly parallelised computing power [8].

Advancements in Green AI for Cancer Diagnosis

The field of cancer detection has experienced notable progress due to the incorporation of AI, specifically deep learning models. This integration has brought about a substantial transformation in diagnostic procedures, resulting in improved accuracy and efficiency. The present study delves into the convergence of AI, deep learning, and green technologies in augmenting cancer diagnostics, while concurrently emphasising the obstacles that arise in tandem with these progressions. AI, specifically deep learning models, has significantly transformed the field of cancer diagnosis by its ability to analyse extensive medical data with unparalleled efficiency and precision [11]. The aforementioned models have exceptional proficiency in identifying intricate patterns within medical pictures, including mammograms, MRIs, and histopathology slides. These patterns play a vital role in the timely identification and accurate categorisation of malignant tissues. By harnessing the computational power of AI to analyse vast datasets, healthcare practitioners can attain more dependable diagnoses, resulting in prompt interventions and enhanced patient outcomes [12]. The diagram below illustrates the overarching methodologies for artificial intelligence in cancer research.

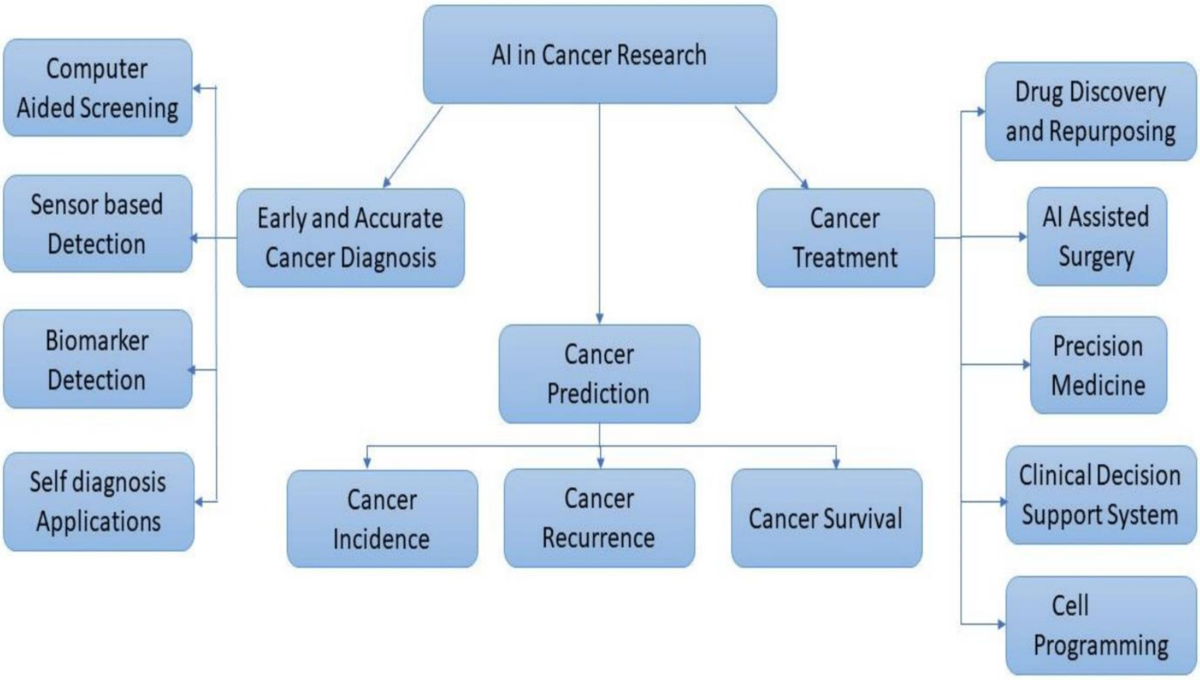

Fig. 2. Approaches for cancer research using AI [8].

Furthermore, the use of green AI in the field of cancer diagnostics signifies a diligent endeavour towards promoting sustainability in healthcare technologies. The concept of Green AI places significant emphasis on the utilisation of energy-efficient algorithms and computer infrastructures, with the aim of mitigating the carbon emissions connected with computationally intensive operations. In addition to its alignment with global environmental objectives, this strategy also improves the scalability and accessibility of AI-powered diagnostic tools, hence increasing their feasibility for wider use in healthcare systems globally [13]. The subsequent table presents a comprehensive overview of the research conducted on the prognosis and prediction of malignancies.

