Development of Prediction and Forecasting Model for Dengue Disease using Machine Learning Algorithms

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***Abstract*—Globally, Dengue is one of the most quickly spreading vector-borne viral sicknesses with an expanding number of territories in danger. Many researchers have worked on different measures to control and prevent the spread of disease. The main objective of the research is to develop a forecast model to control the outbreak of dengue disease that will give an opportunity for medical professionals in designing, planning and handling the disease at an early stage. Moreover, the improvement of the assortment of strategies for determining and predictive modeling utilizing measurable, numerical examination of machine learning was studied. There are mainly six issues need to be solved in determination of dengue disease, those are exploring data sources, analyzing data sources, techniques for data preparation, data representation, dengue forecasting models and evaluation approaches. A major limitation of the traditional methods is that these methods need large volumes of data for data processing, to improve the dynamic characteristics. From the review of existing methods, it can be clearly stated that the K-means clustering method with fuzzy based system has high accuracy and it significantly improves the analysis/prediction of dengue disease. The k-means clustering algorithm separates the dengue diseased patient records into k divisions. As the dengue dataset were fully clustered, k-means clustering method improves the analysis or prediction of dengue disease. Similarly, the fuzzy based system The input factors and changing over these informational factors into fuzzy membership functions will make a better decision making in predicting dengue forecasting model. Thus, the issues stated from comprehensive research provide a useful platform for public health research and epidemiology.**

Keywords—Data preparation, Data representations, Data sources, Dengue, Forecasting models, K-means clustering, Machine learning, Vector-borne.

I. INTRODUCTION

Dengue disease cause by the dengue virus that has a positive sense RNA virus which belongs to Flaviviridae family. According to the results obtained from World Health Organization (WHO) in 2019, 34 to 96 million people have been infected from dengue worldwide [1]. The identification of disease at an early stage is important to prevent the spread of the disease and it also helps to reduce the unnecessary hospitalization and social burden. In people, the immune framework contains natural and versatile reactions that require for fighting against dengue virus. In spite of the fact that dengue doesn't need a particular line of treatment, yet it is basic to be identified and treated on appropriate time [2]. The main strategy to control the outbreak of the disease obtains by preventing and suppressing the vector which is responsible for the disease. The forecast model of dengue holds the guarantee of having the option to give close constant assessments of the spread of dengue, and can be utilized to proficiently direct the arrangement of vector-control tasks [3]. One issue related with these anticipating models is that they just spotlight on accurate prediction over a specific period even after the incapability to identify dengue outbreaks, that is, quick and successive increments of dengue frequencies that digress from the ordinary endemic pattern [4]. The main reason for spreading of dengue disease cause by Aedes mosquitoes, so it needs to be controlled to avoid a rapid increase of viruses. An efficient method to stop spread of dengue disease is to have the knowledge of the life cycle of Aedes mosquito and an efficient action or measure require to be applied. The traditional models need improvement in detecting disease at an earlier stage which would be highly useful for safety of public health. The existing research have described about the recent developments on machine learning and data processing through software systems to achieve the goal [5]. The regular diagnosis needs to be performed by the public health organization using machine learning techniques to analyze the early stage of dengue detection. The early diagnosis not only improves the performance accuracy but also saves cost, time and accompanies pathology tests. The various machine learning classifiers ranging from simple classifiers, supervised, unsupervised classifier involved in detecting the dengue disease at an early stage. These models have the pitfalls of being non-parametric and equipped for depicting nonlinear connections between factors [6]. The performance measures obtained from the existing models have been compared with their respective advantages and limitations.

This paper is organized as follows, the review on the various data processing model and machine learning is analyzed for dengue disease detection is presented in the Section 2, comparison analysis of several researches is presented in Section 3 and conclusion from analysis of existing methods is drawn in Section 4.

II. REVIEW ON CURRENT DENGUE FORECASTING RESEARCH SITUATIONS

A. Data Sources

The source of data present in multiple datasets is known as Data sources. The Meteorology department of Public Health Ministry of a country provides data sources which are used from specific hospitals or World Health Organization (WHO). There are still new data sources taken from different

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form and are often studied by using internet blogs and social media.

