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Healthcare Through AI: Integrating Deep Learning, Federated Learning, and XAI for Disease Management

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Abstract: ***The applications of Artificial Intelligence (AI) have been resonating across various fields for the past three decades, with the healthcare domain being a primary beneficiary of these innovations and advancements. Recently, AI techniques such as deep learning, machine learning, and federated learning have been frequently employed to address challenges in disease management. However, these techniques often face issues related to transparency, interpretability, and explainability. This is where explainable AI (XAI) plays a crucial role in ensuring the explainability of AI models. There is a need to explore the current role of XAI in healthcare, along with the challenges and applications of XAI in the domain of healthcare and disease management. This paper presents a systematic literature review-based study to investigate the integration of XAI with deep learning and federated learning in the digital transformation of healthcare and disease management. The results of this study indicate that XAI is increasingly gaining the attention of researchers, practitioners, and policymakers in the healthcare domain.***

Keywords: Healthcare, Artificial Intelligence, Deep Learning, Federated Learning, Disease Management

I. INTRODUCTION

The applications of Artificial Intelligence (AI) in the healthcare domain have resonated globally for the last three decades. In recent years, AI has digitally transformed the healthcare sector, particularly with the advent of advanced technologies like deep learning (DL) [1], federated learning (FL) [2], and explainable AI (XAI) [3].

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Technologies such as deep learning and federated learning have significantly enhanced disease diagnosis and management. However, the "Black Box" nature of deep learning raises concerns regarding explainability, transparency, and interpretability. Federated learning faces similar challenges. As a relatively new technology, FL enables machine learning models to be trained in a distributed setting, ensuring data privacy. However, because FL heavily relies on privacy protection, providing explainability and transparency becomes challenging. Given the sensitivity of the healthcare domain, it is crucial to employ techniques that are both explainable and interpretable. The need for explainable AI (XAI) delves critically into the fields that directly affect human lives. Researchers and medical experts always prefer interpretable and transparent approaches for decision making and XAI provides the solution. However, approaches like deep learning, federated learning, Generative AI, and large language models (LLMs) lack in providing such transparency. Here, the approaches that provide transparency and interpretability such as machine learning are highly preferred [4]. The researchers, developers, and practitioners are looking for explainable AI-based solutions typically in the domain of healthcare. There is a need to study the role and impact of current practices and future prospects of explainable and non-explainable approaches in healthcare. This study presents a systematic literature review to address this problem. This paper is divided into a set of sections. The related work is discussed in Section 2 and the used methodology for the SLR is described in Section 3. The findings and discussion of this study are given in Section 4 and the paper is concluded in Section 5 [5].

II. RELATED WORK

In the literature review, it was found that researchers are nowadays focusing on XAI-based machine learning [6] and deep learning models in medicine [7, 8], disease management [8, 9], and healthcare domains [10]. In the recent past, XAI-enabled deep learning has been used for the prediction and classification of various diseases. During the literature survey, it was also found that a few survey-based studies have been conducted on the role of XAI-enabled deep learning in medicine and healthcare. Table 1 shows the list of such studies year-wide.

Table 1: Summary of Related Studies in NoSQL Databases

Study	Study Reference	Study Objective	Publication year
Survey	[11]	XAI in machine learning based CDSS	2021
Survey	[12]	XAI to combat Pandemics	2022
Survey	[13]	XAI for healthcare	2022
Survey	[14]	XAI in medical health	2023
Survey	[15]	Disease prediction using XAI and machine learning	2023
Survey	[16]	XAI and ML in healthcare	2023
Survey	[17]	XAI models and their applications in healthcare	2024

Table 1 shows that all the surveys were conducted from 2021 to 2024 and the number of survey studies on usage of XAI in healthcare is rising every year.

III. METHODOLOGY

This section provides the materials and methods of the study presented in this paper. This section includes sub-sections like SLR protocol and research questions.

A. SLR Protocol

A protocol was devised for this systematic literature review-based study. The protocol consists of three phases I) planning, II) Conducting, and III) Concluding. The used protocol is shown in Figure 1.

