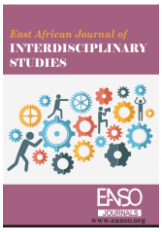

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Original Article

Exploring the Potential of Deep Learning in Healthcare: A perspective

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ABSTRACT

Deep learning has received much interest in the field of healthcare in recent years. Health care plays a significant role in delivering services and practices that promote, maintain, and restore health of an individual. However, applying deep learning in healthcare is still an exciting area of research. This paper explores the application of deep learning, and henceforth, it highlights new perspectives in healthcare by reviewing published state-of-the-art research works from four scholarly databases, including Scopus, Web of Science, Pubmed, and Google Scholar. The selected studies were from April 2014 to April 2024, and based on the predefined quality assessment criteria, 16 articles were thoroughly reviewed after the preliminary extraction, review, and screening phases. The study's findings indicate that deep learning has been applied in healthcare, particularly in medical images, digital consultation, Electronic medical records, and genomics. Furthermore, challenges such as deep learning cannot replicate the human touch and emotional connection that patients often seek in their healthcare journey, and data privacy are highlighted. Lastly, new perspectives, such as leveraging emerging technologies like Augmented Reality (AR), Virtual Reality (VR), and federated learning, are suggested to address these challenges.

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INTRODUCTION

Healthcare encompasses many services and practices to promote, maintain, and restore health. It includes diagnosing, treating, and preventing illnesses and injuries and managing physical and mental well-being (Hamza et al., 2023). The healthcare sector, though incredibly valuable in numerous ways, suffers from challenges that can differ based on location and the specific healthcare system. For example, many people across the globe still do not have access to vital medical services, with disparities resulting from factors such as poverty, region, and ethnicity (Miotto et al., 2017). Moreover, healthcare personnel shortages, such as physicians, nurses, and specialists, can result in extended wait times and limited access to essential care (Nayyar et al., 2021). Concerns about the high cost of medications and the availability of life-saving drugs persist in various parts of the world. Additionally, the increasing number of older individuals in numerous countries is leading to a rise in chronic illnesses, placing added strain on healthcare systems in the provision of long-term care and support. To tackle these obstacles, it is imperative for the healthcare sector to embrace cutting-edge technologies such as machine learning (Hamza et al., 2023; Sheela & Varghese, 2020).

Deep learning is an extension of machine learning that focuses on training large neural networks to recognize patterns in data. Neural networks mimic the structure of the human brain and consist of interconnected layers of artificial neurons (Jadhav & Farimani, 2021). Deep learning algorithms process and learn from vast amounts of data to perform tasks like image classification, speech analysis, machine translation, and more. The deep learning algorithms' usefulness to healthcare has been mostly based on recurrent neural networks (RNN), convolutional neural networks (CNN), Autoencoders (AE), and Restricted Boltzmann Machines (RBM) (Anaya-Isaza et al., 2021; Ashok & Karthika, 2023).

Deep learning as a sub-field of machine learning has found its applications in Natural language processing (NLP), computer vision, and Speech analytics, as shown in Figure 1 (Ashok & Karthika, 2023). In computer vision, deep learning has been utilized in aspects of image classification, object detection, and image segmentation. Likewise, deep learning has found its applications in NLP, including machine learning translation, sentiment analysis, and chart bots such as Siri and Alexa. In speech analytics, deep learning has been found to be useful in speaker diarization, speaker identification, streaming speech-to-text applications, robust speech recognition in noisy environments, and cross-lingual automatic speech recognition. Computer vision, NLP, and speech Analytics are the horizons in which deep learning is extensively applied and promising across different industries ranging from Agriculture, Health, Education, Finance, Transport, manufacturing, and social media platforms (Ashok & Karthika, 2023). In finance, deep learning is used for fraud detection and risk assessment (Bakumenko & Elragal, 2022; Zioviris et al., 2021). Deep learning is used for image and speech recognition in applications like facial recognition on social media platforms and voice assistants like Siri or Alexa (Alsaade & Alzahrani, 2022). While in healthcare, deep learning is widely employed and it performs better in tasks like medical image analysis and drug discovery.