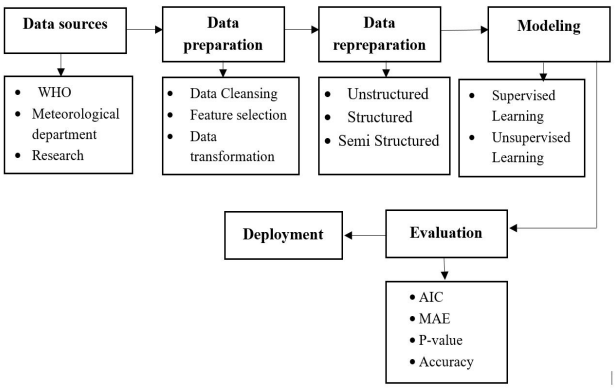

Fig. 1. A dengue forecast model in data science.

The data sources and the conventional data typically include epidemiological data taken from meteorological departments belongs to health centers such as data related to environment, hospital and weather. The dengue forecast model in data science is depicted in figure 1. The main purpose of these departments is to deliver geographical and demographic data from appropriate sources of government. From the primary data, finding of information is not much difficult as the data are divided according to the departments of public health. A large amount of different data from WHO is used for testing purposes in the laboratory, and diagnosing clinical data, etc. that integrated and monitored to control the spread of disease in various regions of the world. Innovative system surveillance is an important measure to control the outbreak of the dengue disease [7]. This has influenced the researchers to acquire modern scheme to meliorate the existing forecasting techniques. The query articles, academic forecasts and research articles are published and collected by data sources gives the information of infected people. Many researchers gathered information from database publications, Scopus, and Web of Science for determining dengue disease using forecasting models.

1) Modern Data Sources

The dengue epidemics are available for forecasting new data sources in large amount of information available in the internet [8]. Various researches are paying an attention close to the following types of data sources.

- **Social Networks**

The internet-enabled remote communication helps to build transparent communication between doctors and patients during the treatment process. In the clinic or hospital patients not only interacting face-to-face with doctors but also interacting through the social networking, which is used as a communication medium between doctors and patients. The interaction between the doctors and patients enables sharing knowledge with each other [9].

- **Query Search from the Internet**

The researchers collected the various dengue related information from social network blogs. The information collected using search engines are utilized for developing a forecasting model and also it analyzed time series of the data to detect dengue disease. The Google insight outbreak forecasting model implemented in Singapore and Thailand. The keywords used for searching disease are symptoms, nomenclature, and treatment [10]. The efficiency is computed by evaluating the effect of the disease on the patients using this forecasting model.

- **Phone Calls**

The areas having restrictions are more prone to dengue disease. For such areas the dengue disease reports are made available through in online. However, the availability of less data in some areas restricts the data replacements. The researchers replace the different data during an outbreak are not available in a timely manner. The telephone calls recorded during the outbreak can help to monitor the occurrence of dengue disease [11]. After collaborating the data sources, the data preparation process is undergone for preprocessing the data.

B. Data Preparation

The preparation of data is obtained by the preprocessing and forecasting process. The reduction of noise is carried out by preprocessing stage that prepares the data for introducing the forecasting process. The noise is reduced and the increase in accuracy maintains the data consistency [12] using diverse and complex methods. The model is used for forecasting the patterns of data using the values from the dataset. The forecasting model is used for learning effectively several incomplete and unnecessary data. Initially, the issues are fixed and applied for performing computational methods using machine learning algorithm which performs 4 stages:

- Data cleansing
- Normalization or Standardization
- Feature selection
- Data transformation

- **Normalization and Standardization:**

The data are analyzed to ensure the relationship between the reliable variables and it needs to be standardized. The standardization and normalization are performed to ensure the analysis by the scaling data process which makes data adjustment with certain factors in the model. The data have a different class range of measurement from the lower to upper bound.

- **Data Cleansing**

Data cleansing is a process that finds and eliminates incorrect, incomplete, inconsistent data. Here, the inconsistent data refer to the occurrence of misspellings in correct data that was initialized from a single source to encounter the non-proper data. The data integration is accomplished from different data sources that perform often in different formats which makes necessary for the data consolidation or integration to eliminate the unused and redundant data [13]. The process of data scrubbing or cleansing plays an important role in predictive modeling. The data relationship between data variables are analyzed and it showed the poor results for traditional methods. The derived model is able to process the poor quality data by implementing a reliable system.