Figure 1: Used Protocol for the SLR Study

The planning phase highlights the need for systematic literature and then on the basis of need, a set of research questions were orchestrated. In the conduction phase, study inclusion and exclusion criteria were defined to include relevant studies and exclude irrelevant studies. The concluding phase records observations and findings of the study and provides validity threats to the study. The phase is concluded with the write-up phase of the survey analysis.

B. Research Questions

A set of research questions was devised to define the scope of this systematic literature review-based study which is given below:

1. What are the main applications in the usage of deep learning, federated learning, and XAI in healthcare and disease management?
2. What are the forums and venues of publications and line of development in studies?

C. Conducting Search

This phase of the SLR study defines a strategy to search a set of studies and short-list the studies relevant to the scope of this study. To search the studies following steps were followed in this research:

1. Select the key research repositories.
2. Identify the key search terms.
3. Shortlist relevant studies using inclusion/exclusion criteria.

A brief description of each step mentioned above, used in this methodology, is given below:

i. Selection of Research Repositories

The first step in the conduct phase of the methodology involved searching various research repositories. To this end, a set of well-known and highly reputed research repositories was identified. These selected repositories and digital libraries were systematically searched to download research studies relevant to this investigation. The databases used for searching studies are shown in Table 2.

Table 2. Identified Research Repositories

Data Source	Website URL
The ACM Digital Library	http://dl.acm.org/
IEEE Xplore Digital Library	http://ieeexplore.ieee.org/Xplore/
Google Scholar	http://scholar.google.com
ScienceDirect	http://www.sciencedirect.com/
SpringerLink	http://www.springerlink.com/

ii. Searching from Research Repositories

The selected research repositories and digital libraries were thoroughly searched. These databases cover all the major journals, conferences, workshops, and symposiums that publish studies on AI, deep learning, federated learning, and XAI. During the search, only studies that were complete and published in peer-reviewed forums were selected. The search period spanned from 2015 to 2024. For the detailed search, a set of research keywords was used for the survey within the domain. Search terms such as healthcare, medicine, disease, XAI, deep learning, machine learning, and federated learning were incorporated into the search queries. Additionally, various combinations of terms were tried using logical operators like “AND” and “OR.” After a thorough search process, a total of 419 publications were found. After removing duplicate studies, the number was reduced to 184.

iii. Study Selection Criteria

Comprehensive study selection criteria were devised to exclude the irrelevant studies and shortlist the relevant set of studies. The used study selection criteria work in two phases. In the first phase, all 184 studies were traversed with a generic overview as below

- Select studies based on the relevant titles.
- Select studies based on the relevance in the abstract.

With the help of the phase I short-listed the 87 relevant studies were shortlisted. Still, 87 was the large number, and we were looking for 20 to 30 of the most relevant studies. For further short-listing and screening of the 87 studies, inclusion and exclusion criteria were devised to screen highly relevant studies. The used inclusion criteria were as below:

1. The study should address a challenge or an issue in XAI for healthcare.
2. The study should be published in a peer-reviewed forum.
3. The study should be published from 2015 to 2024.

4. The study should be in the English language.
5. The study should be a journal or conference paper.

Similarly to further stringent the criteria, the following exclusion parameters were observed:

1. The study does not match one of the research questions.
2. The study has less than 5 pages.

After applying this inclusion/exclusion criteria the total number of studies was restricted to 24 studies. All these 24 studies were thoroughly studied to find answers to RQ1 and RQ2, defined in Section 3.2.

IV. FINDINGS AND DISCUSSION

Adhering to the selection criteria and methodology defined in Section 3, a set of 24 studies was shortlisted for the final study. After a detailed analysis of these studies, a set of observations and findings were identified and noted. This section highlights those observations and findings, and a discussion of these findings is reported here. These observations and findings are synthesized to answer the research questions of this study such as RQ1 and RQ2.

A. What are the Main Applications in the Usage of Deep Learning, Federated Learning, and Xai in Healthcare and Disease Management

All 24 selected studies were studied and reviewed in detail to synthesize key issues and challenges related to the usage of deep learning, machine learning, and federated learning in the healthcare sector considering the XAI factor. The following are the key challenges that were identified through the review of the studies.

i. Key Challenges

All the shortlisted 24 studies address the XAI aspect of various AI techniques such as deep learning, machine learning, and federated learning. Hence, all these studies were examined for their contributions in different areas such as disease diagnosis, healthcare, disease detection, disease prediction, disease classification, and other similar areas. Figure 2 highlights the XAI-based contributions to various health applications.

