Salud, Ciencia y Tecnología - Serie de Conferencias. 2024; 3:652
doi: 10.56294/sctconf2024652

Category: STEM (Science, Technology, Engineering and Mathematics)

ORIGINAL

Deep Learning Enabled Whale Optimization Algorithm for Accurate Prediction of RA Disease

Algoritmo de optimización de ballenas habilitado para Deep Learning para la predicción precisa de la enfermedad de AR

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Cite as: Prabavathy K, Nalini M. Deep Learning Enabled Whale Optimization Algorithm for Accurate Prediction of RA Disease. Salud, Ciencia y Tecnología - Serie de Conferencias 2024;3:652. https://doi.org/10.56294/sctconf2024652.

Submitted: 01-11-2023 **Revised:** 31-01-2024 **Accepted:** 10-03-2024 **Published:** 11-03-2024

Editor: Dr. William Castillo-González

ABSTRACT

Whale Optimization Algorithm (WOA) is an optimization technique and based on food foraging behavior of whales. It has been applied in many domain including processing of images, framework controls, and ML (machine learning). WOA assists in choosing the right parameters required for Deep Neural Networks. This work uses DNN to examine metacarpophalangeal (MCP) rheumatoid joint discomforts in patients from diagnostic medical images including X-rays or Magnetic Resource images. The use of WOA enhances resultant outcomes of DNN as it searched for optimal solutions within search spaces, instead of getting trapped in local minima found by gradient descent. The combination of WOA and DNN for grading MCP rheumatoid arthritis can provide an efficient and accurate solution for medical practitioners and researchers.

Keywords: Whale Optimization Algorithm; Deep Neural Network; Rheumatoid Arthritis; Accurate Prediction.

RESUMEN

El Algoritmo de Optimización de Ballenas (WOA) es una técnica de optimización basada en el comportamiento de búsqueda de alimento de las ballenas. Se ha aplicado en muchos ámbitos, como el procesamiento de imágenes, el control de marcos y el aprendizaje automático. WOA ayuda a elegir los parámetros correctos necesarios para las redes neuronales profundas. Este trabajo utiliza DNN para examinar las molestias de la articulación reumatoide metacarpofalángica (MCP) en pacientes a partir de imágenes médicas de diagnóstico que incluyen radiografías o imágenes de recursos magnéticos. El uso de WOA mejora los resultados de DNN, ya que busca soluciones óptimas dentro de los espacios de búsqueda, en lugar de quedar atrapado en mínimos locales encontrados por el descenso de gradiente. La combinación de WOA y DNN para la clasificación de la artritis reumatoide MCP puede proporcionar una solución eficiente y precisa para los médicos e investigadores.

Palabras clave: Algoritmo De Optimización De Ballenas; Red Neuronal Profunda; Artritis Reumatoide; Predicción Precisa.

INTRODUCTION

The term "arthritis" is used to refer to a variety of inflammatory disorders that can impact the muscles, bones, joints, and other parts of the body. Unlike bacteria and viruses, the disease destroys healthy tissue.[1] It can cause stiffness, soreness, redness, and swelling in the joints. It appears in a variety of types, including gouty arthritis, juvenile arthritis, psoriatic arthritis, osteoarthritis, and rheumatoid arthritis[2] are represented as shown in the figure 1. If left untreated, the illness, which is characterized by harmful joint changes that begin with tiny joints impact larger joints. Because there are no established diagnostic criteria or gold-standard testing for rheumatoid arthritis, diagnosing it may be challenging.[3]

