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Progress and trends in neurological disorders research based on deep learning

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Highlights

- To design a survey on neurological disorders based on computer vision.
- To find out the way of real-time clinical data analysis using deep learning.
- To conduct a survey on Alzheimer, Strock, Parkinson and Brain Tumor based on Image Processing.

- To find out the research gap and future scope in this area.

Abstract

In recent years, deep learning (DL) has emerged as a powerful tool in clinical imaging, offering unprecedented opportunities for the diagnosis and treatment of neurological disorders (NDs). This comprehensive review explores the multifaceted role of DL techniques in leveraging vast datasets to advance our understanding of NDs and improve clinical outcomes. Beginning with a systematic literature review, we delve into the utilization of DL, particularly focusing on multimodal neuroimaging data analysis—a domain that has witnessed rapid progress and garnered significant scientific interest. Our study categorizes and critically analyses numerous DL models, including Convolutional Neural Networks (CNNs), LSTM-CNN, GAN, and VGG, to understand their performance across different types of Neurology Diseases. Through particular analysis, we identify key benchmarks and datasets utilized in training and testing DL models, shedding light on the challenges and opportunities in clinical neuroimaging research. Moreover, we discuss the effectiveness of DL in real-world clinical scenarios, emphasizing its potential to revolutionize ND diagnosis and therapy. By synthesizing existing literature and describing future directions, this review not only provides insights into the current state of DL applications in ND analysis but also covers the way for the development of more efficient and accessible DL techniques. Finally, our findings underscore the transformative impact of DL in reshaping the landscape of clinical neuroimaging, offering hope for enhanced patient care and groundbreaking discoveries in the field of neurology. This review paper is beneficial for neuropathologists and new researchers in this field.

Introduction

Neurological diseases (NDs) are disorders that impact the brain. These illnesses cover a broad spectrum of diseases, such as Parkinson's disease (PD), multiple sclerosis, dementia, epilepsy, and migraines (Ali et al., 2021, Heyat and Bin, 2016). Worldwide morbidity and mortality are significantly influenced by these disorders. These conditions have different prevalence. For example, one billion people globally suffer from migraines, making it the most common neurological condition (Ashina et al., 2021). About 50 million people worldwide have epilepsy, with nearly 80% of these people living in low- and middle-income countries (Singhi and Gupta, 2021). Approximately 50 million people have dementia, with nearly 10 million new cases every year. Alzheimer's disease (AD) is the most common form of dementia (L. Liu et al., 2021; Vogt et al., 2023). Over 6 million people globally are estimated to live with PD (Ray Dorsey et al., 2018). Multiple sclerosis (MS) affects more than 2.3 million people worldwide and stroke is the second leading cause of death and the third leading cause of disability globally (Liang et al., 2023, Reynolds et al., 2018). There are over 13 million new cases every year (Giofrè et al., 2020). Neurological disorders were responsible for 9 million deaths worldwide in 2016, which was about 16% of the global total. Among them, stroke, AD, and other dementias were the most income countries deadly (Feigin et al., 2017). Stroke accounted for 67% of those deaths, while AD and other dementias accounted for 20% (Tatemichi et al., 2011).

The primary challenges in treating and preventing NDs revolve around a lack of understanding regarding the genetic and molecular drivers and inhibitors of ND-related conditions such as amyloid and tau retinopathies and ND dementia. Furthermore, there is a lack of comprehension concerning ND-related retinopathies and ND dementia. Using advanced models like deep neural networks (DNNs) has the challenge of the scarcity of high-quality brain expression data. The availability of post-mortem brain RNA-sequencing datasets from the AMP-ND (Accelerating Medicines Partnership Neurology Disease) presents a unique opportunity to conduct integrative analyses by combining multiple datasets (Katsel et al., 2007). Deep learning (DL) in neurological pathology is a key area of interest. Artificial neural networks (ANNs) have been developed using a model focused on small, round blue-cell cancers (SRBCTs) (Lecun et al., 2015). These diseases often pose diagnostic challenges in clinical practice. Remarkably, the ANNs successfully classified all examples and identified the features most relevant to the classification process (Khan et al., 2001). Over the past decade, there has been a significant transformation in the evaluation and treatment of ND patients using image datasets, leading to improved patient outcomes. Essentially, the progress in the scope and depth of imaging examination techniques has expanded the expertise required for translating imaging data effectively. This is evident in the swift changes observed in stroke treatment and assessment guidelines over the past couple of years. Traditional randomized trials aimed at assessing the impact of new imaging tools under development are unlikely to be conducted because such evaluations would involve limiting the data accessible to clinicians, potentially posing harm to patients. The ready availability and rapidity of multimodal CT imaging have revolutionized the data accessible to clinicians for making treatment decisions. However, these advancements in imaging and treatment options have also heightened the complexity of assessment, posing a continuous challenge for specialists to remain updated (Lee and Lee, 2020, Pirooznia et al., 2008, Sundararajan et al., 2017). Further automation of image capture and analysis through DL is necessary to fully comprehend the potential of assessment methods.