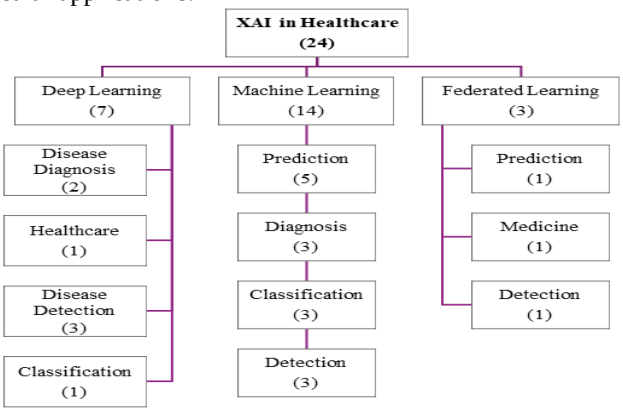

Figure 2: Applications of XAI Techniques in Healthcare

All the studies that were considering XAI in disease management were considered for this study. In 24 studies, 7 studies were using XAI-enabled deep learning, 14 were using machine learning and just 3 were using federated learning. These studies addressed challenges like disease diagnosis, healthcare, disease selection, prediction, classification, medicine, etc. 4 studies addressed disease diagnosis, 7 studies addressed disease prediction, 6 studies addressed disease prediction, and 4 studies addressed disease classification. Table 3 shows the classification of the studies for the identified challenges in the literature:

Table 3. Major Challenges Addressed by XAI Studies

Application	Relevant Studies
Disease Diagnosis	[S01], [S02], [S09], [S19], [S20]
Disease Detection	[S03], [S04], [S05], [S12], [S15], [S18]
Healthcare	[S24]
Disease Classification	[S06], [S07], [S11], S[13]
Disease Prediction	[S08], [S10], [S14], [16], [S17], [S21], [S22]
Medicine	[S23]

Figure 3 highlights the dispersion of the 24 studies among identified challenges in the usage of XAI in the field of disease management and healthcare. It is shown that the highest number of seven studies are available in the field of disease prediction and the lowest number of studies exist in the area of healthcare and medicine is one.

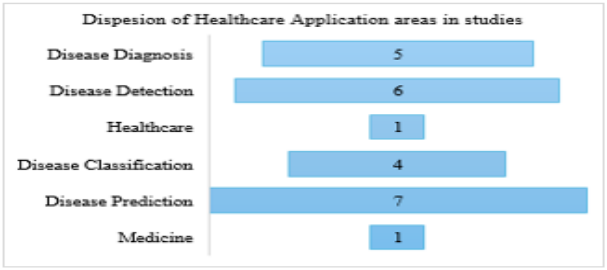

Figure 3: Funnel Chart of Dispersion of XAI Application Areas in Healthcare Studies

ii. Key Solutions

Besides the application of XAI-assisted learning, it also investigated what are the major diseases that are considered for study using XAI-assisted learning. The data for various diseases was compiled and it is shown in Figure 3. The collected data reflects that the major diseases addressed were heart, kidney, liver, cancer, allergy, tuberculosis, pneumonia, asthma, fungal, skin, Parkinson's, and a few other diseases. The collected data about diseases reflects that heart disease was addressed 4 times and 3 other diseases such as Parkinson's, asthma, and skin diseases were addressed twice in the selected studies. There were 5 studies from the total selected studies that were conducted for general healthcare applications and no specific disease was addressed in these studies. All other diseases were addressed once in the collected studies.

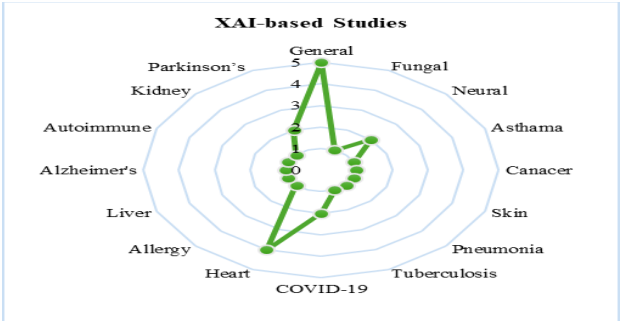

Figure 4: Radar Chart of XAI Applications for Various Diseases

B. What are the Forums and Venues of Publications and Line of Development in Studies

To answer this question, all 24 selected publications were investigated for their publication forums and venues. The results of publication forums are shown in Figure 5. According to these results, 71% of the selected studies were published in journals, 25% of studies were published in conferences, whereas, the remaining 4% of studies were published in other venues.