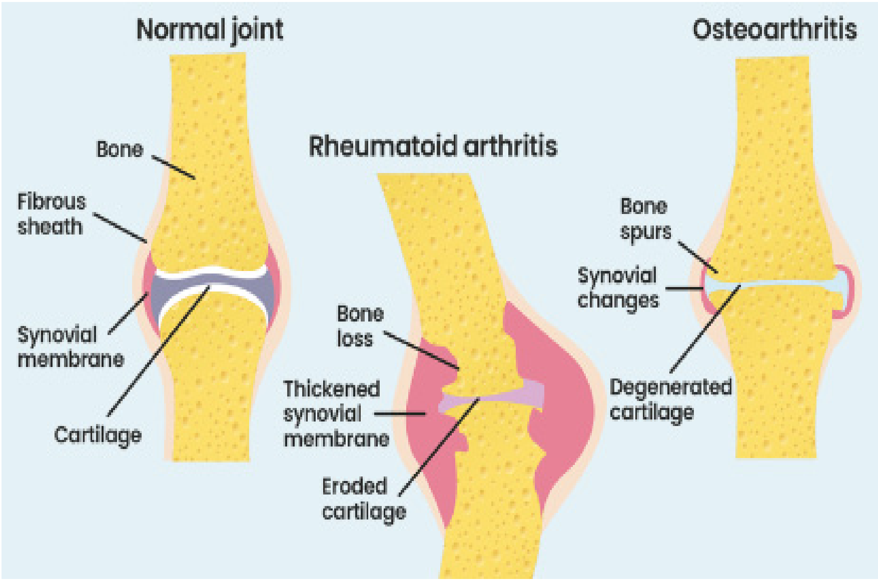

Figure 1. Structure of Rheumatoid Arthritis (RA)

In order to distinguish RA from other autoimmune illnesses and to categorise people according to their clinical features, a number of categorization schemes have been developed.[4] Early diagnosis and treatment of RA can lessen its severity and development. To forecast the onset and course of RA, deep learning techniques, more specifically a Convolutional Neural Network (CNN) model, can be utilized. CNNs are potent machine learning models that are extensively used in computer vision and image identification applications.[5] One interesting use for CNNs is the analysis of medical images, such as X-rays and MRIs, to identify RA.

Algorithms for machine learning can automatically find pertinent data representations. They are capable of handling a wide range of data inputs, including genetic data, languages, electronic health records, patient groups, and clinical images.[6] Additionally, by identifying disease patterns and qualities, it can provide results by utilizing the knowledge discovered in clinical data.

It can also help with the development of therapeutic strategies. The void created by automated learning based on clinical experience has thus been substantially filled by ML.[7] Deep learning (DL), a subfield of machine learning, also takes use of enormous amounts of data, multi-layered neural networks, and computationally challenging methods. Over the preceding ten years, both ML and DL have worked in the medical industry.

WOA's optimizations are inspired by the social behaviours of whales. WOA can assist in identifying optimum solutions on specific issues and execute iteratively for required solutions. The combination of WOA and DNN can assist in determining severity of rheumatoid arthritis (RA) in MCP joints[8] by examining patterns. DNN learns from massive volumes of medical imaging data for identifying required patterns. WOA enhances DNN's performances of determining of RA severity in MCP joints by optimizing its parameters. This combined schema can enhance accuracy and efficiency of assessing RA severities in MCP joints when compared to traditional manual diagnostics by rheumatologists. Moreover, the use of combined DNN and WOA also reduced subjectivity and increases consistency of examinations.

Survey Study

A literature survey study for the use of Whale Optimization Algorithm with improved Deep Neural Network in RA prediction would involve a comprehensive review of existing studies and research articles that have used this approach for RA prediction.

The study would consider factors such as data, model design, evaluation metrics, comparison with other methods, and limitations and future work.

The outcomes for patients with RA have significantly improved as a result of therapy advancements mainly due to early intervention, and customized treatments. After the development of clinically evident arthritis, however, patients with RA frequently do not return to their pre-disease symptomatic condition, even with therapies.[9,10] Delayed diagnostics, lack of access to rheumatologists, and higher pharmaceutical prices are main obstacles for these patients with RA. Therefore, preventive interventions could be valuable for managing

RA as a disease.[11,12,13]

A new approach was proposed by Sungmin Lee et al.[14] to identify RA from radiographed hand images while Seiichi Murakami et al.[15] identified bone erosions on hand radiograph images using multi-scale gradient vector flow algorithm and recognition classifiers. Detecting RA all finger joints from X-ray and computed tomography (CT) images of the hand is possible. Using ultrasound imaging is more prevalent than other medical images to identify and assess the severity of RA which can aid in early clinical diagnosis of RA.

