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Weighted Random Forest with Rule-Based Evaluation for Pediatric Nutrition Assessment

Madhumita Chanda[1], Kolli.Srikanth[2], Bobbadi.Manasa[3]
[1]*Department of Information Technology, JNTU-GV CEV, AP, India.*
[2]*Department of Information Technology, JNTU-GV CEV, AP, India.*
[3]*Department of Information Technology, JNTU-GV CEV, AP, India*
[1]*madhumitachanda.it@jntugvcev.edu.in*

Abstract: *Pediatric Nutrition Assessment is a pervasive global health crisis that severely affects both physical growth and cognitive development in children. Existing manual assessment methods for evaluating nutritional status are often inefficient, inconsistent, and unable to support timely intervention. To address these challenges, this project proposes the development of a Child Nutrition Monitoring Deficiency Alert System (CNDAS), an automated solution that integrates multiple data sources to provide comprehensive nutritional analysis. The system uses an Anthropometric Feature Extraction Engine to process key indicators such as height, weight, and BMI. This data, along with dietary logs, is evaluated using a Rule-Based Model based on WHO standards to determine nutritional status and detect deficiencies. For advanced analysis, a Machine Learning module using a Weighted Random Forest classifier predicts the severity of malnutrition accurately. Furthermore, the system includes a Behavioral Analysis Module and Context-Aware Recommendation Logic to generate personalized, adaptive, and cost-effective dietary and remedial suggestions. These recommendations consider not only conventional medical guidance but also holistic approaches such as Ayurveda, naturopathy, homeopathy, and home remedies. All system interactions and data processing are managed through a Conversational AI Chabot Framework, which provides care-givers with real-time assistance, personalized guidance, and answers to nutritional queries, ensuring a scalable and data-driven platform for effective child nutrition monitoring and intervention.*

Keywords: *Anthropometry, Context-Aware Systems, Feature Engineering, Random Forest, Rule-Based Analytics, Malnutrition Detection, Behavioral Analysis, Recommendation Systems, Explainable AI, Conversational AI, Chatbots.*

I. Introduction

Child malnutrition continues to be a critical public health concern that significantly impacts the physical growth and cognitive development of children. It primarily arises due to inadequate nutrition, improper dietary habits, and lack of awareness about proper healthcare practices. Conventional methods for assessing nutritional status depend on manual measurements and observations, which are often time-consuming, less reliable, and unable to support early detection. By combining anthropometric parameters such as height, weight, and Body Mass Index (BMI) with dietary and behavioral information, intelligent systems can provide more accurate and timely predictions of a child's nutritional condition. The aim of this project is to develop an intelligent malnutrition tracking system using a Weighted Random Forest algorithm combined with rule-based evaluation. The system predicts malnutrition levels accurately and provides personalized Traditional dietary recommendations, helping caregivers take timely actions to improve children's health.

II. Problem Statement

Monitoring and identifying malnutrition in children remains a complex challenge in many healthcare systems. Most as-assessments are based on manual measurements such as height, weight, and BMI, which are often conducted periodically and may not reflect real-time nutritional conditions. These methods are prone to human error and may fail to detect early signs of malnutrition, leading to delayed treatment and serious health consequences. In addition, existing systems do not effectively consider multiple influencing factors such as food intake patterns, lifestyle behavior, and environmental conditions some key limitations of current systems include:

To overcome these challenges, there is a need for an advanced, data-driven system that integrates multiple health indicators and utilizes machine learning techniques. The proposed system aims to provide accurate prediction of malnutrition levels using a Weighted Random Forest model combined with rule-based evaluation, enabling early detection and effective intervention.