Tab. 1. Summary of the studies for the prognosis/prediction of cancers [1, 14,15,16]

Type(s) of cancer	Type of data	Methods	Performance
Astrocytic tumour	Microarray gene dataset	ANN	96.15% accuracy
Breast cancer	Nuclear morphometric features	ANNs	Good (>5 years) and bad (<5 years)prognoses
Breast invasive carcinoma	Gene expression data	Multiomics neural networks	Improved performance using more omics data
Breast cancer	TCGA	Random forest, neural network	Log-rank p < 0:05
Malignant melanoma	Custom dataset	Nonlinear ANN model	ANN model performs better than Cox model
Multiple	WHAS, SUPPORT, METABRIC, Rotterdam tumour bank	Deep feedforward neural network	Better prognostic accuracy than the clinical experts for the prognosis of nasopharyngeal carcinoma
Glioblastoma multiforme	TCGA	Pathway-associated sparse deep neural network	AUC = 0:6622 ± 0:013, F1 = 0:3978 ± 0:016
Breast cancer	Gene expression profile+copy number alteration profile+clinical data	Multimodal deep neural network	The proposed method achieves better performance than the prediction methods with single dimensional data and other existing approaches

Hepatocellular carcinoma	TCGA	DL-based model	p value = 7:13 × 10−6 Concordance index = 0:68
Colorectal cancer	Images of tumour tissue samples	Combined convolutional and recurrent architectures	Prediction with only small tissue areas (hazard ratio 2.3), tissue microarray spot (hazard ratio 1.67), and whole-slide level (hazard ratio 1.65)
Ovarian cancer	CT images	Combined DL and Cox proportional hazards model	Concordance index was 0.713 and 0.694
Multiple	TCGA	ANN framework	Same or better predictive accuracy compared to other methods
Multiple	WHAS, SUPPORT, & METABRIC	Cox proportional hazards deep neural network	Superior in predicting personalized treatment recommendations
Lower-grade glioma and glioblastoma	TCGA	CNNs	Median concordance index = 0:754
Mesothelioma	TCGA + French source	CNNs	Concordance index of 0.656 on TCGA cohor
Multiple	TCGA + Gene Expression Omnibus dataset	DL-based model	For both marker types, the specificity of normal whole blood was 100%

Challenges in Implementing Green AI Models

The issue of data quality and availability poses a significant hurdle in the efforts to improve cancer diagnosis using Green AI deep learning models. AI models, namely deep learning algorithms, heavily depend on extensive datasets in order to effectively identify and categorise malignant tissues. Nevertheless, obtaining well-curated, annotated medical datasets poses a substantial obstacle. Medical data frequently exhibit fragmentation, is housed in heterogeneous formats across multiple organisations, and is subject to stringent privacy restrictions. The presence of fragmentation poses a significant obstacle to the development of comprehensive datasets that are essential for training resilient AI models. Moreover, the current datasets often fail to sufficiently capture the diversity of patient populations, hence introducing potential biases in the predictions made by artificial intelligence systems [17]. It is imperative to prioritise the training of AI models on a wide range of diverse and representative data in order to cultivate dependable diagnostic tools that can be applied universally across various demographic cohorts. To effectively tackle these difficulties pertaining to data, it is imperative to engage in collaborative endeavours focused on data harmonisation, privacy-preserving methodologies, and international partnerships aimed at establishing comprehensive and inclusive datasets.

One other significant obstacle is to the transparency and interpretability of AI models employed in the field of cancer detection. Advanced deep learning models, namely those utilising intricate architectures such as CNNs, frequently face criticism for their perceived opaque nature. Although these models have the capability to generate predictions with a high level of accuracy, the decision-making processes employed by these algorithms may not always be readily apparent to doctors. The absence of interpretability poses a substantial obstacle to the widespread use of AI-driven diagnostic tools in clinical settings, since healthcare practitioners necessitate the ability to place trust in and comprehend the rationale behind AI-generated outcomes. The improvement of transparency in AI models entails the advancement of explainable AI (XAI) methodologies, which offer valuable insights into the decision-making processes employed by these models [18]. Nevertheless, the development of XAI techniques that maintain the precision and effectiveness of deep learning models continues to pose a substantial research obstacle. Striking a balance between the imperative of interpretability and the aspiration for elevated diagnostic accuracy is of paramount importance in establishing the confidence of healthcare practitioners and guaranteeing the secure incorporation of artificial intelligence into clinical practice.