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- The factors those are used for the prediction of dengue disease includes
- Climate (rainfall, weather, humidity, temperature and seasonality)
- Movement of population
- Demographics
- Geographical features
- Migration patterns
- Ratio of rate at which dengue disease is occurring to that particular location [14]

- **Data Transformation:**

Once the data cleansing process is finished, the data transformation makes use of several techniques where the absolute values is incompatible for some cases [15]. Therefore, the data representation process is carried out in order to analyze the data more accurately.

C. Data representation

A variety of data is represented in various formats to make use of the available forecast models. The formats of data include ontology which is a new type of language called as Resource Description Framework (RDF) and Ontology Web Language (OWL) and these enables different tasks that are available in the standard form [16]. According to the study, data models are categorized into three types:

1) Structured
2) Semi structured
3) Unstructured data

The exploitation of the structured information in different ways is a difficult task. The collection of dengue information enables the application to access data accurately, supports decision making policy, and quickly enables setting the policy in disease prevention.

- The unstructured data are those which are stored as free hand text, for example, in the form of photographs, videos, graphical images, natural language and recordings. The cloud based storage overcomes problem of storing data in large volumes for particular structured data. The unstructured data are now available in many applications for accessing the low cost unstructured data.
- Semi-structured is a type of data those are not structured completely in that form as in a Relational Database Management System (RDBMS). For example, data storage in a new form available for storing tags together for indicating marker characteristics to determine the type of data. These markers and tags are known as the markup language that allows data to store its respective types, data types and data structures.
- The data is stored in the form of structured format allows access the data easily. An appropriate database management is processed for accessing the structured data using SQL language.

D. Modeling evaluation

The performance of the modeling evaluation is estimated by using predicting accuracy forecasting model. A different form of information is available to the user that provides evaluation measures for the forecasting model. The data execution is carried out by statistical and mathematical during data preparation. The measures are usually used for collecting information from different user to efficiently evaluate the performance of forecasting model. The structured data are usually used by supervised learning methods to incorporate machine learning algorithms. The Decision tree is one of the forecasting techniques which is a popular and widely used method for different types of applications [17].

1) Supervised learning

- **Decision Tree**

The structure of decision tree includes root node, intermediate node and leaf nodes,those are linked in a unidirectional manner[18].The function of decision tree includes association analyzing, dependencies among variables, tree model structuring which classifies the data effectively.

- **Regression Analysis**

The relationships between two or more variables are analyzed by statistical method, regression analysis that determines the correlation between the variables [19]. The prediction of correlation coefficients is having variables, use desired equation for finding regression. The regression analysis is carried out by creating the numerical values for the selection of variables in the predictive modeling.

- **Artificial Neural Network**

The Artificial Neural Network (ANN) is designed in the same way as the human brain works. The number of nodes consisted by the network are interconnected with the output. The output obtained from the first node is fed as an input to the next node. The process continues among all the nodes and forms chain of the network together looks like a human brain. ANN requires large datasets to obtain results nearer to the testing data based on adjusting the nodes in the sigmoid values [20].

- **Support Vector Machine**

Support Vector Machine (SVM) is a supervised learning that represents the principle data in $N \times N$ vector dimensions for the learning algorithm. SVM creates the plane or line data that divide many data into segments. The SVM classifies the data and compares the tested data with the classification resulted yield in a best way to perform feature selection.

- **K-Nearest Neighbor**

K-Nearest Neighbor(K-NN) is used for predicting the dengue disease in the models. The results obtained from the KNN is used in both numerical and categorical data and classifies the vector space based on the distance. The usage of Nearest Neighbor index analyses the risk areas of the dengue infected region using hemorrhagic data.

2) Unsupervised Learning

The derived datasets are fed into unsupervised learning to perform clustering, but sometimes it does not respond to

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interferences. Under the unsupervised learning, clustering techniques are the most common technique used for forecasting models. The cluster groups that are near to neighborhood finds the best among all the groups based on the distance from one point of data to another. However, these unsupervised learning are not used extensively for forecasting, especially for dengue disease [21].