- Absence of intelligent and automated monitoring systems
- High dependency on manual data collection and analysis
- Inadequate consideration of dietary and behavioral factors
- Limited capability to process large and complex datasets
- Late identification of malnutrition risks

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III. Related Work

Various predictive models have been developed in recent years; machine learning techniques have been increasingly applied in the field of healthcare, particularly for analyzing and predicting child malnutrition. Researchers have focused on identifying key factors such as anthropometric measurements, dietary intake, and environmental conditions that influence the nutritional status of children into classifies malnutrition levels using health-related data several studies have proposed intelligent systems that utilize machine learning algorithms to analyze child growth indicators. In these approaches, datasets containing parameters such as age, height, weight, Body Mass Index (BMI), and dietary patterns are used for prediction. AI-Algorithms including Support Vector Machines, Random Forest, Decision Trees and Gradient Boosting have been evaluated for their effectiveness in detecting malnutrition. Ensemble learning methods have also been explored to enhance prediction accuracy and improve model performance. The results indicate that machine learning models can effectively identify malnutrition risks when relevant health and nutritional features are considered.

Another line of research has focused on integrating rule-based evaluation with machine learning techniques to improve reliability and interpretability. These systems use established standards such as WHO growth charts along with predictive models to classify children into different nutritional categories. Although existing methods show promising results, many systems still lack comprehensive integration of behavioral, dietary, and contextual factors, highlighting the need for more advanced and intelligent malnutrition monitoring systems. In many existing systems, machine learning models are used in-dependently without incorporating domain-specific rules based on medical standards. This limits the interpretability and reliability of predictions, especially in healthcare applications where decision accuracy is critical. Combining data-driven models with structured rule-based approaches can significantly enhance the quality and trustworthiness of the results.

IV. System Architecture

The proposed system is designed using a structured and modular architecture to efficiently monitor and predict child malnutrition. It integrates data collection, feature extraction, machine learning prediction, and recommendation modules into a unified framework. The system ensures accurate analysis by combining data-driven models with rule-based evaluation techniques

A. User Interface Layer

This layer enables users such as caregivers or healthcare providers to interact with the system. Through this interface, users can input child-related details and view the predicted nutritional status along with recommendations.

The interface includes the following features:

- Child health data entry forms (age, height, weight, etc.)
- Display of predicted malnutrition levels
- Visualization of growth and nutritional data

B. Processing Layer

This layer begins with data validation and preprocessing, where the input data is cleaned, normalized, and structured to ensure accuracy and consistency

Operations performed in this layer include:

- Data validation and cleaning
- Data preprocessing and normalization
- Feature extraction (anthropometric, dietary, behavioral)
- Rule-based evaluation using standard health guidelines
- Malnutrition prediction using Weighted Random Forest

C. Recommendations System Output

The system provides personalized diet plans, daily nutrition alerts, and simple home remedies. It also includes alternative healthcare suggestions such as Ayurveda, Naturopathy, and Homeopathy. These combined approaches ensure a holistic solution for improving child nutrition

D. Overall System Architecture

The proposed system follows a structured architecture for detecting and managing child malnutrition. It begins with the input layer, where data such as height, weight, BMI, diet logs, and behavioral information is collected.

