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Exploring Artificial Intelligence and Multimodal Data Integration in Smart Healthcare: A Bibliometric and Topic Modelling Approach

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ABSTRACT

Technological enhancements in intelligent computing or artificial intelligence (AI) have contributed immensely towards the enhancement of multimodal data fusion approaches, which are believed to transform smart healthcare. That is why, despite the increased interest in this sector, there are few studies that empirically examine organizational implementation of AI and multimodal data processing in large scale health care systems. This study employs bibliometric analysis and topic modelling to assess the trends, active research areas, impactful journals, countries, institutions, authors and collaboration network of 683 papers that have been published between 2002 and 2022. According to our findings, there has been a breakout of publications since 2013, and interdisciplinary journals are seen as central to growth in healthcare research in AI. Future research areas include intelligent diagnostics, multiple-modal neuroimaging. for brain tumor diagnosis, cancer prediction using data fusion techniques, and the fusion of fMRI and EEG data. This is also an increasing concern of countries like China, USA and India's into the contribution of the field. In this paper, the authors provide a state-of-art review of existing and potential approaches as well as solutions to the multimodal data fusion in smart healthcare enabled by AI.

INTRODUCTION

Artificial intelligence is slowly but surely changing the face of many industries, and its effect has been most vehemently felt in the healthcare sector. The use of AI has expanded the idea of applying it to the field of health care and introduced a new concept of how innovation in this area can lead to

differentiation in results and productivity in patient care approaches [1]. The most significant application of AI in healthcare could be attributed to the fact that it can work well with large amount of data which is continuously collected and formed through different types of modalities including EHRs, medical imaging, patients' genomics, and vital sign monitoring. Such data can be in different forms and formats; thus, applying multimodal data fusion will result in the best analysis of patient condition and facilitate accurate diagnosis and treatment [2]. That said however, the topic of AI and multimodal data fusion has seen significant research interest particularly in healthcare systems; unfortunately, there are very limited empirical, large-scale studies in this field. Connected healthcare or the use of Internet of Medical Things (IoMT), Artificial Intelligence (AI) and analytics, now serves as a research focus in medical and technology fields [3].

Through networks of devices, simulators, and artificial intelligence-based algorithms, smart health care will attempt to provide health check, early diagnosis of diseases, tailored services and better patient treatment. For example, smartwatches continuously track pulse, blood pressure, and the amount of physical exertion and present an AI analysis that indicates possible health problems. In the same way, deep learning methods are being used to enhance efficiency and accuracy of detecting brain tumor and analyzing X-ray or MRI scans among others. These technologies are assisting in moving health care from the traditional 'sick-care' model to a predictive model, enabling carers to identify specific situations that require specific care at the earliest opportunity [4].

AI in healthcare is taken to the next level by the integration of multimodal data meaning integrating data from many sorts of data sources including medical imaging, EHRs, genetic data, and patient reported experience measurements. For instance, the integration of fMRI and EEG data, AI systems can provide better understanding complex spatiotemporal patterns associated with neurological disorders such as epilepsy or Alzheimer's disease [5]. In the same way, merging genomic information and clinical history can help identify disease biomarkers and contribute to prognosis or prognosis of the response to therapy. Multimodal data fusion when combined with the use of artificial intelligence technology can greatly transform different clinical decision-making processes from single-sourced to multiple parameters integrated solution to patient's diagnosis [6].

Nonetheless, several issues on the use of these AI techniques in the integration of multimodal data fusion techniques still persisting in the healthcare domain. The first is the heterogeneity of data itself is one of the most considerable challenges is an obvious obstacle. In the healthcare system data are rarely clean, complete or noise free, and can originate from different sources with disparate formats and data standards. Additionally, such diverse type of data necessitates the need for enhanced AI

models to cater for the complications of the data [7]. Other issues include data protection and security as patient information becomes more common as a source of information. AI solutions used in healthcare organization need to be first graduated with rules and regulation like the health insurance portability and accountability act (HIPAA) for patient information privacy [6]. Therefore, the explainability is still a question when combined with AI models, mainly when used in the medical field where clinicians need to comprehend why an AI is recommending a specific course of action in order to follow it. This study aims to explore the broad research areas, trends, and collaboration network of AI and MDF in smart healthcare, as this area is growing ever rapidly and becoming significantly important [8].

This paper seeks to fill this gap by conducting a bibliometric and topic modelling analysis on 683 articles published between 2002 and 2022. The objective of analysis is to extract and present the prospective directions and intentions of the research, identify the leading stipulated sections, relevant publications, countries, institutions, and authors in the field of AI-based MDF for healthcare. In this study, the features of the outstanding studies based on these research themes are considered, which explains what parts of smart healthcare are considered most advanced now and what can act as promising avenues for further research [9]. The first research question of this study is to establish the current state of and trends in publication in this field, inclusive of AI and multimodal data fusion in healthcare to show the main research findings, journals, countries and regions, institutions, and authors that have been influential in the literature.