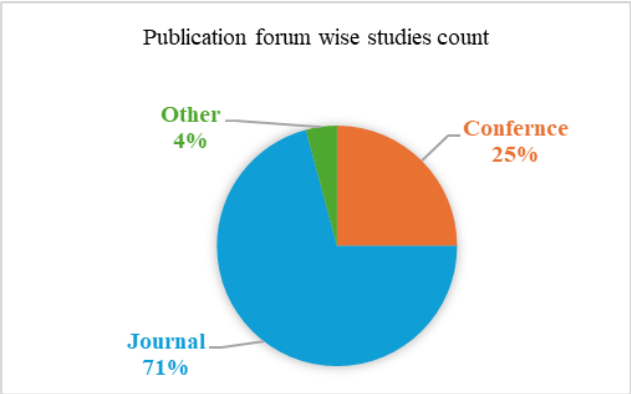

Figure 5: Publication Forum-Wise Study Count

The publication venues and publishers of these selected studies were also analyzed. The analysis showed that 17% of the selected studies were published by IEEE conferences or journals. Similarly, 29% of studies were published by Springer, and 21% were published by Elsevier. The remaining 33% of the selected studies were published by other publishers.

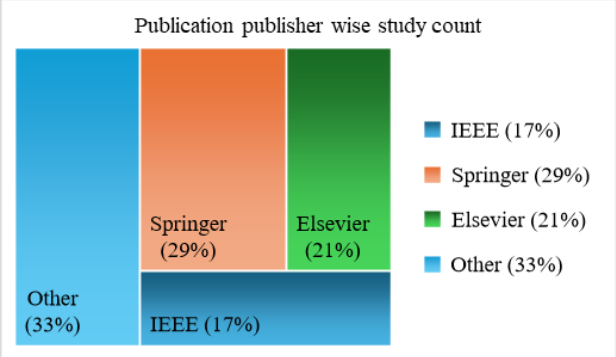

Figure 6: Publication-Publisher-Wise Study Count

RQ3 is about the analysis of the publication timeline of the selected studies besides the analysis of forums and venues of the selected studies. For the timeline analysis, the publication year and time of each selected study were collected. This study was conducted from 2015 to 2024. However, it was found that no significant study in XAI for disease management was published before 2021. All the 24 selected studies were published from 2021 to 2024. The results show that XAI-based disease management is a relatively new area and research contributions in this area are soaring each year. The results show that the highest number of 38% of studies were published in 2022. The integration of Explainable Artificial Intelligence (XAI) in machine learning-based clinical decision support systems has been recognized as a pivotal step in addressing the transparency and interpretability issues inherent in AI models. Antoniadi et al. [18] discuss the current challenges and future opportunities for XAI in this domain, emphasizing its crucial role in enhancing the reliability of AI-driven decisions in clinical settings. Additionally, XAI has shown significant potential in combating pandemics, as highlighted by Giuste et al. [19], who systematically reviewed various XAI methods applied during global health crises. The future of medicine is also being shaped by AI, particularly in drug discovery, where language models are pioneering new approaches, as discussed by Kathiriya et al. [20]. Furthermore, the role of XAI in securing the IoT ecosystem and addressing smart device cybersecurity challenges has been explored by Kolluru et al. [21], indicating its broader applicability beyond traditional healthcare. Recent systematic reviews, such as those by Loh et al. [22] and Band et al. [23], provide comprehensive analyses of the application of XAI in healthcare, underscoring the growing importance of interpretability in medical AI systems. The use of XAI in enhancing patient-centered care, particularly in oncology, through telehealth and personalized strategies, has also been examined, revealing the benefits of advanced data analytics in breast cancer treatment [24]. Moreover, Alsaleh et al. [25] explore the prediction of disease comorbidity using XAI, further showcasing the broad scope of XAI applications in medical research. Allgaier et al. [26] and Gupta & Seeja [27][28][29] provide systematic reviews and comparative studies of XAI models, offering valuableinsights into their explanatory power and effectiveness in healthcare.