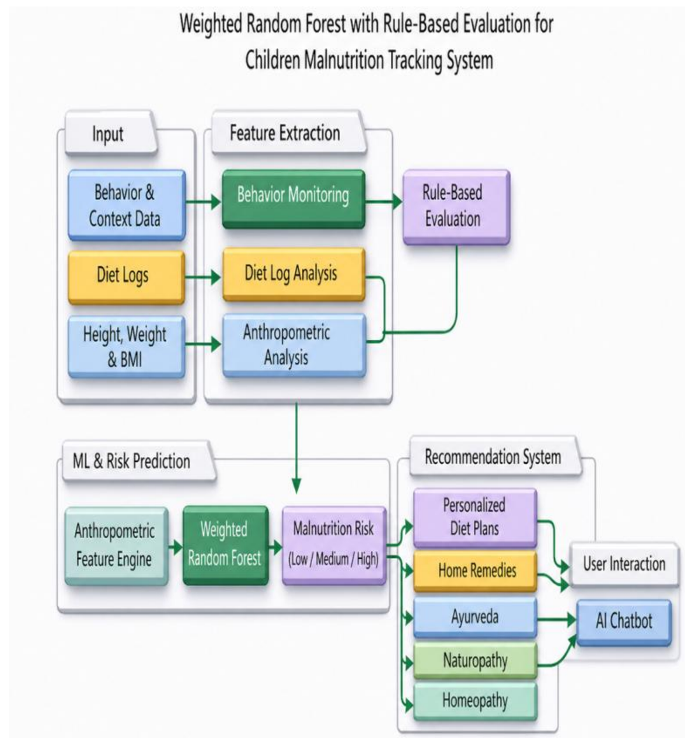

Fig. 1. Proposed System Architecture for Pediatric Nutrition Assessment

V. Dataset Description

The dataset used in this project is the Child Malnutrition Indian Dataset (2019–2021), which contains comprehensive information related to children's health, nutrition, and socio-economic conditions. The primary objective of this dataset is to analyze various factors influencing child malnutrition and support accurate prediction of nutritional status. The dataset consists of approximately 2,32,920 records with 16 features, where each record represents the health and demographic details of an individual child. It includes a wide range of attributes covering physical measurements, health conditions, and socio-economic indicators. target variable represents the malnutrition status of children, which is categorized into different levels such as nor-mal, underweight, or stunted. This dataset helps the system understand the relationship between multiple health and environmental factors, enabling accurate prediction of malnutrition risk.

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VI. Data Preprocessing

To ensure accurate and reliable predictions, the dataset must be properly prepared before applying the machine learning model. Raw data often contains inconsistencies, missing values, and irrelevant information that can affect model performance. The preprocessing phase starts with data cleaning, where incomplete or incorrect records are identified and handled using appropriate methods. Missing values are treated carefully to main allowing the algorithm to process them effectively. Unnecessary or less significant features are also removed to optimize the model train consistency and improve data quality. After that, data normalization is applied to numerical attributes such as height, weight, and BMI, ensuring that all values are within a uniform range. This helps in improving the stability and efficiency of the model.

The major preprocessing operations include:

- Data cleaning and handling missing values
- Data normalization of anthropometric measurements
- Encoding of categorical attributes
- Feature selection and removal of irrelevant data
- Splitting dataset into training and testing sets Handling missing values

These steps ensure that the dataset is clean, consistent, and suitable for training the prediction model.

VII. Proposed Prediction Model

The prediction component of the proposed system is based on the Weighted Random Forest algorithm. Random Forest is an ensemble learning technique that builds multiple decision trees and combines their outputs to improve prediction accuracy.The weighted approach further enhances performance by giving importance to critical classes, especially in imbalanced datasets.

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TABLE I

COMPARISON OF WEIGHTED RANDOM FOREST WITH ML ALGORITHMS FOR PEDIATRIC NUTRITION ASSESSMENT

Algorithm	Accuracy (%)	Precision	Recall	F1-Score
Decision Tree	87	0.85	0.84	0.79
Random Forest	91	0.90	0.88	0.89
Support Vector Machine	89	0.88	0.86	0.87
Logistic Regression	84	0.82	0.80	0.81
K-Nearest Neighbors	85	0.83	0.82	0.82
Weighted RF(Proposed)	**95.4**	**0.95**	**0.95**	**0.95**