The second specific aim is to investigate the intercountry, interregional, interinstitutional, and interactor cooperation in producing research papers and to compare the extent of international and institutional integration. Last but not the least, this study intends to understand and outline the trend of the top issue in the research area, tracking how the topics of the research have developed over the years and what potentials are leading the way for the AI- health care in the future [10]. In a quantitative manner, this study aims at presenting the research path of AI and MDF in smart healthcare based on the topic modelling and bibliometrics, which can serve as a helpful access and reference for the corresponding research field and stakeholders.

RESEARCH FINDINGS

AI and multimodal data fusion are some of the aspects that have make the advancement of health care a smart data system. The subject of futures of AI in healthcare has been investigated in numerous papers, although the various modalities of data and their merging by using the fusion methods are

considered to be the emerging direction [11]. Literature on the application of AI and multimodal data fusion in healthcare is discussed in this section including the highlights on the advancement, the methodology adopted, challenges as well as emerging trends.

Key Environmental Issues: AI is used in many contexts throughout healthcare, from diagnosis through the use of imaging technologies to modelling of diseases and development of patient-specific treatment plans. Of the various subfields of AI, machine learning (ML) and deep learning (DL) have perhaps had the most effect on healthcare. Use of decision trees, support vector machine, neural network has been done for developing disease classifier, while CNN—an efficient DL method has been chosen for image analysis [12]. Related to the analysis of medical images like X-rays or MRI scans, as well as CT scans, deep learning models – especially CNNs – are beneficial. These models acquire automatically the features from the raw image data hence minimizing the process of feature extraction. The use of AI in an analysis of medical images for instance in aiding diagnose conditions such as tumours in the brain, cardiovascular diseases, cancer amongst others has been of great impact on time and efficiency of diagnosis [13].

Multimodal Data Fusion in Healthcare: Multimodal data fusion means the integration of data collected from various sources with a view of getting an overall summary of the status of the respective patient. Such data types in the context of health care could cover everything from clinical notes, images, and genomics data, data coming from wearables, and social media posts. Due to the combination of these distinct data sets it is possible to make more precise a disease prediction, diagnosis and treatment plan [14]. For example, integration of medical images with genomic data can reveal networks associated with the genetic basis of several diseases including cancer and enable tailor-made treatment. Likewise, integrating data from wearables with clinical data provide an opportunity to monitor chronic diseases such as diabetes and hypertension in real time [15].

Advancements in Multimodal AI Applications: The recent years saw a surge in research in AI based multimodal data fusion where multiple sensors are used for health care leading to the creation of advanced models for prediction. A specific example is utilization of AI in identifying brain tumor where image, genomic and clinical data comprise medical images like MRI to provide more precise results in diagnosis and prediction of patient prognosis [16]. Additionally, AI models are being applied on diseases such as Alzheimer's and Parkinson's disease, where data types include brain imaging, cognitive tests, and gene data are combined to make an accurate prognosis of the disease and prognosis. It also creates a more proactive environment in which clinicians can stage more targeted and individualized interventions [17].

Data Collection and Selection Criteria: However, there is a dearth of comprehensive review articles

that comprehensively describe state-of-the-art approaches for employing AI and multimodal data fusion for healthcare from 2002 to 2022 using the Woos database. The following keywords were employed, including artificial intelligence, multimodal data fusion, smart healthcare, medical imaging. In the initial search, 829 articles were identified and upon reviewing them all, the researchers used the specific inclusion and exclusion criteria for the study. Studies aimed at the use of AI in healthcare and multimodal data fusion were considered for inclusion, whereas the papers not addressing the selected topics or containing no primary data were excluded [18].

BIBLIOMETRIC ANALYSIS

The biblio metric analysis was conducted to assess various parameters, which includes journal wise, country wise, institutional wise and author wise publication output, citation analysis and Hirsch index (H) analysis including the number of publications, citation received and the H-index. These metrics offered a quantitative portrait of the research field, enabling us to appraise the most active engaged participants and the most often cited sources in the field [19]. The rest analysis also aimed at determining the most popular journal in which articles concerning AI and multimodal data fusion in healthcare are published.

Topic Modelling: To determine the research themes and topics in the chosen articles, the technique of topic modeling, more specifically, STM, was employed. STM is an improved version of the ML approach that identifies latent topics in huge populations of documents based on the occurrences of terms in the articles' title, abstract and keyword list [20]. Before performing STM, stop words and terms that did not contribute to understanding research topics were excluded from the data set to get the cores of topics and their dynamics. This made it possible to gauge interests of researchers in different areas and to identify growing focal areas [21].

