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Artificial Intelligence (AI) Based Techniques for Reducing Neonatal Mortality in Nigeria: A Descriptive Review

Odeyemi C. S., Olaniyan O. M., Sobowale A. A. and Samuel I. B.

Abstract Neonatal diseases are the disturbances of normal condition of the body, organs and abnormal function of newborns. They range from minor ailments like jaundice, to serious issues such as congenital heart defects encompassing a wide range of health conditions that affect newborns within the first 28 days of life. Thus, the first four weeks of life are critical and vulnerable period that require identification, accurate diagnosis, and management. The major causes of death of diseased newborns have been found to be late detection and misdiagnosis due to confusions in diagnosing diseases with similar symptoms. Hence, artificial intelligence (AI) techniques, especially those based on deep learning algorithms have emerged as important tool in handling very difficult tasks. In spite of its prospect, the potentials of AI are yet to be maximized in newborns' health management. This paper explored the prospects of deep learning method in neonatal diseases classification. The study proposed a Long Short-Term Memory-Artificial Neural Network (LSTM-ANN) model, the model would be trained on a large dataset comprising of age, symptoms, laboratory test results, x-ray image results and diseases diagnosed. These would be obtained from the medical records of previously diagnosed and treated newborn. The technology will enhance accurate and timely diagnosis of neonatal diseases.

Keywords: Neonatal, Artificial intelligence, Algorithm, Deep learning, Diagnosis

I. Introduction

The first four weeks of newborn's life is a cruiser and challenging period, a time of joy, hopes, and celebrations. It is also a delicate time for the baby because it is a time when newborns can easily be affected by infections, poor care or unhygienic conditions which can turn the season of joy to season of sorrow. Available studies have shown that the risk of death is higher at neonatal stage than any other stage of human life [1]. According to the World Health Organization findings, over one million newborns died within 24 hours of birth. About a million do not survive to the first seven days, and 47% of infants death occur within the first 28 days of birth [2]. Nigeria Demographic and Health Survey (NDHS) 2017 estimated neonatal mortality rate in Nigeria to be 37 per 1000 live birth and 54% of all infant [3,4].

This high mortality rate is attributed to a group of ailments called Neonatal Diseases. Major neonatal diseases are Respiratory distress syndrome, pneumonia, jaundice, prematurity, birth trauma, congenital malformations, neonatal infection and haemolytic disorders [5]. These diseases have claimed the lives of several newborns especially in developing countries of

Odeyemi C. S.
(Department of Computer Engineering, Federal University of Technology Akure Nigeria)
Olaniyan O. M., Sobowale A. A.
(Department of Computer Engineering, Federal University Oye Ekiti Nigeria)
Samuel I. B.
(Department of Pediatrics, Federal Medical Center Owo, Nigeria)
Corresponding Author: csodeyemi@futa.edu.ng

the world because they are not easy to detect and in many occasions misdiagnosed because many of them have similar symptoms [6]. An artificial intelligent system which is not subject to stress, sentiments, and less prone to error will be a viable alternative in rural communities where medical professionals are not available and will also serve as a tool for a decision support system for health and medical practitioners. It could also be a cost effective way of reducing misinterpretation of symptoms and laboratory test results as well as overcoming delay in newborns diseases diagnosis.

Artificial intelligence (AI) has become part of our daily lives and society in that it is penetrating very fast into almost all fields of life especially the health sector. Through the deep learning techniques, AI technology has been exploited in adult healthcare. It has impacted therapeutics, personalized diagnostics, drug delivery and medical imaging considerably [7]. In spite of the prospect of AI in adult healthcare, its use in managing the health of neonates is just emerging [8]. Although, AI approach in newborn health management may meet some challenges like large datasets required to train the model and the presence of unbalanced data, nevertheless, it is a promising tool for neonatal health decision support system [6]. The technology will enhance accurate and timely diagnosis of newborn diseases both in urban and rural communities of Nigeria thereby aiding quick medical intervention. These will greatly increase the chances of survival of neonates.

II. Artificial Intelligence Based Approach in Neonatal Care

Artificial intelligence (AI) is about the development of computer systems (software or software and hardware) which are capable of performing tasks that are peculiar to human [9]. Such tasks attributed to AI includes:

i. Learning
ii. Perception
iii. Problem solving
iv. Language processing
v. Decision making

AI technologies leverage on the massive data with which the systems are trained to make suggestions, predictions and decisions. The basic goals of AI are to automate tasks in other to improve efficiency and productivity, improve customers' experience in business places, create intelligent machines to aid humans, and helping decision making ability [7]. It is a broad field of technology that includes:

i. Machine learning
ii. Deep learning
iii. Robotics
iv. Computer vision
v. Natural language processing

Some of the application areas of AI are finance, transportation, production, education and healthcare.