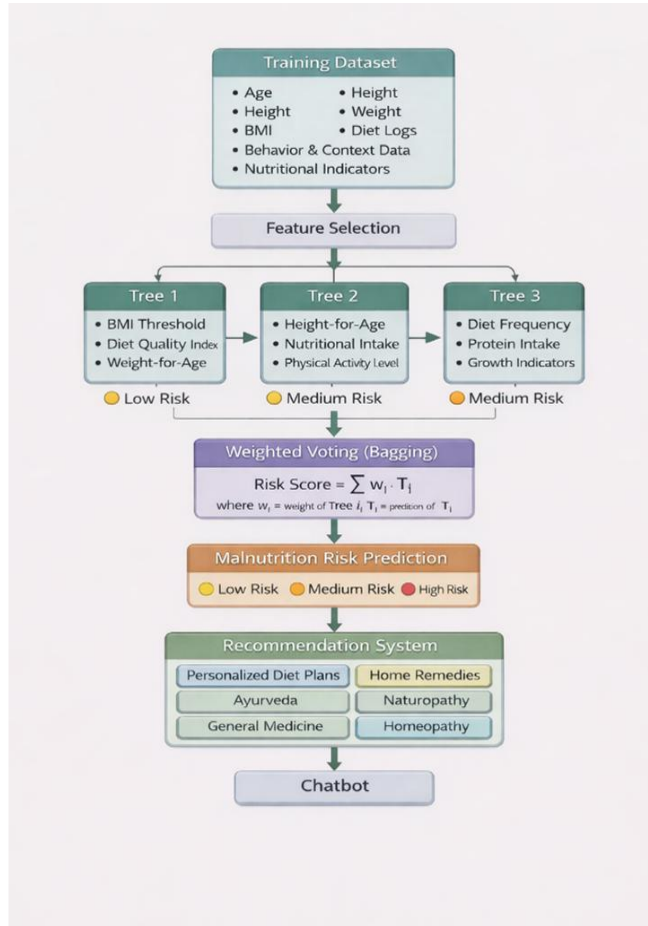

Fig. 2. Weighted Random Forest Model Architecture

VIII. Algorithm Comparison

In order to evaluate the effectiveness of the proposed prediction model, different machine learning algorithms can be compared using the same dataset and performance metrics. Algorithm comparison helps determine which model performs better in identifying malnutrition levels based on health, dietary, and behavioral attributes.. Several supervised learning algorithms are commonly used for classification problems. Among these, Decision Tree, Random Forest, Support Vector Machine (SVM), Logistic Regression, and Weighted Random Forest are widely applied in malnutrition detection and health-care analysis tasks. Each algorithm has its own strengths and limitations depending on the nature of the dataset and the relationships between features. Decision Tree algorithms are simple and easy to interpret. They divide the dataset into smaller subsets by applying a series of decision rules. Al-though decision trees are useful for understanding how features influence the final prediction, they may sometimes produce unstable results when the dataset is complex. To assess the effectiveness of the proposed system, multiple machine learning algorithms can be evaluated using the same dataset and performance measures. This comparison helps in selecting the most efficient model for predicting malnutrition levels based on various child health and lifestyle factors. Various classification techniques such as Decision Tree, Random Forest, Support Vector Machine (SVM), Logistic Regression, and Weighted Random Forest are commonly applied in healthcare prediction tasks. Among these, the Weighted Random Forest algorithm performs better by effectively handling complex data patterns and class imbalance. In this project, the Weighted Random Forest model is integrated with rule-based evaluation using standard nutritional guidelines. This combined approach enhances prediction accuracy and ensures dependable classification of malnutrition risk levels. Logistic Regression is another commonly used classification method that estimates the probability of belonging to a particular class. While this model works effectively for linear relationships between features, it may not capture complex interactions between health and nutritional factors. Compared with traditional algorithms, Weighted Random Forest provides several advantages such as improved accuracy, better handling of feature interactions, and reduced overfitting. These characteristics make it suitable for analyzing child health data where multiple factors influence nutritional status In the proposed system, the Weighted Random Forest model is further combined with rule-based evaluation logic. This hybrid approach strengthens the prediction process by allowing the model to identify patterns in the data while predefined health rules help interpret specific nutritional conditions. As a result, the proposed method provides reliable classification of malnutrition.