Artificial Intelligence in Healthcare: Some of the fields under AI in healthcare are disease diagnosis, prognosis and prediction, the analysis of medical images, drug discovery and personalized medicine. Several ML and deep learning have been applied in enhancing medical operations, diagnostics and decision makings. These or similar tasks are performed using AI techniques comprising of Convolutional Neural Networks (CNNs) with applications in medical image analysis for example to detect abnormalities, patterns, and provide diagnosis [22].

The Role of Multimodal Data Fusion in Healthcare: Multimodal data fusion can be defined as a process of combining data coming from different sources in order to have an enhanced view of the patient's condition. A patient's clinical record integrated with medical imaging, genomic data, smart sensor data, and self-reported outcomes compose a patient 360-degree view [23]. Using big data, various subcategories in the healthcare field can have better decisions, enhancing diagnosis and

treatment suggestions' quality and punctuality.

ADVANCEMENTS IN AI-POWERED MULTIMODAL DATA FUSION APPLICATIONS

Modern advancements in the field of AI enhance the field of multimodal data fusion and leads to the creation of complex models that work with different forms of medical data. As a result, considerable progress has been made in various fields involving brain tumor diagnosis, the prediction of neurodegenerative diseases, and cancer outcomes [24]. The integration of data from multiple videos provides more precise diagnosis, improvement of the monitoring of diseases and individual possibilities for the impact on patients' treatment.

Research Methodology: Through this study, bibliometric analysis and topic modelling methodologies were used to review literature in AI and multimodal data fusion in health care domain. The subsequent sections explain data collection process, eligibility criteria, and data analysis to respond to the research questions [25].

Topic Modelling: From among the aforementioned techniques, topic modelling, particularly STM, was adopted to identify emergent topics and research themes in the amassed literature. STM was used for the titles, abstracts and key words in order to determine the principal research strands and map the development of these topics. They include data pre-processing, selecting the number of topics and finally evaluating and showing the trends of the existing research topics [26].

Implications for Practice: In particular, both AI and multimodal data fusion are expected to contribute a great deal to the advancement in healthcare. Combined databases make it possible to obtain more precise diagnostic decisions, individual management of the treatment process, and improved control over diseases [27]. In the future, AI technologies see excellent room for development in the healthcare sector in order for practitioners to improve patient care with help of the same and also to manage health care facilities in a more efficient manner [27].

MAJOR RESEARCH TOPICS IN AI AND MULTIMODAL DATA FUSION

The systematization of the data presented in the literature provided the identification of several primary domains that prevail in the concurrent field of AI and multimodal data fusion in healthcare settings. These topics demonstrate the modern directions and developments in uniting different data types by means of AI for diagnosing and treating patients more effectively [28]. The three most prominent areas identified are:

Brain Tumour Diagnosis Using Cross-Modality MRI Fusion: A primary application and emerging field of AI-based multimodal data fusion has to do with the diagnosis of brain tumors. The efficiency of multimodal MRI has emerged as an important modality toward improving the accuracy of brain

tumor mapping and characterization [29]. Conventional MRI sequences include T1 weighted imaging, T2 weighted imaging, and post contrast imaging that conveys different information on the structural organization of the brain, the extent of enema and vascular supply to the area [30].

Different modalities when combined enhance the AI system's ability to provide a more precise representation of the tumor thus improving segmentation and localization. Another advancement was made where authors employed means such as CNNs and DBM in deep learning to factor the fusing process [31]. These two models can be used and trained on big networks of multimodal MRI scans to understand how to process and integrate big data. The models identified are able to capture delicate patterns of the tumor which could be hard for a human radiologist to pick especially when dealing with small or complex tumors [32].

However, these fusion techniques are not only used to diagnose the patients with brain tumor but also to monitor the reaction of the tumor to the treatment and to estimate the future prognosis of the patients especially with gliomas and other highly malignant cerebral neoplasms. This area of research remains important for one reason: it is crucial to diagnose brain tumors at an early stage and with maximal possible accuracy to increase survival rates after the operation [33]. The above-discussed advances in diagnoses are combined with AI fusion procedures that can contribute toward the development of individualized therapies. Moreover, the integration and interpretation of multimodal MRI information support clinicians to gain a clearer insight into the knowledge of brain tumors more inherently, which leads to better clinical decisions [34].