There are some reviews studied in the field of ND. However, none of them focused on neuropathology and DL imaging models based on computer vision classification tasks. In (Bagheri et al., 2023), web-based resources like Scopus, Google Scholar, Web of Science, and PubMed/MEDLINE were thoroughly explored up to December 2020, using terms such as review, neurological disorders, and CoQ10. CoQ10 is naturally produced within the body and can also be obtained from supplements or certain foods. It possesses antioxidant and anti-inflammatory properties and is involved in energy generation and the stabilization of mitochondria, through which it provides its neuroprotective benefits. In this study, connection between CoQ10 and various neurological conditions, including AD, depression, MS, and stroke was investigated. In (Moggio et al., 2022), to collate and assess the impact of vibratory therapy in the treatment of neurological conditions, a thorough review of databases including PubMed, Scopus, Embase, PEDro, Web of Science, and the Cochrane Library up to November 2020 was conducted. All studies that examined whole-body vibration (WBV) or focal muscle vibration (FMV) against placebo, sham, or other exercises for rehabilitating neurological issues in both children and adults leading to motor challenges and disabilities were considered. A systematic review of cost-analysis of telemedicine interventions compared with traditional care in the management of chronic ND has been done in (Maida et al., 2024). Telemedicine has been effective in alleviating the strain on healthcare systems due to chronic neurological disorders by providing tailored and efficient treatment plans. The efficacy of telemedicine's economic impact on managing chronic ND is not as clear. The researchers in this study try to bridge this knowledge gap by systematically examining research articles that assess the economic value of telemedicine against conventional care for CNDs. They searched for relevant literature on platforms like PubMed, Google Scholar, Scopus, Embase, and Medline. The financial analysis indicated that telemedicine is more cost-efficient and effective than traditional face-to-face care for CNDs.

DL models, such as Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN), have shown great promise in neuroscience. CNNs excel at image analysis tasks, which aid in medical imaging for neurological problems, whereas RNNs are good at processing sequential data, which helps us comprehend temporal trends in NDs. The combination of these DL algorithms shows promise in improving diagnosis accuracy and personalized treatment options in neurology. The main contributions of this article are as follows:

- Show how DL techniques can help understand nervous system problems.
- Analyze current DL approaches utilized in clinical practice for ND.

- Explore the benchmarks and datasets used to train and test DL models for neurological illnesses.
- Discuss the many types of nervous system illnesses under research.
- Assess the effectiveness of DL in clinical scenarios involving ND.

Section snippets

Related works

In this study, to ensure the thoroughness and pertinence of findings, we have considered a curated selection of recently published survey articles. To assemble a comprehensive panorama of the field, we have meticulously scrutinized review articles that were published between 2017 and till now. These articles originate from reputable and peer-reviewed journals, including IEEE, Elsevier, and Springer. These journals are highly regarded for their rigorous academic standards, making them great…

Methods

To perform this research, we used standard systematic review methods as defined in the Preferred Reporting Items for Systematic Reviews and Meta-research (PRISMA) guidelines (Bin Heyat et al., 2020, Heyat et al., 2020). Our approach, which includes search methods, inclusion and exclusion criteria, data collecting, and quality evaluation, is detailed below:…