Rheumatologists will probably benefit from machine learning in their ability to forecast the trajectory of a patient's illness and pinpoint key risk factors.[16] Even more intriguing is the likelihood that machine learning may suggest therapies and determine their anticipated benefits (for instance, through reinforcement learning). Therefore, machine-learned evidence as well as patient viewpoints and rheumatologists' empirical and evidence-based experience will have an impact on future public decision-making.[17]

The assessments of RA in patients may be viewed as an issue of image classification.[18,19] Low-level pixel processing techniques like edge detections and region generations were applied in medical image analysis.[20] The training and classifications of handmade features were done using HOG and SIFT[21,22] and statistical analysis approaches. However, feature extractions, crucial stages for these techniques can be challenging for processed images. Recently deep learning algorithms, including CNN,[23,24] have made major advancements in the processing of medical images. Deep learning algorithms outperform conventional statistical learning techniques and offer great accuracies and reliability of results.[25]

METHODS

WOA is a meta-heuristic optimization method that draws inspiration from whales' hunter-scavenger behaviour is shown in the figure 2. It is employed to address optimization issues in a variety of industries, including ML. The improved deep neural network approach involves integrating the WOA with deep neural networks to enhance the accuracy and efficiency of the prediction. WOA can assist in DNN parameters including weights and biases, in an iterative manner. The optimizations continue until errors between predicted and actual outputs are reduced or minimized resulting in models achieving best performances.

The combination of WOA and DNN has been shown to produce better results than traditional optimization algorithms, such as gradient descent, in some cases. It is crucial to remember that the effectiveness of the optimization strategy depends on the particular issue that has to be resolved and the caliber of the training data. In summary, the integration of the WOA with DNN is a promising approach for solving optimization problems in various fields, including ML, with improved accuracy and efficiency.

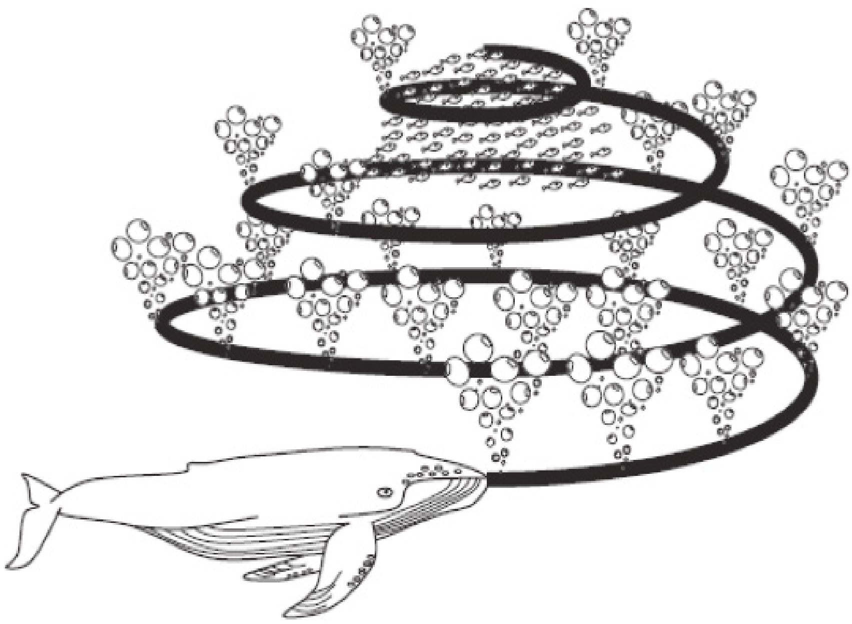

Figure 2. Whale Optimization Algorithm visualization of bubble-net feeding hunting method

Figure 2 represents the outline of the steps to implement the Whale Optimization Algorithm with an improved Deep Neural Network for the prediction of Rheumatoid Arthritis:

1. Data preparation: Collect and pre-process the data relevant to the prediction of Rheumatoid Arthritis, such as demographic information, medical history, lab results, and imaging studies.
2. Segmentation Process: Initialize the center of the segments randomly or using a pre-defined method

as improved U-Net framework inclusive of modifications such as additional layers, skip connections, or different activation functions.it attains the input data into segments and using the segments to improve the performance of the deep neural network.

3. Feature extraction: Extract relevant features from the pre-processed data that can be used for training the deep neural network.
4. Model design: Designing DNN architecture applicable for predicting RA.
5. Initialization: Initialize DNN's weights and biases using randomized values.
6. Optimization: Optimise DNN's weights and biases using WOA and carry out optimization procedure repeatedly until the differences between projected and actual results is minimal.
7. Evaluation: Evaluate the performance of the optimized deep neural network using metrics including accuracies, precisions, recalls, and F1-scores.
8. Fine-tuning: Fine-tune the deep neural network by adjusting its architecture, hyperparameters, and other elements based on the evaluation results.
9. Deployment: Deploy the optimized deep neural network in a production environment and use it to make predictions on new, unseen data.