Newborn health care has been surrounded by controversy and affected by the ethical, cultural, religious and political values of the various societies. There have been so much changes in neonatal and infant mortality and morbidity in the past 150 years which gave birth to the concept and technology in perinatology and neonatology [10]. After the second world war in the 1960s, the development of neonatal physiology and pathophysiology provided insights into neonatal diseases and the treatment of newborn ailments like jaundice, brain complications and respiratory distress [11]. This

seems to be the birth of neonatology. Attention to newborn healthcare grew rapidly led to the major changes in clinical care 1970s when the idea of miniaturizing of blood samples to for serum electrolyte, blood gas, bilirubin and liver function tests was developed [12]. By the 1990s, there has been increase in technological means of caring for premature infants as well as an increase in the professional knowledge about preterm babies. This gave chances of survival to babies who in years past were regarded as lost causes [1].

A. Understanding Deep Learning Method for Neonatal Diseases Management

Machine learning (ML) is a branch of Artificial intelligence (AI) as illustrated in figure 1. AI deals with the ability of a computer program or a machine to think and learn from very large dataset. That is learning from experience to carry out human functions like reasoning, decision making to solve problems. Therefore, AI mimics human intelligence. ML focuses on developing algorithms that learn or improve through experience using data and make predictions without being programmed. ML has several potentials in human health prediction and has been applied in managing high-risk neonates' illnesses and mortality [13].

Implementing deep learning approach for neonatal health management by using large clinical data of neonatal patients could address the high rate of neonatal mortality in Nigeria and other developing countries of the world. Neonatal diseases are the major cause of death in Nigeria they rated as the highest cause of newborn death in Africa and rank number two in the world as seen in Table 1.

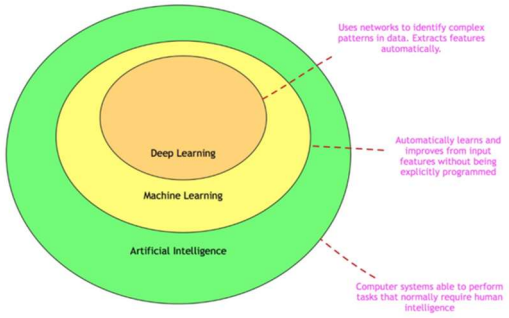

Figure 1: Illustration of the Relationship between AI, ML and DL [14]

Table 1: Global Ranking of Neonatal Mortality in 2020 [15]

Country	Number of newborn deaths in thousands
India	490 (425–558)
Nigeria	271 (199–374)
Pakistan	244 (198–298)
Ethiopia	97 (77–123)
Democratic Republic of the Congo	96 (56–163)
China	56 (49–64)
Indonesia	56 (45–70)
Bangladesh	51 (45–57)
Afghanistan	43 (32–55)
United Republic of Tanzania	43 (30–62)

Previous studies have shown that there is high rate of death of newborns in developing countries because of lack of cutting edge technology for timely medical intervention. This has resulted in delay in the detection of ailments and misdiagnosis on several occasions because the symptoms of some neonatal diseases are very

similar [16]. Deep learning algorithms have been found very useful in dealing complex tasks such as natural language processing, image and text classifications.

Deep learning (DL) is an arm of machine learning which uses artificial neural networks. DL uses deep architectures such as the one shown in figure 2, 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 [17].

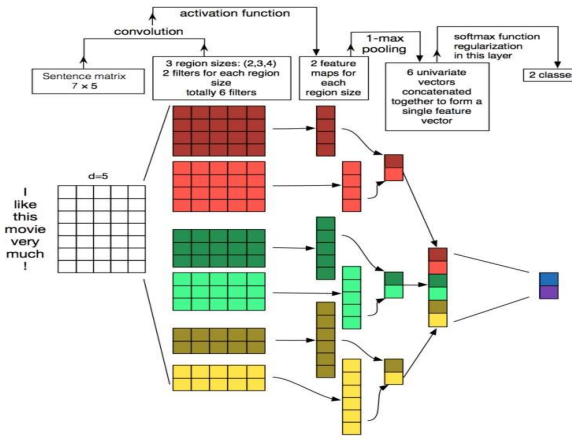

Figure 2: Architecture of Deep Learning

Other fields of application of DL include computer vision and bioinformatics. Development of clinical decision support systems for routine clinical care is still a challenge to overcome even with the applications of deep learning. One of such challenge is the unavailability or inadequacy of big data required to train a deep learning model, it is also very difficult to obtain reliable labels. Availability of large amount of labeled data is very important in training deep architectures [17]. Deep learning networks learn by discovering hiding structures in the data they are trained with. Artificial neural networks which are the foundations of deep learning mimic the brain neurons. The neurons are grouped into three layers:

i. Input layer – This receives input data and passes them to hidden layer

ii. Hidden layer – This is where mathematical computations are done. Deep learning is so called because the hidden layers are more than one.

iii. Output layer – This returns the output.

