A Proposed Machine Learning-Driven Framework for Multi-Disease Classification in Neonatal Morbidity Prediction Using LSTM Networks in Nigeria

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Abstract- Neonatal morbidity and mortality are significant public health challenges in many low- and middle-income countries, with Nigeria facing problems such as respiratory distress syndrome, pneumonia, jaundice, prematurity, birth asphyxia, congenital anomalies, neonatal infections, and hemolytic diseases, among others, contributing to neonatal mortality. During the initial 28 days of life, the neonate makes significant physiological adaptations from intrauterine to postnatal life, during which the immature organ systems are vulnerable to minor pathological infections. However, while early and effective detection is essential in improving survival outcomes, existing detection methods, which are based on clinical observation, have limitations of subjectivity and delay in diagnosis. Although some studies have employed machine learning in disease detection, they have focused mainly on adults and disease classification, with little emphasis placed on data sets relevant to the Nigerian population. In this study, a framework is proposed that utilizes deep learning and its subset, Long Short-Term Memory (LSTM) networks, which will facilitate multi-disease classification in neonates based on data sets from tertiary healthcare institutions in Southwestern Nigeria, with the aim of more accurately and timely identifying diseases that commonly occur in neonates. The integration of artificial intelligence in neonatal disease detection is intended to improve clinical decisions and lower mortality rates among this vulnerable group of patients in resource-constrained settings.

Keywords- Neonatal health, Deep learning, Long Short-Term Memory (LSTM), Artificial Intelligence, Disease classification, Neonatal care.

1   INTRODUCTION

Human development begins in gestation and progresses into the neonatal period, which is defined as the first 28 days of life (Khan, 2023). The neonatal period is an important transitional phase of life where significant physiological adaptations occur from an intrauterine environment to an extrauterine environment after birth. In view of their developmental state, which is immature, the vital organs of the neonate, which include the pulmonary, cardiovascular, immune, and nervous systems, remain vulnerable to disease and disease processes; even minor deficiencies, infections, or birth defects can have serious and life-threatening consequences.

Neonatal diseases cover a broad spectrum of clinical conditions, including neonatal respiratory distress syndrome, neonatal sepsis, jaundice, birth asphyxia, hypoglycemia, heart problems, neonatal abstinence syndrome, meningitis, and pneumonia, among others (Hackett *et al.,* 2021; Marshall, 2019). Despite the numerous challenges associated with neonatal diseases, the importance of timely diagnosis and effective management cannot be overstated, considering the long-term implications of neonatal disease on infant survival. Despite the tremendous progress made globally in neonatal disease management, disparities still exist, and they are quite substantial. Neonatal disease is a major cause of infant mortality, with neonatal disease-related deaths ranked highest among causes of death among the under-five population in Nigeria (WHO, 2022; WHO, 2023). Neonatal disease is ranked second highest cause of mortality among African countries and among the top five globally (GBD, 2023). Traditional diagnostic methods, which rely on a combination of physical examination and laboratory confirmation, may also be affected by issues of subjectivity, accessibility, and time constraints.

In recent years, artificial intelligence, particularly machine learning, and deep learning have shown significant promise in handling intricate pattern recognition in various medical fields. Nevertheless, most machine learning-based research in neonatal care has focused on single-disease classification. Yildirim and Canayaz (2023) utilized C+EffxNet in machine learning-based prediction of respiratory disorders in neonates based on chest radiographic images. Ribeiro *et al.,* (2023) implemented machine learning-based models incorporating clinical parameters and cardiotocographic parameters in birth asphyxia classification. Jang *et al,.* (2023) utilized seven machine learning algorithms in RDS classification based on laboratory parameters and symptoms. These research

contributions, although significant, have limitations in their single-disease-based approaches, which are not likely to be beneficial in neonatal screenings. There is a scarcity of machine learning-based diagnostic models that have utilized data collected from Nigerian healthcare settings. There is a need to consider contextual differences in disease burden, genetic predisposition, healthcare practices, and environmental determinants.