Neuropathology using deep learning

A specialist area of medicine called neuropathology is dedicated to the study of illnesses and conditions that impact the nervous system, which includes the brain and spinal cord. However, DL has demonstrated great promise in transforming our knowledge and treatment of neuropathology diseases. CNNs and RNNs, two DL approaches that have shown to be extremely useful in the interpretation of medical imaging data, are able to automatically detect and classify neurological disorders. Additionally,…

Alzheimer disease

Marioni et al. (Marioni et al., 2018) found that genome-wide association analysis based on a self-report of a parent's history of AD. 314,278 participants from the UK Biobank were included in the study, which provided a trustworthy proxy for examining the genetic components of AD. Three further loci linked to AD were discovered during a meta-analysis of the data (Marioni et al., 2018). A thorough genome-wide association analysis was carried out for clinically diagnosed AD and AD-by-proxy in the …

Stroke disease

Even seasoned neurologists may find it difficult to completely understand all of the imaging data due to the enormous collection of accessible imaging data and the overwhelming number of raw information encountered while assessing a patient with suspected neurological symptoms. Decision assistance systems aid physicians in simplifying and standardizing imaging evaluations for stroke patients in this fascinating setting. Imaging assessment and interpretation models should ideally be fully…

Parkinson's disease

Significant improvements in clinical outcomes are shown when Deep Brain Stimulation (DBS), a common therapy for PD, is combined with DL. In order to determine the best stimulation settings for each patient, the authors of (Boutet et al., 2021) looked at the viability of using functional magnetic resonance imaging (fMRI). Using both optimal and non-optimal stimulation settings, they analyzed fMRI data from 67 individuals with PD. A specific fMRI brain response pattern determined by the activity...

Brain tumor

Oh et al. (Oh et al., 2020) to reliably anticipate bedside assessments, a unique procedure was described that combines huge CNNs with label-free optical imaging method called Illuminated Raman Histology (SRH). Compared to traditional approaches that often take 20–30 minutes, CNNs trained on a dataset with over 2.5 million SRH photos can predict brain tissue evaluations in the operating room in less than 150 seconds. The analysis of SRH images by CNN was found to be similar to pathologist-based...

Other neurological disorders

Lim et al.(2021)used DL-based methodology in conjunction with 7 Tesla MRI to propose an automated technique for habenula segmentation and volume assessment. Although the habenula is essential in Major Depressive Disorder (MDD), manual segmentation is difficult because to its tiny size and poor contrast. The suggested approach demonstrated efficacy in differentiating between 33 MDD patients and 36 healthy controls in automated segmentation, achieving high accuracy, sensitivity, and Dice...

Discussion

This review paper provides an insightful comparison of neurological illnesses and DL techniques, shedding light on the benefits and drawbacks of employing AI to diagnose and treat a variety of conditions. AD has emerged as a focus among the neurological disorders being studied. DL algorithms have shown promise in comprehending complicated patterns in neuroimaging data, perhaps assisting in the early detection and diagnosis of AD. The ability of these algorithms to detect minute changes in brain ...

Future works and limitation

Future research in ND with DL will benefit from the prospects outlined in this review. Above all, large-scale clinical trials and longitudinal research are essential for establishing the practical use of DL models in a wide range of healthcare settings. Using prospective data rather than retrospective analysis can improve the reliability and generalizability of DL applications for ND diagnosis and treatment. Furthermore, efforts should be made to create benchmarks and standardized procedures...

Conclusions

This review underscores the transformative potential of DL techniques in revolutionizing the diagnosis and treatment of neurological disorders. By harnessing the power of multimodal neuroimaging data and advanced DL models, researchers have made significant strides in understanding complex neurological conditions. In this review article, we explore various neurological disorders such as Alzheimer's, stroke, Parkinson's, brain tumors, and other neurological disorders. We summarize the most...

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CRediT authorship contribution statement

Muhammad Shahid Iqbal: Writing – original draft, Validation, Software, Methodology, Formal analysis, Conceptualization. **Md Belal Bin Heyat:** Writing – original draft, Validation, Software, Methodology, Formal analysis, Conceptualization, Data curation. **Mohamad Roshanzamir:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation. **Roohallah Alizadehsani:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation. **Sadiq Hussain:** Visualization,...

Declaration of Competing Interest

We confirm that our work belongs to the scope of the journal. It's not been published anywhere and also authors don't have any conflicts of interest in this paper....

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