III. Proposed Deep Learning Technique for Neonatal Health-care

Traditional machine learning algorithms would give a good performance with textual data but the necessity to employ deep learning algorithms would arise as the dataset becomes more complex and bigger. As a result of that, this study proposed the used of some deep learning algorithms like Long short-term memory (LSTM), being a good model for processing sequential data, and Artificial Neural Network being the mother and originator of all the deep learning algorithm. As shown in figure 3, these two algorithms would be implemented individually and also cascaded as LSTM-ANN for performance evaluation.

A. The LSTM-ANN model

The deep learning LSTM and machine learning ANN algorithms would be combined together in cascade as shown in figure 3 to produce an LSTM-ANN model which would be used for the classification of neonatal diseases. The output of LSTM units are summed and fed into the inputs layer of the ANN. The figure consists of three LSTM units as a representative example to show the flow of data, which transfer the outputs ht−1, ht , and ht+1 to the ANN layers. The ANN layers then process the time-invariant input data

through nonlinear activation functions and connect to the output layer. By using LSTM layers first the network is able to extract time-varying information directly from the input layer, making it easier to extract temporal dependencies.

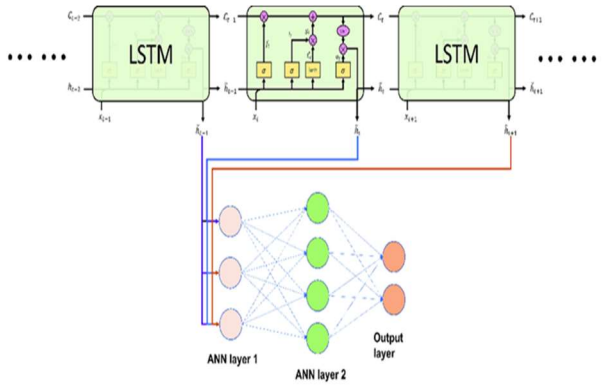

Figure 3: The architecture of the proposed LSTM-ANN model [19]

Step-by-step operations of LSTM cells are as represented in Eqs. 1 to 6. Eq. 1 represents the input gate where the input data are fed into the cells. The actual memory cell value is obtained based on Eq. 2. Eq, 3 defines the forget gate, while Eq. 4 calculates the new memory cell value. Eqs. 5 and 6 define the final output gate value.

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

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

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

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

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

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

In equations 1 - 6, each ***b*** represents a bias vector, each ***W*** represents a weight matrix, and $\boldsymbol{x}_t$ 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 [20].

Since Eqs. 5 and 6 represents the output of the LSTM block,

Equation 6 now becomes:

$$h_t = \text{LSTM}(x_t\,,\,h_{t-1}) \qquad (7)$$

which enters the input layer of the ANN, where computation of the trainable weighted sum of the inputs and a bias is carried out as shown in Eq. 1.

The output of ANN denoted by y is given by Eq. 8:

$$y_t = \sigma(w_a * h_t + b_a)\ [19] \qquad (8)$$

B. Proposed System Implementation and Evaluation

The system would be implemented using Python 3.9v in Google Collab environment for easier and faster computation. 80% of the preprocessed data would be used to train the proposed model, while the remaining 20% would be used for testing the performance of the model in predicting neonatal diseases.

Clinical data are normally prepared in text format in the hospitals. During prediction as shown in Figure 4, the textual data would be preprocessed to remove the stop words and punctuations, lemmatization, stemming, tokenization and vectorization will also be carried out. The preprocessed data are then fed into the predictive model and the results evaluated.