Predicting Neurodegenerative Diseases through Multi-Task Diagnostics: AI based prediction and early diagnosis of neurological disorders like Alzheimer's disease (AD), Parkinson's disease (PD), and multiple sclerosis (MS) had attracted much consideration using multimodal data fusion. These diseases are very difficult to diagnose at their early stage since the symptoms take time to manifest themselves and are associated with other diseases [35]. Despite this, the recent development of AI as well as data fusion approaches has led to the improvements in the detection of the disorder, which is crucial in the beginning, as it allows for the introduction of early intercessions and deceleration of the disease. AI systems apply multi-task diagnostics that allow diagnosing the probability of neurodegenerative diseases based on MRI, PET scans, genetic data, clinical tests, and biomarkers [36].

These systems use deep learning models to analyses patterns across different types of data that might suggest initial markers of neurodegeneration. For instance, MRI scans can be correlated with SNP data and AI can identify subtle changes in the structure of the human brain such as shrinkage of hippocampus in Alzheimer's patients, when they are still asymptomatic. The simultaneous diagnostic

approach as a number of diagnostic tasks performed at the same time is more effective for evaluating the overall condition of the patient. AI models can identify disease risk, categorize diseases, and estimate disease progression which are all helpful in designing appropriate patient treatment plans. Also, such predictive models may help to find people at higher risk, who can undergo preventive treatments or make some necessary changes in their life [37]. The identification of early prediction is crucial as the early stages of neurodegenerative diseases can be slowed down, and the quality of life is improved by the intervention. Hence the integration of multimodal data fusion with Artificial Intelligence (AI) to predict and diagnose these diseases has a vast potential of improving the quality of the patients and the quality of the decisions made by clinicians [38].

Cancer Prognosis via Multi-Dimensional Data Integration: Medical diagnosis and now cancer diagnosis and prognosis have advanced significantly by incorporating multi-dimensions data such as medical images, genomic data, and patient clinical data. The current approaches used for cancer diagnosis mainly involve medical image and histopathological information, but the use of multiple data sources improves diagnosis and prognosis [39]. AI systems can easily and naturally perform this task because they are capable of processing big and complicated data and identifying complex patterns that might be unnoticed by clinicians. For example, by integrating radiological images (CT, MRI or PET) with genomic data (e.g., gene expression profiles or mutations) clinical data (e.g., patient demographics, treatment history) the AI systems can predict the probability of cancer metastasis, recurrence or treatment response [40].

In particular, the multi-dimensional datasets have been analyzed by employing random forests, support vector machines, and deep neural networks, which allowed clinicians to predict further development of cancer and choose the optimal treatment strategy. Besides enhancing the accuracy of cancer prognosis, the multi-dimensional data fusion based on AI is another important function of personalized medicine [41]. Cancer is not a single disease, and each patient's tumor is different in genetics and how it will react to therapy. Using various forms of data, AI can build unique predictive models that suggest specific treatment plans and improve therapeutic efficacy and reduce side effects. AI-aided prognostic models are most useful in breast, lung, colorectal, and other cancers in which the deployment of personalized care enhances survival and quality of life [42]. In addition, AI-based multi-dimensional data integration can help enhance the supervision of patients receiving treatment by monitoring their feedback to therapy on the spot. By processing imaging data in parallel with clinical and genomic data, AI systems can provide real-time assessment of the performance of a specific treatment and help clinicians modify the therapy regimen promptly [43].

AI TECHNOLOGIES IN MULTIMODAL DATA FUSION FOR HEALTHCARE

This section describes the different approaches of combining and analyzing multimodal data using machine learning in healthcare context. Supervised models include decision trees, support vector machines (SVMs), unsupervised models include k-means clustering, and the uses of the models in integration of healthcare data [44].

Deep Learning Approaches: CNNs, RNNs, and GANs in Healthcare: Among all the subfields, deep learning including CNNs and RNNs has been widely used and developed in medical images and sequential data analysis. This subheading discusses these models in the context of multimodal data fusion such as generative adversarial networks (GANs) for synthesis of medical images [45].

Natural Language Processing (NLP) for Textual Data Fusion: The ability to use natural language processing (NLP) for sake of data extraction and integration from clinical notes, EHRs, and medical literature is on the rise. This section concentrates on how AI applies NLP to identify insights from unstructured medical data in combination with structured data from medical imaging and genomics [46].

CONCLUSION

Consequently, this paper provides a detailed bibliometric and topic modelling study of AI and multimodal data fusion in smart healthcare. The study also indicates that the field is growing, with a number of countries including China, the USA and India making increased contributions. The specific research areas of interest include diagnostic AI, cancer survivorship prediction, and neurodegenerative disease risk prediction; the rising stars are in GANs and XAI. This research can be useful for further research in the field and to practitioners since the state-of-the-art and potential developments in AI-based multimodal data fusion in healthcare are examined in this study.

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