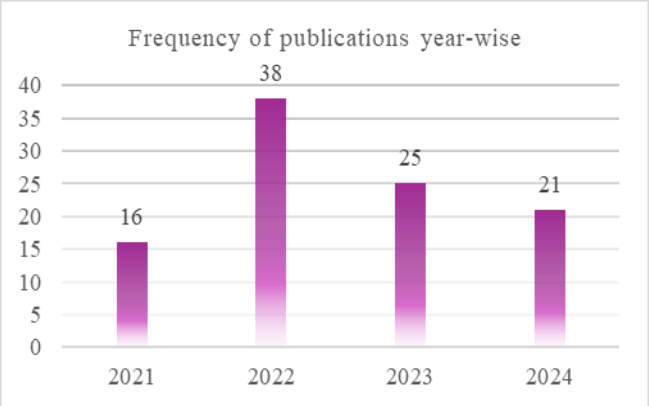

Figure 7: Frequency of Selected Studies Year-Wise

C. Discussion

This SLR-based study was conducted to identify the various challenges and applications of deep learning, federated learning, and XAI generally in healthcare and specifically in disease management. The study duration was from 2015 to 2024. Two research questions were devised that are answered in this research study. A thorough literature survey was conducted to collect all the relevant studies and inclusion/exclusion criteria were devised and followed to extract the most relevant 24 studies to this study. Among the selected 24 studies, seven studies were using XAI and deep learning, fourteen were using XAI and machine learning and only three were using XAI and federated learning. Here, four studies addressed disease diagnosis, seven studies addressed disease prediction, six studies addressed disease prediction, and four studies addressed disease classification.

The further analysis of the selected studies reflected that the major diseases covered were heart, kidney, liver, cancer, allergy, tuberculosis, pneumonia, asthma, fungal, skin, Parkinson's, and a few other diseases. It was also analyzed that 71% of the selected studies were published in journals, and 25% of the studies were published at conferences. Similarly, 29% of studies were published by Springer, and 21% were published by Elsevier. The remaining 33% of the selected studies were published by other publishers. The results show that XAI-based disease management is a relatively new area and research contributions in this area are soaring each year. The results show that the highest number of 38% of studies were published in 2022.

D. Findings of The Study

Following are the key observations and findings of this SLR-based study.

- The selected studies addressed challenges like disease diagnosis, healthcare, disease selection, prediction, classification, medicine, etc.
- The collected data about diseases reflects that heart disease was addressed four times and three other diseases such as Parkinson's, asthma, and skin diseases were addressed twice in the selected studies.
- The results show that XAI-based disease management is a relatively new area and research contributions in this area are soaring each year.
- The results show that the highest number of 38% of studies were published in 2022.
- Nowadays, researchers are harnessing XAI-enables learning techniques and models to ensure transparency and interpretability.

E. Quality Threats

This SLR study used an SLR protocol and it was ensured that all the selected studies were chosen carefully. However, there is still a chance of some biases or skewness in the data identified by the selected studies. The following are factors key factors that may be a threat to the quality of this SLR:

- the selected studies may possibly show bias in results and the same bias may be reflected in the results of this study.
- A thorough survey was conducted using a set of search terms and it was ensured that all relevant studies are included in this study.
- The selection of studies and analysis results presented in the article were vetted by another expert, as well to ensure fairness and transparency in the results of this study.

V. CONCLUSION

This SLR-based study was conducted to investigate and identify the usage of various AI-based techniques in healthcare especially for disease management. This study specifically focuses on applications of XAI-enabled deep learning, machine learning, and federated learning in disease management. This study concluded that XAI is the latest concern in AI-based solutions especially in healthcare. For the last few years, researchers have been harnessing XAI-enables learning techniques and models to ensure transparency and interpretability. This study also concluded that researchers have revealed the importance of XAI since 2021 and after that, the focus on XAI-based research in healthcare is rising. Moreover, academicians, researchers, are practitioners putting especial attention to XAI's role in the domain of healthcare.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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APPENDIX I. RESEARCH STUDIES

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