To bridge these gaps, this research proposes a novel application of a unified deep learning model in the diagnosis of multiple diseases in newborn babies. Long Short-Term Memory networks are often used in natural language processing, but they can be particularly useful in analyzing temporal patterns in clinical data. With retrospective data from major hospitals in Southwestern Nigeria, this model can be a useful tool in bridging gaps in healthcare in Nigeria, particularly in neonatal care. With this model, it is possible to improve diagnostic delays, resource allocation, and patient care. Ultimately, this research adds to the growing body of research indicating that AI-based solutions can be useful in bridging gaps in healthcare in Nigeria.

2.   DEEP LEARNING APPROACH IN HUMAN HEALTH MANAGEMENT

The Artificial intelligence based deep learning technology has become a major part of modern society. This is because of its special potential for extraction of features from very large and complex data sets. Deep learning (DL) is an arm of machine learning which uses artificial neural networks. DL uses deep architectures as shown in figure 1, thus it is able to learn complex patterns and relationships within data. This makes deep learning very suitable for complex tasks like speech recognition, image recognition, and natural language processing (Honore, 2023).
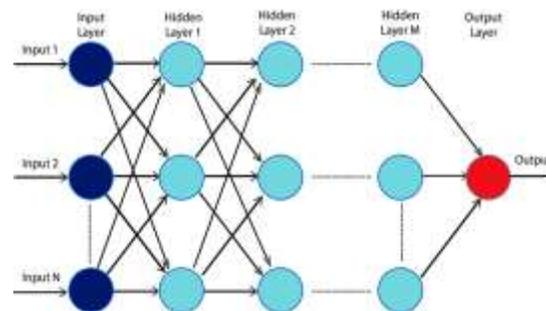

Figure 1: Architecture of Deep Learning (Nayagi and Shiny, 2023)

In recent times, deep learning methods have yielded good results in several fields of Natural Language Processing (NLP), such as analysis of sentiment, spam filtering, answering questions and text categorization (Zulqarnain *et al.*, 2023). Some of the areas of application of deep learning include image recognition, automation and robotics systems, games, financial account auditing and business financing, security, manufacturing, agriculture, medicine and health care. Diagnosis of human health status is one of the important tasks into which deep learning has been deployed.

Mujahid *et. al*., (2024) proposed a deep learning-based model EfficientNet using red blood cell images as training data, the experiment recorded 97.57% accuracy. Shen *et. al.,* (2024) developed end-motif inspection via transformer (EMIT), an unsupervised learning model to discriminate between patients with or without cancer from cfDNA , it performed creditably. Rao *et. al.,* (2024) developed an attention based gated recurrent unit-hybrid mutation based swarm intelligence (AttGRU-HMSI) hybrid deep learning model for classification of heart diseases in adults. The system used data obtained from Apache Hadoop network and was compared with some machine learning models such as K-Nearest neighbor, Logistic regression, Autoencoder and Naïve Bayes. The hybrid model outperformed all the machine learning models (Rao *et al,.* 2024) These are cases of deep learning algorithms being applied to the diagnosis of diseases in adults. Since deep learning has been found to be very effective in detecting diseases in adults, it would be a promising technology in neonatal health status prediction.

3.   COMMON NEONATAL DISEASES IN NIGERIA

The major neonatal diseases are prematurity, jaundice, birth asphyxia, pneumonia, sepsis, meningitis, respiratory distress syndrome, congenital malformation, neonatal tetanus and haemolytic disorder. However due to environmental factor being one of the main causes that influence the occurrence of these diseases, some are more common or peculiar to some geographical location. Therefore, those that are commonly experienced in southwestern part Nigeria are what this research is focusing on.