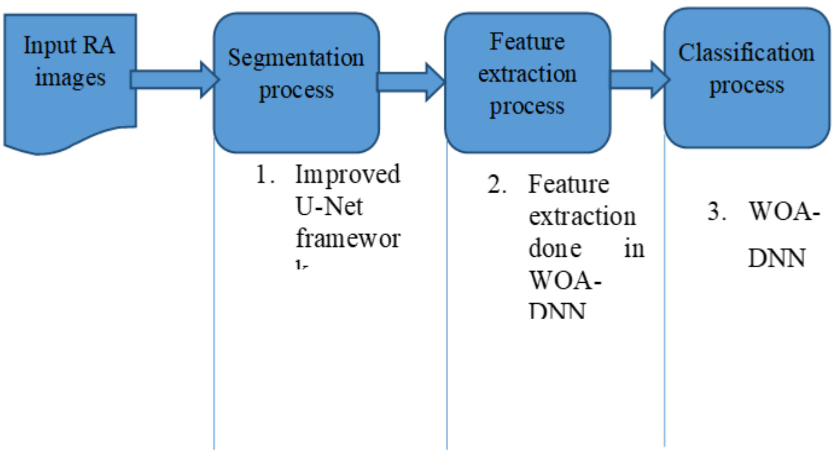

Figure 3. Block Diagram for WOA-DNN

RESULTS AND DISCUSSION

Dataset

The dataset on rheumatoid arthritis from Selcuk University's Faculty of Medicine was used in this study. The 1,690 real-world research participants who provided the data for this dataset included 190 individuals who did not have rheumatoid arthritis and 1,500 patients with the disease. In the dataset, the research participants were measured for a total of 11 characteristics; Table 1 lists these characteristics in further detail.

Table 1. RHEUMATOID ARTHRITIS (RA) Dataset (Information about the Characteristics)

S.NO	MESEAUREMENT DESCRIPTIONS
1	Patient Ages
2	Levels of C-reactive proteins (CRP)
3	Levels of Iron (FE)
4	Levels of Iron-binding capacities (IBC)
5	Levels of Ferritin
6	Levels of Transferrin
7	Sedimentation rates
8	Levels of Hemoglobin (HGB)
9	Levels of Mean corpuscular volume (MCV)
10	Levels of Hepcidin
11	Levels of Prohepcidin

The results and discussion for the use of Whale Optimization Algorithm with improved Deep Neural Network in the prediction of RA depend on the specific implementation and application. However, some general observations can be made based on existing literature and studies.

Improved Accuracy: The integration of the Whale Optimization Algorithm with a deep neural network can lead to improved accuracy in RA prediction compared to traditional methods or deep neural networks without optimization. WOA optimizes DNN's weights and biases to reduce prediction errors, which can result in improved accuracy.

Better Generalization: The optimized deep neural network can also have better generalization performance, meaning that it can make accurate predictions on new, unseen data. This is important for RA prediction, as the disease can have varying symptoms and manifestations.

Feature Selection: The Whale Optimization Algorithm can also help with feature selection, meaning that it can identify significant and predictive RA features in data. This can lead to improved accuracy and reduced complexity, as the deep neural network only needs to focus on the most important features.

Metrics used in the studies, including accuracy, precision, recall, F1-score, and other metrics relevant to RA prediction. Comparisons of performances of Whale Optimization Algorithm and improved Deep Neural Networks with other methods and algorithms used for RA prediction, including traditional ML algorithms and deep learning methods. The study's evaluation parameters for RA prediction in comparison to methodologies like Support Vector Machine, RandomForest, CNN and Recurrent Neural Network and DBN included obtained values of accuracies, precisions, recalls, and F1-scores. The values of evaluation metrics are explicated in tabulated in table 2.

Table 2. Comparison Table for Evaluation Metrics

Methods	Accuracy	Precision	Recall
Support Vector Machine	80	78	63
Random Forest	78	81	69
CNN	86	85	72
RNN	88	89	79
DBN	92	91	89
PROPOSED WOA-DNN Algorithm	98,5	97,6	95

Support vector machine (SVM): This well-liked ML approach is frequently employed for classification and regression problems. SVM is a common option for AR prediction since it can handle nonlinear data and be successful with high-dimensional data.