Energy efficiency, a fundamental tenet of Green AI, poses an additional array of obstacles in the advancement of AI-powered cancer detection instruments. Deep learning models have a high level of computational intensity, necessitating substantial energy resources for both the training and inference processes [7]. The significant carbon emissions associated with the training of extensive AI models give rise to apprehensions over the environmental consequences of the widespread implementation of AI in the healthcare sector. The primary objective of Green AI is to address these concerns through the development of energy-efficient algorithms and the optimisation of hardware architectures in order to minimise power usage. Nevertheless, the process of attaining these objectives while maintaining the optimal performance of AI models is a multifaceted endeavour. The optimisation of energy consumption in AI models frequently necessitates making compromises between the intricacy of the model and its computing efficiency, hence potentially impacting the precision and efficiency of cancer diagnosis approaches [19]. Academic researchers are currently investigating a range of methodologies, including model compression, quantisation, and hardware acceleration, in order to develop AI models that are more energy-efficient. However, the implementation of these tactics within current healthcare infrastructures, which may not be fully optimised for the deployment of artificial intelligence, presents more obstacles.

Additionally, the wider healthcare landscape poses difficulties pertaining to the incorporation and uniformity of diagnostic instruments based on artificial intelligence algorithms. The integration of AI in the healthcare sector encompasses more than just technological considerations. It necessitates the navigation of intricate regulatory frameworks, the resolution of ethical dilemmas, and the assurance of compatibility with established medical processes. In light of the swift advancements in AI technology, it is imperative for regulatory entities to create unambiguous protocols for the validation and authorisation of diagnostic instruments based on artificial intelligence. It is imperative to address ethical considerations, including those pertaining to patient confidentiality and the potential for AI to perpetuate biases within the healthcare sector. It is imperative to establish uniformity in the use of AI tools among diverse healthcare systems and guarantee their compatibility with pre-existing electronic health records (EHRs) and imaging technologies in order to achieve their effective implementation. In order to address these problems, it is imperative to foster collaboration among AI researchers, healthcare providers, policymakers, and industry stakeholders [17]. This collaborative effort is necessary to provide an environment that facilitates the secure and efficient use of AI in the clinical diagnosis of cancer.

Potential future advancements in the field of cancer diagnosis using Green AI deep learning models are expected to prioritise various crucial aspects. These include the refinement of algorithms to enhance efficiency and interpretability, the incorporation of multimodal data sources, and the adoption of sophisticated privacy-preserving techniques [19]. As AI models advance in complexity, there will be a systematic endeavour to decrease their processing requirements by implementing techniques such as model pruning, quantisation, and the utilisation of energy-efficient hardware. These developments aim to uphold or maybe enhance diagnostic accuracy. Furthermore, it is anticipated that forthcoming AI systems would progressively integrate diverse data categories, including genomic data, electronic health records, and real-time patient monitoring. This integration aims to offer a comprehensive perspective on patient well-being and facilitate the provision of tailored diagnostic and treatment suggestions. Furthermore, given the enduring importance of data privacy and security, the use of methodologies such as federated learning and homomorphic encryption would guarantee the utilisation of patient data for the purpose of training artificial intelligence models, while safeguarding individual privacy [20]. The aforementioned achievements, in conjunction with ongoing endeavours to develop AI models that are transparent and verifiable, will contribute to the establishment of confidence among healthcare providers and patients, hence facilitating the broader implementation of Green AI in the field of cancer detection. The advancement of AI in this particular domain will ultimately not only augment diagnostic capacities, but also make a significant contribution to the long-term viability and ethical soundness of healthcare systems on a global scale.

CONCLUSION

In conclusion, the study provides a concise overview of the primary outcomes pertaining to the progress and obstacles encountered in augmenting cancer detection through the use of green AI deep learning models. While notable advancements have been achieved in mitigating the environmental consequences associated with AI-powered cancer diagnosis, there remains a substantial amount of work to be undertaken in order to attain extensive use of these technologies. Additionally, the study will delineate prospective avenues for future research, placing emphasis on the imperative for ongoing advancements in green AI and the establishment of universally accepted frameworks for evaluating the sustainability of AI models. Additionally, the study will emphasise the significance of multidisciplinary collaboration among academics in the field of artificial intelligence, healthcare professionals, and environmental scientists in order to guarantee that the future of cancer detection is characterised by both technological advancement and environmental sustainability.

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