According to Kareem *et. al.,* (2020) and Odejimi *et. al*., (2022), Sepsis, Birth Asphyxia and Jaundice are the commonest newborn diseases in southwestern Nigeria. Therefore the proposed deep learning model would be designed for Neonatal Sepsis, Birth Asphyxia and Jaundice.

   i.   **Neonatal Sepsis:** Sepsis is caused by the presences of bacteria or blood stream infections (BSI) in newborns. Neonatal sepsis is the highest cause of newborn death in the world.

   ii.   **Birth Asphyxia:** This is due to inadequate oxygen and nutrients supplied to the brain and other organ before, during or right after birth.

   iii.   **Jaundice**: Jaundice is the sign of disturbance in liver and not the disease. Newborns are prone to get jaundice and hyper-bilirubinemia due to immaturity of liver and/or some associated pathological cause.

4.   PROPOSED DEEP LEARNING TECHNIQUE FOR DETECTING NEONATAL DISEASE

Basic machine learning algorithms would have been enough for developing the classification model for this task, but the large size and complexity of the text dataset require a deep learning algorithm. Thus, the Long Short-Term Memory networks (LSTM) which is a variant of Recurrent Neural Networks (RNN) would be used in this study.

Long Short-Term Memory (LSTM)

Long Short-Term Memory (LSTM) networks whose architecture is shown in figure 2 have gained prominence in various natural language processing (NLP) tasks, including text classification, due to their ability to capture long-term dependencies and handle sequences of data effectively (Hassan, 2021).

It is equipped with special memory cells that can remember information for a long period of time with the aid of gates that control the flow of information into and out of the cell. The input gate which is described with equation (1) controls which information the current input to store in the hidden state. Equation (2) calculates the memory cell value, the forget gate represented as equation (3) determines which information from the previous hidden state to keep or discard. The new memory cell value is calculated based on equation (4), while the output gate (equations (5) and (6)) controls the information from hidden state to output as the final prediction. These gates allow LSTM to retain important information from long sequences and discard irrelevant ones. LSTM are more complex in structure than traditional RNN, therefore it is often used for tasks involving long-term dependencies such as natural language processing (Hassan, 2021; Esan *et al.*, 2023).
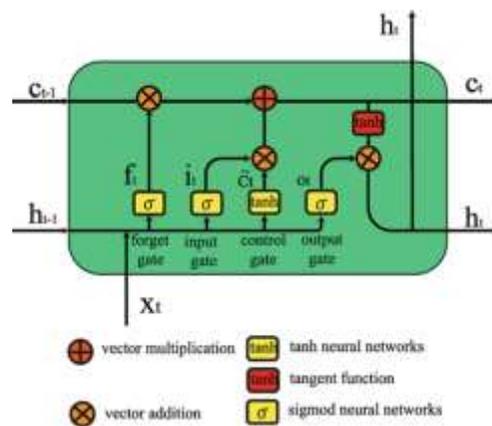

Figure 2: Long Short-Term Memory (LSTM) Architecture (Banoula, 2023).

LSTM is very useful especially in overcoming the problem of vanishing gradient. LSTM is similar to the conventional RNN in terms of its chain-like structure, but it is able to regulate the flow of information into every node state due to the use of multiple gates.

A step-by-step explanation of a LSTM cell is as follows :

$$i_t = \sigma(W_i\,[x_t\,,\,h_{t-1}] + b_i), \qquad\qquad (1)$$

$$\tilde{C}_t = \tanh(W_c[x_t\,,\,h_{t-1}] + b_c), \qquad\qquad (2)$$

$$f_t = \sigma(W_f\,[x_t\,,\,h_{t-1}] + b_f\,), \qquad\qquad (3)$$

$$C_t = i_t * \tilde{C}_t + f_t C_{t-1}, \qquad\qquad (4)$$

$$o_t = \sigma(W_o[x_t\,,\,h_{t-1}] + b_o), \qquad\qquad (5)$$

$$h_t = o_t \tanh(C_t), \qquad\qquad (6)$$

In the above description, each **b** represents a bias vector, each **W** represents a weight matrix, and x_t represents input to the memory cell at time **t**. Furthermore, **i, c, f, o** indices refer to input, cell memory, forget and output gates respectively (Banoula, 2023). The system flow chat is as represented in Figure 3. The model would be developed using Python 3.9v in Google Collab environment for easier and faster computation.