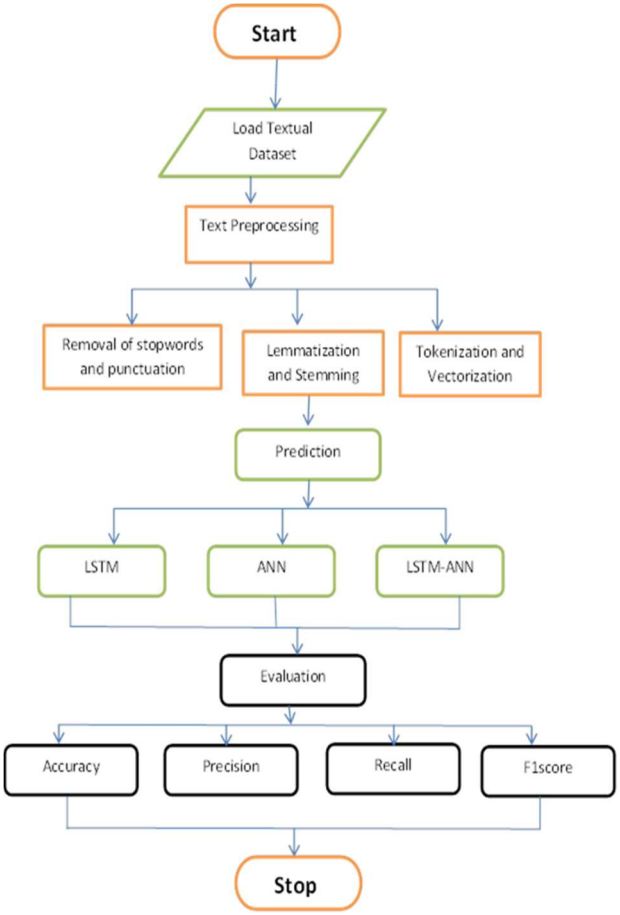

Figure 4: Flowchart of the System Implementation

To ensure the quality of model, it is important to conduct in-depth evaluation of machine or deep learning models to determine the effectiveness. Machine learning ML models are evaluated based on some metrics in other to ascertain their capabilities to make insightful predictions. There are no universal metrics for evaluation of ML models because every model is design for unique purpose, therefore different ML task requires different evaluation metrics [21]:

i. Clustering tasks are evaluated using such metrics as Silhouette score, Dunn index and Rand index.

ii. Ranking and Recommendation are evaluated using MAP, NDCG and precision at K.

iii. Regression tasks use Mean Squared Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and R-squared

iv. Classification tasks employ Accuracy, Recall, Precision and F1 Score

This research being a classification task would be evaluated using the best set of evaluation metrics for deep learning algorithms; accuracy, precision, recall and F1 score. 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 metrics would serve as a good performance metrics for this study due to its proven application and results.

i. **Accuracy:** This metric calculates overall prediction correctness as a ratio of the sum of correctly predicted positive (True Positive TP) and correctly predicted negative (True Negative TN) to the total number of events (Eq. 9). This is expressed mathematically thus [22]:

$$Accuracy = \frac{TN+TP}{TN+FN+TP+FP} \qquad (9)$$

Where:

TP – True Positive

TN – True Negative

FP – False Positive

FN – False Negative

ii. **Precision:** This metric computes the quality of positive predictions by calculating their correctness. This is expressed in Eq. 10 as the ratio of

correct positive prediction (True Positive TP) to that of the sum of correct positive prediction (True Positive TP) and wrong positive prediction (False Positive FP) [21]:

$$Precision = \frac{TP}{TP+FP} \quad (10)$$

iii. **Recall:** Recall or sensitivity measures how the model is able to detect the positive events correctly. As shown in Eq. 11, it is expressed as the percentage of accurately predicted positive events out of all the positive events. It is expressed mathematically thus:

$$Recall = \frac{TP}{TP+FN} \quad (11)$$

iv. **F1score:** This metric is expressed as the harmonic mean of the precision and recall of the classification model. As shown in Eqs. 12 and 13, precision and recall contribute equally to the score to make F1 score correctly express the reliability of the model [22].

$$F1 = \frac{2}{\frac{1}{Recall}+\frac{1}{Precision}} \quad (12)$$

$$= 2 \times \frac{(Precision \times Recall) \times 1}{(Precision \times Recall) \times \frac{Precision+Recal}{Precion \times Recall}}$$

$$= 2 \times \frac{Precision \times Recall}{Precision+Reca} \quad (13)$$

IV. Conclusion

Employing artificial intelligence (AI) method in newborns disease detection could reduce the time of diagnosis and enhance biomedical professionals' decision making process. The proposed deep learning approach has the potential to unveil the factors surrounding the high rate of neonatal mortality in African countries such as Nigeria and other developing nations of the world. The study will investigate neonatal data to established makers and variables including ethical considerations. The research methodology will focus these identified variables towards positive outcomes using AI. The cascaded LSTM-ANN model proposed is very efficient in natural language processing and text classification, especially in tasks involving similar features like the neonatal diseases symptoms. This study took into consideration the limitations of unavailability of structured data in the hospitals. The successful acquisition of neonates' diseases data from the written medical records would serve as a path towards clinical data management in Nigeria. The proposed technique will reduce neonatal mortality through accurate and timely newborns diseases diagnosis.

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