Moreover, in transport, Deep learning has been a fundamental technology in autonomous vehicles and is used for tasks like object detection and lane keeping (Lobanov & Sholomov, 2021; Park, 2019). In education, Deep Learning has proved to be an invaluable tool for improving and innovating digital learning methods (Bhardwaj et al., 2021; Khemakhem et al., 2022). For example, Bhardwaj et al. (2021) implemented a deep learning model that tracks the emotions (disgust, anger, sadness, fear, surprise, and happiness) of students attending online classes in real-time.

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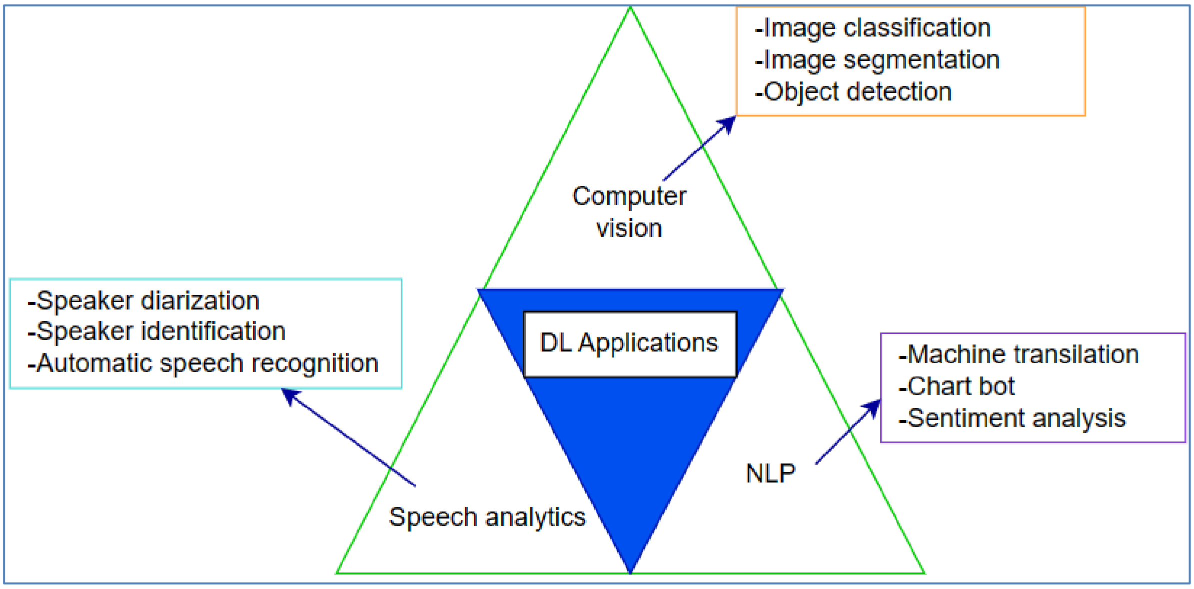
Figure 1: Deep Learning applications



METHODOLOGY

Based on the objective of this study, a clear search strategy was defined, in tandem with inclusion and exclusion criteria, databases to search, and methods for data extraction and synthesis. A comprehensive search is conducted across multiple databases, including grey literature, to ensure a thorough topic coverage. Titles and abstracts of the identified studies are screened based on predefined criteria, followed by a full-text screening to refine the selection further. Relevant information from the included studies is extracted and synthesized qualitatively to identify patterns and insights and draw conclusions.

Specifically, only studies conducted between April 2014 and April 2024 were considered. Search filters were established to screen for English-language study abstracts. The search query used in the selected four scholarly databases (Scopus, Google Scholar, Web of Science, and Pubmed) was as follows: "(TITLE-ABS-KEY ("Deep Learning") AND TITLE-ABS-KEY ("Healthcare") AND TITLE-ABS-KEY ("Medical Imaging") AND TITLE-ABS-KEY ("Electronic Medical Records") OR TITLE-ABS-KEY ("Digital Consultation"))."

