International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN - 2395-1990
Online ISSN : 2394-4099
Available Online at : www.ijsrset.com
doi : https://doi.org/10.32628/IJSRSET24115113

# Integration of Neuro-Fuzzy Systems in Medical Diagnostics and Data Security - A Review

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ARTICLE INFO

**Article History:**
Accepted : 25 Sep 2024
Published: 14 Oct 2024

**Publication Issue :**
Volume 11, Issue 5
Sept-Oct-2024

**Page Number :**
196-200

ABSTRACT

Adaptive Neuro-Fuzzy Systems (ANFS) have become increasingly prevalent in a variety of fields due to their ability to process complex and uncertain data with high accuracy. This research article reviews three major contributions of ANFS: their application in deep neuro-fuzzy systems (DNFS) for healthcare and industrial systems, neuro-fuzzy logic controllers for paralysis estimation, and ANFIS-based solutions for secure cloud storage in medical IoT (MIoT). The findings emphasize the importance of ANFS in improving decision-making, diagnosis, and data security. This paper concludes with a discussion on challenges, future research directions, and the need for optimization in real-time applications.

**Keywords :** Adaptive Neuro-Fuzzy Systems, Deep Neuro-Fuzzy Systems, Medical IoT, Cloud Security, Healthcare Diagnostics, Fuzzy Logic, Machine Learning

## I. INTRODUCTION

Adaptive Neuro-Fuzzy Systems (ANFS) are hybrid models that combine the interpretability of fuzzy logic with the learning capabilities of artificial neural networks (ANNs). These systems are particularly well-suited for applications that require the handling of uncertain, imprecise, or noisy data, making them highly valuable in fields like healthcare diagnostics, intelligent systems, and data security. The ability of ANFS to model complex behaviours and adapt to real-time data provides unique dvantages, especially in mission-critical domains such as healthcare and cloud storage systems.

This paper focuses on three key applications of ANFS:

1. The integration of deep neural networks (DNN) with fuzzy logic in deep neuro-fuzzy systems (DNFS) for handling complex datasets.[1]
2. Neuro-fuzzy logic controllers in diagnosing and analyzing paralysis.[8]

3. Secure cloud storage for medical IoT data using ANFIS, ensuring data privacy and security in the healthcare industry.[13]

## I. Deep Neuro-Fuzzy Systems: Current Trends and Applications

In recent years, deep learning models have shown impressive results across various industries, but the complexity and "black-box" nature of these models have limited their interpretability. To address this, researchers have explored the integration of DNNs with fuzzy logic systems, leading to the development of DNFS.

Talpur et al.[1]conducted a systematic survey of DNFS applications, outlining how DNFS models are particularly effective in healthcare, transportation, and financial sectors(AISC rp2). Their study[1-7] shows that DNFS models, which combine the high precision of deep learning with the transparency of fuzzy logic, offer significant potential in handling complex and large datasets, while also providing more interpretable decision-making systems.

### 2.1 Application in Healthcare

One prominent application of DNFS is in healthcare diagnostics, where DNFS models can analyze complex patient data with high accuracy. By using fuzzy rules, these systems provide clearer explanations for their decisions, which is essential for clinical applications where the interpretability of AI-based predictions is critical for patient trust and medical compliance.

### 2.2 Future Challenges

The main challenges associated with DNFS include computational complexity and the need for efficient real-time processing. To mitigate these issues, hardware implementations such as field-programmable gate arrays (FPGAs) are recommended for future research(AISC rp2). Further work is also needed to explore optimization techniques that balance model accuracy with performance.

## II. Estimation of Paralysis Effects Using Neuro-Fuzzy Logic Controllers

Ramesh et al.[8] demonstrated the application of neuro-fuzzy logic controllers in analyzing the effects of paralysis on the human nervous system(AISC rp5). Paralysis is one of the leading causes of disability worldwide, and early diagnosis and treatment can significantly improve patient outcomes. The study introduces a neuro-fuzzy model to estimate paralysis progression based on various symptoms, aiding clinicians in making timely decisions.

### 3.1 Key Findings

The neuro-fuzzy logic controller achieved a high accuracy of 91.39%, with recall and precision values exceeding 91%, making it an effective tool for identifying and categorizing different stages of paralysis (AISC rp5). The model's ability to handle uncertain and incomplete medical data is especially useful in scenarios where symptoms are not fully visible or clear in the early stages of diagnosis [8-12]

### 3.2 Clinical Implications

This neuro-fuzzy system is particularly relevant for emergency medical applications where rapid decision-making is critical. By integrating neuro-fuzzy logic with patient data from wearable devices or medical records, healthcare providers can predict the onset or progression of paralysis and take preventive measures. This approach reduces the need for invasive testing, speeding up the diagnostic process and minimizing patient discomfort.

## III.Secure Cloud Storage for Medical IoT Data Using ANFIS

The increasing use of Internet of Things (IoT) devices in healthcare has raised concerns regarding the privacy and security of medical data. Mohiyuddin et al.[13] propose an Adaptive Neuro-Fuzzy Inference System (ANFIS) model for secure cloud storage of Medical IoT (MIoT) data(AISC rp8). With the rise of remote patient monitoring, healthcare providers need robust methods to store and transmit sensitive data securely. ANFIS offers a promising solution by combining fuzzy logic with machine learning to improve security measures.

### 4.1 Methodology and Results

In this study[13] ,the authors evaluated the performance of five machine learning algorithms in predicting diseases from MIoT data, followed by a secure data storage mechanism using ANFIS. The system achieved minimal training and testing errors (6.2506e-06 and 0.3429, respectively), indicating high accuracy and robustness in handling medical data(AISC rp8). ANFIS effectively mitigates risks such as data breaches, ensuring the confidentiality and integrity of patient information.

### 4.2 Importance of Data Security

Medical data is highly sensitive, and any breaches can have severe consequences for patient privacy. ANFIS helps ensure that medical data, particularly from MIoT devices, is securely transmitted and stored in cloud environments. This is vital in the age of telemedicine and remote healthcare, where patients' health data is collected and transmitted in real-time.

## IV. Comparative Analysis of ANFS Applications

The following table summarizes the key applications of ANFS as reviewed[1-20] in this paper

| Study | Application Domain | Key Performance Metrics | Challenges |
|---|---|---|---|
| Talpur et al. (2023)[1] | DNFS in healthcare and ITS | N/A | Computational complexity, real-time processing |
| Ramesh et al. (2022)[8] | Paralysis diagnosis | 91.39% accuracy, 93.02% recall | Symptom variability |
| Mohiyuddin et al. (2021)[13] | Secure MIoT data storage | 6.2506e-06 training error, 0.3429 testing error | Data encryption and security challenges |

## V. CONCLUSION

The use of Adaptive Neuro-Fuzzy Systems across various domains highlights their potential in handling complex data, improving decision-making, and ensuring data security. In healthcare, ANFS models have proven effective for disease diagnosis and progression analysis, while in cloud computing, they enhance data privacy and protection for IoT applications. However, challenges remain in optimizing these systems for real-time use and reducing computational overhead.

Future research should focus on developing efficient algorithms that address these limitations, particularly in critical fields such as healthcare, where time-sensitive and accurate decisions are paramount. Additionally, hardware implementations and cloud-based solutions should be further explored to scale ANFS for broader applications in industrial and clinical settings.

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