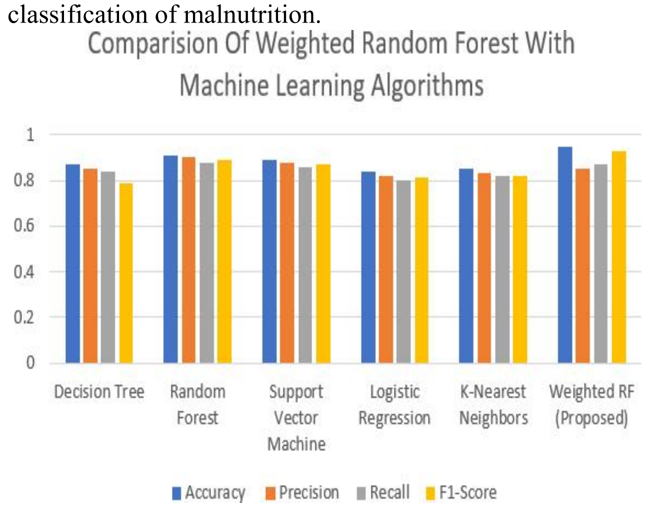

Fig. 3. Comparision of Algorithms

IX. Model Training and Implementation

After completing data preprocessing, the next step involves training the prediction model and integrating it into the system. Model training is essential as it enables the system to learn patterns from the dataset and understand the relationships between various health and nutritional factors that influence malnutrition levels. The dataset used in this system includes important attributes such as age, height, weight, BMI, dietary intake, and behavioral factors. These features represent different aspects of a child's health and lifestyle. Before training, the dataset is divided into training and testing sets. The training data is used to build the model, while the testing data is used to evaluate its performance on unseen data. The proposed system utilizes the Weighted Random Forest algorithm for malnutrition classification. This algorithm constructs multiple decision trees using different subsets of data and combines their outputs to produce accurate predictions. The weighted mechanism helps improve performance by giving importance to critical classes, especially in imbalanced datasets. During the training phase, the model analyzes input features and learns how different factors affect the nutritional status of children. It identifies patterns such as how improper diet, low body weight, or poor growth indicators contribute to higher Malnutrition risk. Through repeated learning, the model adjusts its parameters to minimize prediction errors and improve accuracy. In addition to machine learning, the system incorporates a rule-based evaluation mechanism based on standard health guidelines. These rules examine specific conditions related to child growth and nutritional indicators and work alongside the machine learning model to enhance prediction reliability. Once the training process is completed, the trained model is integrated with the system interface. When users enter child-related data, the information is processed and passed to the model for prediction. The system then displays the malnutrition risk level and stores the results for future analysis. This implementation ensures that the prediction process is efficient, accurate, and capable of supporting early detection and effective nutritional intervention.

X. Results and Discussion

After implementing the prediction system, experiments were conducted to evaluate the performance of the prediction model. The effectiveness of the Weighted Random Forest algorithm was analyzed using the prepared dataset containing various child healths, nutritional, and behavioral attributes. The evaluation was carried out using performance metrics such as accuracy, precision, recall, and F1-score to measure reliability. The trained model was evaluated using unseen data from the testing dataset to measure its performance. This evaluation helps determine how effectively the model can generalize its learning to new inputs. Various performance metrics such as accuracy, precision, recall, and F1-score were used to assess the effectiveness of the prediction model. Accuracy represents the proportion of correctly classified instances out of the total predictions made by the system. Precision indicates how many of the predicted malnutrition cases are actually correct, while recall measures the model's ability to identify all relevant malnutrition cases in the dataset. The F1-score provides a balanced measure by combining both precision and recall. The experimental results show that the Weighted Random Forest model performs effectively in identifying malnutrition levels based on selected health and nutritional attributes. The ensemble learning approach enables the model to capture complex relationships between factors such as growth indicators, dietary patterns, and health conditions, resulting in reliable predictions. An important observation is the contribution of the rule-based evaluation component. By combining machine learning predictions with predefined health rules, the system can better interpret specific nutritional conditions. For example, when low body weight and poor dietary intake occur together, the rule-based logic strengthens the prediction of higher malnutrition risk. This hybrid approach improves system reliability compared to using machine learning alone. This integration also enhances the interpretability of the system, allowing healthcare practitioners to understand the reasoning behind each prediction.