In subsequent phases, the selection criteria, screening, and extraction of literature, precision was prioritized over exhaustiveness based on the domain application of medical imaging, electronic medical records, and digital consultation and monitoring. Towards this approach, the included article reflects disease diagnosis, digital consultation, health monitoring, surgical treatment, medical data management, and health plan analysis, focusing on medical imaging, digital consultation, Genomics, and Electronic Medical Records (EHRs) medical domains. These aspects each contributed to 1 point in formula 1 and 2 and were leveraged for the quality assessment (QA_i) of the articles; henceforth, the formula ensures that studies meet the 2 points or more, passing the inclusion Predefined Threshold Score (PTS) for qualitative synthesis to identify patterns and insights and draw conclusions. The summary of this approach is illustrated in Figure 2.

Quality Assessment Criteria Formula:

$$\text{If PTS } (Study_n) = \sum_{i=1}^{n} QA_i \geq 2 \rightarrow \text{ Study included} \quad (1)$$

$$\text{If PTS } (Study_n) = \sum_{i=1}^{n} QA_i < 2 \rightarrow \text{ Study excluded} \quad (2)$$

Where, QA_i is the Quality assessment of the i^{th} study and n is the number of studies.

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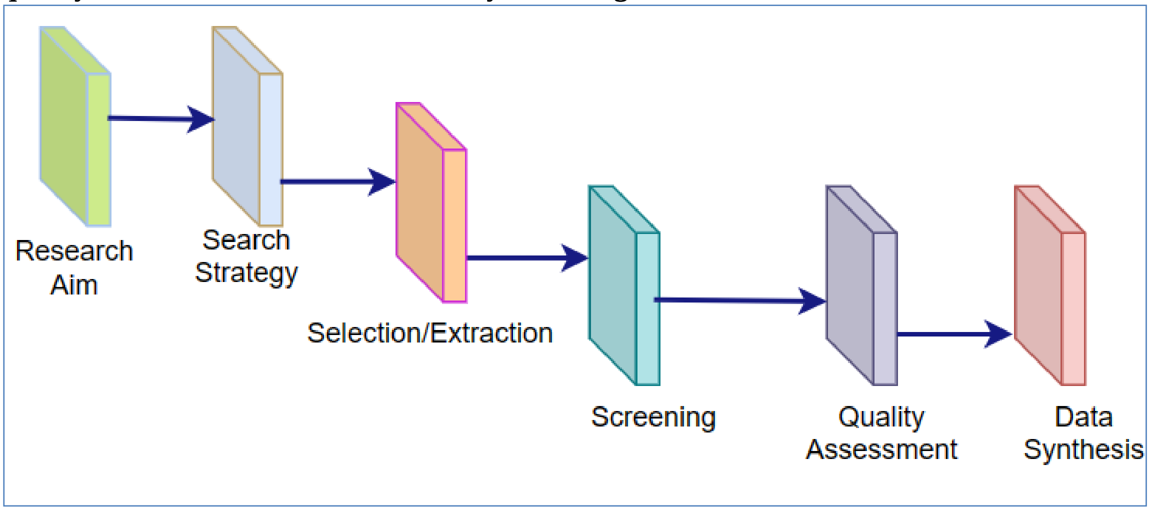
Figure 2: An approach adopted in conducting literature searching, selection, screening, and quality assessment towards literature synthesizing



THE POTENTIAL OF DEEP LEARNING IN HEALTHCARE

Deep learning has prompted various use cases in healthcare applications such as disease diagnosis, digital consultation, health monitoring, surgical treatment, medical data management, and health plan analysis (Kaul et al., 2022). These use cases and many more are categorized into medical imaging, digital consultation, Genomics, and Electronic medical records (EHRs) medical domains and are discussed as follows.