The study would begin with data acquisition with ethical considerations for data management. The dataset would include the symptoms, laboratory test results, radiological scan results (if any) and diseases diagnosed, excluding the identity of the neonate patients. The clinical data will not be printed but copied in a file with password to prevent unauthorized copying and piracy. The collected data will then be preprocessed to convert it to electronics format. Neonatal health information would be collected from some of the major tertiary health institutions in South West Nigeria; Ladoke Akintola University of Technology Teaching Hospital Ogbomosho Oyo State, Ondo State Specialist Hospital, Akure Ondo State, Afe Babalola Multisystem Teaching Hospital, Ado Ekiti Ekiti State and Federal Teaching Hospital Ido Ekiti, Ekiti State. The datasets will include age of neonate, disease symptoms, X-ray results, Laboratory test results and type of disease diagnosed.

Since the proposed data would be a textual data which are not quantitative but qualitative data, and as such there are no problem of missing values, the bias would be taken care of by the algorithm. This study would employ Natural Language processing technique, the data would undergo preprocessing such as removal of stop words and punctuation, lemmatization, stemming, vectorization and word and sentence tokenization. All these preprocessing would enrich the performance of the proposed system for improved accuracy and accurate prediction of neonatal diseases.
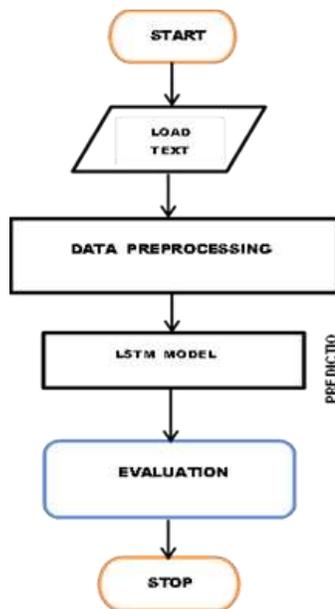

Figure 3: System Flow Chat

The preprocessed electronics neonatal health data then go into the algorithm for training the LSTM model for classification. The dataset would be divided into three; 70% for training the model, 20% for testing and 10% for validation. This research being a classification task would be evaluated using the best set of evaluation metrics for deep learning algorithms; accuracy based on equation (7), precision shown in equation (8), recall as shown in equation (9) and F1 score represented in equation (10). These would be employed as the evaluation metrics as they take into consideration the true positive, true negative, false positive and false negative values during evaluation. These serve as good performance metrics for this study due to its proven application and results.

$$Accuracy = \frac{TN+TP}{TN+FN+TP+FP} \qquad (7)$$

$$Precision = \frac{TP}{TP+FP} \qquad (8)$$

$$Recall = \frac{TP}{TP+FN} \qquad (9)$$

$$F1 = 2 \times \frac{Precision \times Recall}{Precision+Recall} \qquad (10)$$

Where :

TP – True Positive

TN – True Negative

FP – False Positive

FN – False Negative
(Rainio, 2024)

5. CONCLUSION

Errors associated with confusion due to similarities in symptoms as well as delay as a result of not been able to make accurate diagnosis on time are the human errors which have caused the death of many newborns. The proposed deep learning technique will be suitable for use as a component of neonatal clinical decision support system (NCDS) to mitigate these human errors. If the tool is included in the neonatal diseases diagnostic procedures, medical practitioners will be relieved of the stress faced day by day and the rate of survival of newborns will increase in Nigeria.

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