Recurrent neural networks (RNNs): RNNs are a subset of deep learning algorithms that are frequently employed in time series prediction and sequential data processing. RNNs are capable of analysing time-series medical data from sources like lab results and electronic health records. They can be used to identify patients and predict RA by analysing the results of laboratory tests.

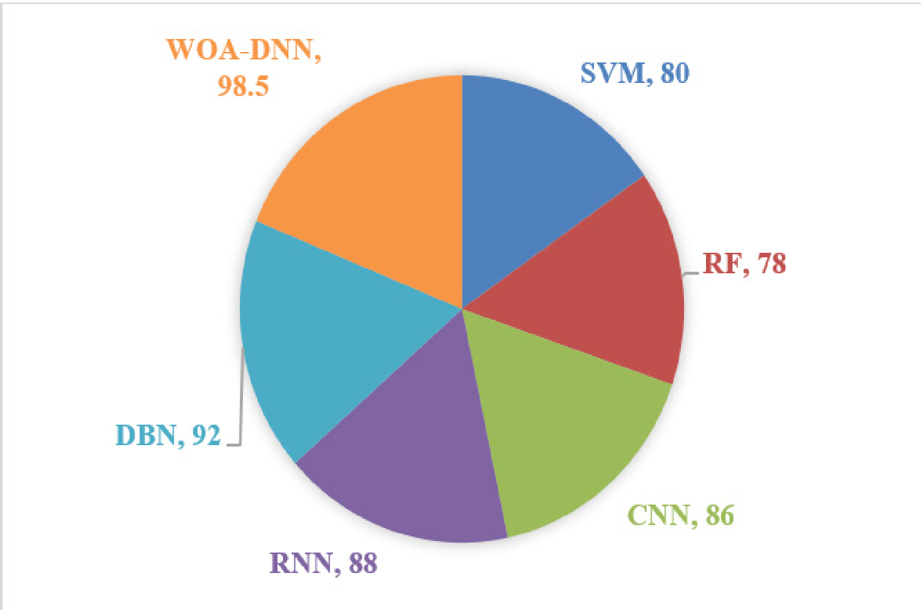

Figure 4. Evaluation Metrics of Proposed and Existing Methods

Figure 4 shows the local optima trap and reduced feature selection convergence are constraints of the Support Vector Machine, RNN, CNN, DBN, and RNN. A drawback of the WOA model is that it tends to lose possible solutions in the classification due to lesser exploitation. The Optimal Guiding technique boosts exploitation by shifting the search agent's position in accordance with a greater fitness value. WOA-DNN has a 98,5 % accuracy rate, 97,6 % precision rate, and 95 % recall rate.

Convolution Neural Networks (CNNs): CNNs are a subset of deep learning algorithms that are very effective in analyzing images. They may be used to categorize patients as having RA or not by automatically extracting information from medical imaging data.

DBN (deep belief network): A deep learning technique called DBN may be used to examine intricate data structures, such as those seen in medical imaging. They may be used to medical imaging data to identify traits that can be used to categorise patients as having RA or not.

CONCLUSION

In conclusion, RA can lower quality of life, which also has a variety of detrimental physical and social effects. Pain, incapacity, and early death may be the result. The Proposed Method employs DNN to analyse diagnostic medical images, such as X-rays or Magnetic Resource images, to assess patients' metacarpophalangeal (MCP) rheumatoid joint discomforts. The application of WOA improves the outputs of DNN as it searches for the best answers within search spaces rather than becoming stuck in local minima discovered via gradient descent. The results and discussion of the use of Whale Optimization Algorithm with improved Deep Neural Network in RA prediction depend on the specific implementation and application. However, some general observations include improved accuracy, better generalization, feature selection are attained.

Future Enhancement

Like any algorithm or method, the Whale Optimization Algorithm with improved Deep Neural Network has limitations. Some limitations include the dependence on a large amount of data, the sensitivity to initialization, and the difficulty in interpreting the results.

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FINANCING
The author did not receive funding for the development of this research.

CONFLICT OF INTEREST
No conflict of interest.

AUTHORSHIP CONTRIBUTION
Conceptualization: Dr. K. Prabavathy.
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