Domain of Medical Imaging

Deep learning algorithms have revolutionized disease diagnostics by enabling highly accurate and efficient analysis of medical imaging data (Chen et al., 2023). Deep learning has been utilized in tasks like a diagnosis of disease from microscopic images, identifying tumors in radiological images, detecting abnormalities in mammograms, and diagnosing various conditions from X-rays (Chen et al., 2023; Hasan et al., 2019; Moassefi et al., 2023). For instance, Irmak (2021) proposed a novel deep-learning method for malaria parasite diagnosis from blood cell images. A convolutional neural network (CNN) specifically developed to differentiate infected malaria cells from uninfected ones was used on a dataset of 27,558 blood cell images, resulting in an impressive overall accuracy of 95.28%. Also, a study by Gulshan et al. (2016) demonstrated the effectiveness of the deep learning approach in identifying diabetic retinopathy in pictures of the retinal fundus. The approach exhibited high accuracy when tested on approximately 10,000 images, outperforming annotations provided by certified ophthalmologists (BD et al., 2018). Likewise, deep learning algorithms have been applied for segmenting various sclerosis lesions in 3D Magnetic resonance imaging (Yoo et al., 2014), as well as discerning between non-cancerous and cancerous breast nodules based on ultrasound images (Cheng et al., 2016; Nguyen et al., 2022). Additionally, CNNs have demonstrated comparable performance to twenty-one dermatologists certified by a board in classifying clinical images representing various skin cancers, such as carcinomas versus benign seborrheic keratoses. This evaluation was conducted on a substantial dataset comprising 130,000 images, with 1,942 biopsy-labelled test images (Andre et al., 2017).

Domain of Electronic Medical Records

Deep learning has been used in healthcare to process and learn from vast amounts of electronic medical records, including both structured (diagnoses, lab tests, medications) and unstructured (clinical notes in text form) data to predict diseases, create personalized health plans, and health monitoring (Pham et al., 2017). Numerous studies have employed deep learning techniques to forecast diseases based on patients' clinical conditions. For instance, Liu et al. (2018)

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implemented a four-layer CNN model to diagnose cardiovascular failure and severe obstructive pulmonary disease, demonstrating notable improvements compared to the established benchmarks. In another approach, DeepCare incorporated Recurrent Neural Networks (RNNs) and LSTM units, along with pooling and word embedding for deducing present illness states and projecting future medical consequences using medical records data (Pham et al., 2016). Moreover, Choi et al. (2016) used deep learning approaches to develop Doctor AI, an end-to-end model that predicts diagnoses and medications based on patient history. Differently, Rao et al. (2022) proposed a deep-learning framework for accurately predicting heart failure (HF) using 100,071 patients from longitudinally linked electronic health data from across the United Kingdom.

Domain of Digital Consultation and Monitoring

Integrating deep learning in digital health platforms enables remote patient monitoring, consultations, telemedicine, and automated symptom analysis. NLP models are used for chatbots and virtual assistants that offer medical advice and appointment scheduling (Miles et al., 2021). For instance, Ingawale et al. (2022) proposed a deep learning framework that contains a chatbot, voice transcription, and other functionalities to improve doctor-patient interaction. Sheela & Varghese (2020) have also applied deep learning to develop a Smart Health Monitoring System (SHMS). The SHMS identifies and predicts diseases based on deep learning algorithms and helps patients identify doctors for consultation. Likewise, Hamza et al. (2023) developed a deep belief network (DBN)-based system for predicting sleep quality based on the data gathered from wearable devices, where a doctor could make consultation with a patient remotely.

Domain of Genomics

Deep learning in biology helps us understand big and complex datasets like DNA and RNA information. It uses advanced models such as DeepNano, DeepBind, DeepSEA, and ADAGE, to mention a few, to find important patterns that perform better than conventional methods and make the information easier to understand (Liu et al., 2020). Deep learning algorithms have been applied in various genomic studies. Zhou and Troyanskaya (2015) applied DeepSEA, a deep learning model, to predict certain marks on DNA based on its sequence. Furthermore, Angermueller et al. (2017) applied deep learning to classify the state of DNA in individual cells in a type of genetic sequencing called single-cell bisulfite sequencing.

Similarly, CNNs were used by Koh et al. (2017) to improve the accuracy of estimating how common different marks on chromatin are in data from a technique called chromatin immunoprecipitation followed by sequencing. Scholz et al. (2005) also estimated missing metabolite and gene expression data values using an autoencoder. Their findings demonstrated that autoencoders outperform linear techniques in estimating missing values for nonlinear structured data. Likewise, ProLanGo, an RNN-based model, was implemented by Cao et al. (2017) to predict protein function. These previous studies on genomics demonstrate the promising potential of deep learning in healthcare.