Weighted Random Forest Result Table

Metric	Value
Accuracy	95.4%
Precision	0.95
Recall	0.95
F1-Score	0.95
Model Type	Ensemble (WRF)
Handles Imbalance	Yes
Training Time	Moderate

The proposed system incorporates Ayurveda and traditional dietary practices to provide natural and holistic nutritional support for children. Ayurveda focuses on improving digestion (Agni), strengthening immunity, and restoring body balance through nutrient-rich foods and herbal remedies. The system recommends easily available foods such as milk, ghee, fruits, green leafy vegetables, and herbal preparations that help improve weight gain and overall health. Traditional home-based remedies, such as protein-rich diets, locally available grains, and balanced meal patterns, are also suggested to ensure affordability and accessibility for families in different regions.

In addition to Ayurveda, the system includes homeopathic support as a complementary approach for improving nutritional conditions. Homeopathy emphasizes gentle and individualized treatment based on the child's symptoms, aiming to enhance appetite, digestion, and immunity. Remedies are selected carefully to address issues such as weakness, poor growth, and low energy levels without causing side effects. This approach is particularly useful for long-term health improvement and supports the child's natural healing process. Furthermore, the system integrates allopathic (modern medical) recommendations to ensure scientifically validated and effective treatment. This includes guidance on balanced diets, vitamin and mineral supplementation, and medical consultation for severe malnutrition cases. Allopathic methods provide quick and reliable intervention, especially in critical conditions. By combining Ayurvedic, homeopathic, allopathic, and traditional practices, the system offers a comprehensive and holistic solution for improving child nutrition and ensuring better health outcomes.

Fig. 4. Results Of Weighted random forest

XI. Conclusion

This study presents a machine learning-driven framework for detecting malnutrition levels in children by analyzing a combination of health, dietary, and behavioral parameters. The system utilizes features such as age, height, weight, BMI, food intake patterns, and lifestyle factors to evaluate a child's nutritional condition. The architecture of the system is organized into multiple layers, including the user interface, processing module, and data storage component. Users can input child-related data through the interface, while the processing layer handles data validation, preprocessing, feature extraction, and prediction using the Weighted Random Forest model. The outcomes are then displayed and stored for future reference. The selection of the Weighted Random Forest algorithm is based on its ability to effectively manage complex datasets and address class imbalance issues. Additionally, the system incorporates rule-based evaluation aligned with standard health guidelines, which enhances the interpretability and consistency of the predictions. Experimental results indicate that the proposed approach performs well in identifying malnutrition levels. By evaluating multiple factors simultaneously, the system can detect potential risks at an early stage and provide suitable recommendations. Beyond prediction, the system supports caregivers by offering actionable guidance for improving child nutrition.

XII. Future Work

Although the proposed system provides an effective approach for identifying stress levels among students, several improvements can be explored in future developments. One possible extension is the use of larger and more diverse datasets collected from students across different institutions and academic programs. A larger dataset would allow the model to learn broader patterns and improve its generalization capability. Future developments may also involve incorporating additional parameters such as physical activity levels, environmental influences, and real-time health monitoring data. Including these factors can provide a more comprehensive understanding of child health. Another potential extension is the development of mobile-based or IoT enabled applications for continuous monitoring of child health data.

This would facilitate real-time tracking and quicker decision-making. Further research can focus on implementing advanced machine learning or deep learning techniques to enhance prediction performance. Integration with hospital or healthcare systems can also increase the practical usability of the proposed solution. Future work can also focus on incorporating additional health-related parameters such as physical activity levels, environmental conditions, and genetic factors. Including these attributes can provide deeper insights into the causes of malnutrition and improve prediction accuracy. The system can also be extended by integrating advanced machine learning and deep learning models to further improve performance. Techniques such as neural networks or hybrid ensemble models can be explored for more accurate and scalable predictions. .

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