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Table 1: An overview of the articles reviewed with a focus on the architecture of the deep learning model and the domain involved

Domain	Author	Use case	Model architecture
Medical imaging	Irmak, (2021)	Deep-learning technique for detecting malaria parasites in thin blood cell pictures.	CNNs
	Gulshan et al. (2016)	Diagnosis of diabetic disease	CNNs
	Nguyen et al., (2022)	Thyroid Nodule Segmentation in Ultrasound Images Using Suggestion and Enhancement Network Information Fusion	CNNs
	Cheng et al.,(2016)	Diagnosis of breast cancer from ultrasound images	Stacked Denoising AE
	Yoo et al., (2014)	Deep learning method for segmenting multiple sclerosis (MS) lesions in integrated 3D magnetic resonance (MR) images	RBM
	Andre et al.,(2017)	Deep neural networks for skin cancer image classification	CNN
Domain of Electronic medical records	Rao et al., 2022	Forecasting heart failure (HF) using health record data	BERT NLP
	(Pham et al., 2016)	DeepCare for predictive medicine	LSTM RNN
	Choi et al., (2016)	Recurrent Neural Networks for Predicting Clinical Events.	GRU RNN
Domain of Digital consultation and monitoring	Hamza et al., (2023)	Deep learning for Sleep Quality Prediction using smart health monitoring devices	DBN
	Vijay Ingawale et al., 2022	Virtual Doctor Consultation and Appointment via Smart Hospital Chatbot	Transformer-NLP
	Sheela and Varghese (2020)	Forecasting of epileptic seizures	LSTM RNN
Domain of Genomics	Zhou and Troyanskaya (2015)	Deep learning for chromatin effects of DNA sequence changes prediction.	DeepSEA CNN
	Angermueller et al. (2017)	Deep learning for forecasting DNA methylation states of a single cell	DeepCpG CNN
	Cao et al. (2017)	Predicting protein function	RNN
	Koh et al. (2017)	Estimating the commonality of different marks on chromatin in genomic data	CNN

New Perspective on Deep Learning in Health Care

In the coming years, integrating deep learning into the field of medicine will revolutionize how healthcare is delivered and managed. Deep learning offers tremendous potential in tasks such as diagnostic assistance, treatment recommendation, data analysis, and even the optimization of healthcare processes. However, while helpful in many respects, Deep Learning cannot replicate the human touch and emotional connection patients often seek during their healthcare journeys. It is worthwhile to blend deep learning-based healthcare applications with evolving technologies like augmented reality (AR) and virtual reality (VR) to achieve human touch and emotional connection. These

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technologies have shown promising potential in replicating human touch and emotional connection (Hsieh & Lee, 2018; Kim et al., 2020). In this way, the integration of DL into medicine can be harmonious, ensuring that patients receive not only cutting-edge medical treatment but also the emotional support and understanding that are fundamental to the healing process.

Furthermore, many use cases focus on one horizon of deep learning: Computer vision, NLP, or Speech Analytics (Chen et al., 2023; Hasan et al., 2019; Moassefi et al., 2023). Our new perspective is combining all horizons and creating a hybrid architecture that simultaneously takes advantage of multimodal data. Since information from diverse sources such as imaging, genomics, and electronic medical records are combined, the new hybrid architecture has the potential to unlock more profound insights into personalized medicine. Additionally, data privacy concerns affect the full exploitation of deep learning in healthcare. Our perspective would be to leverage federated learning technology, which enables model training across multiple institutions without sharing sensitive patient data. This approach will offer an avenue for collaborative research while preserving privacy.

CONCLUSION

This perspective gives an overview of the application of deep learning and highlights new perspectives in healthcare. Applying deep learning in healthcare represents a paradigm shift towards more precise, data-driven, and personalized medicine. While acknowledging the remarkable progress made thus far, addressing the existing challenges and exploring novel avenues such as incorporating human touch through emerging technologies such as AR and VR, multimodal data integration, and federated learning is crucial. With careful consideration, deep learning stands promising to revolutionize healthcare, ultimately leading to improved patient outcomes and a more efficient, sustainable healthcare system.

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