3) Time Series Analysis

The time series analysis chooses data points in order to determine the features or pattern in interest regions. The time series methods are used commonly in the forecasting model of dengue prediction. The four categories that are consisted in time series components are the followings.

1) **Long-Term Trend (T):** It denotes the change of data or movement for long periods.
2) **Seasonal variation (S):** It refers to the variation in the season which is also a reason for the occurrence of disease with respect to a number of years. The variations occurring in the seasons measures the seasonal indexes.
3) **Cyclical Variation (C):** It means the movements occurs in cyclic fashion as there is a seasonal fluctuation showing no movement for a particular duration of time.
4) **Irregular Variation (I):** The variations occur during unpredictable natural disasters such as volcanoes, earthquake, Tsunami, etc. to perform time series analysis using Auto-Regressive Integrated and Moving Average (ARIMA) technique gives better results.

E. Evaluation

Evaluation means computing the standard measures by comparing the efficiency and effectiveness of the forecasting models. The outcomes obtained from the proposed performance measure are used for determining the measurement of results that used reliable information for any forecasting model [22]. The general formula used for the evaluation of the performance is measured using the following equations.

- **Akaike Information Criterion**

Akaike Information Criterion (AIC)measures the over fitted events that avoid to measure the prediction accuracy. AIC measures the values for large dataset more often used for selecting the best model. The equation for AIC is given in the following equation (1).

$$AIC = 2k - 2\ln\left(\widehat{L}\right) \tag{1}$$

- **Sensitivity, specificity and Accuracy**

Specificity is the term that represents the true negative rate of the obtained actual negative values to that of correctly identified values (percentage). The equation for specificity is expressed in the equation (2). Sensitivity is the rate at which the positive rate for the recall functions are detected with respect to particular fields, thereby calculating the actual positive values in particular proportion, which is expressed in the equation (3). Accuracy is the description of systematic errors, which is a statistical bias low accuracy measure that causes a difference among "true" values. The equation for Accuracy is expressed in the equation (4). An effective forecasting model is used for evaluation of the measures are Sensitivity and Specificity.

$$Specificity = \frac{TrueNegative}{TrueNegative + FalsePositive} \tag{2}$$

$$Sensitivity = \frac{TruePositive}{TruePositive + FalseNegative} \tag{3}$$

$$Accuracy = \frac{TruePositive + TrueNegative}{TruePositive + FalsePositive + FalseNegative + TrueNegative} \tag{4}$$

- **Mean Absolute Error**

Mean Absolute Error(MAE) measures the forecasting error which computes the error occurred during the comparison made by the predictive values in the model. The equation for MAE is represented in equation (5).

$$MAE = \frac{\sum_{i=1}^{n} |A_i - F_i|}{n} \tag{5}$$

- **Root Mean Square Error**

Root-Mean-Square-Error (RMSE) is a measure used for predicting the difference between the predicted and observed values by a model and used for computing the sample data or predicting the errors when the data with sample is used. RMSE formula as shown in equation (6).

$$RMSE = \left(\frac{\sum_{i=1}^{n} (A_i - F_i)}{n} \right)^{\frac{1}{2}} \tag{6}$$

- **p-value**

p-value refers to the probability obtained from the observed results (tested) where the assumption is made as the null hypothesis. The significance occurring in the statistical hypothesis represents the probability event.

III. Comparative Analysis

For the past several decades, researchers have developed many methods to control the outbreak of the dengue disease are discussed in table 1. The comparison made for the existing models are discussed in the table 1.

The graph for the existing methods with respect to Accuracy is plotted in the figure 2.

TABLE I. Comparison of Existing Models.

Authors	Proposed method	Advantage	Limitation	Performance Measure
Torres et al. [23]	Fuzzy Modeling technique	The developed procedure permitted the making of a model that enough depiction to the dynamic of a dengue and extreme dengue plague in	The created model needs to notify the presence of the disease and required awareness of giving ideal direction on the	Accuracy=75.01%. VAF= 90.06% RMSE = 277.37 Delays = 16

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		Colombia.	assessment of patients and the important prescriptions or administrations.	p-value = 0.8102
Vijayakumar et al. [24]	Social Network Analysis (SNA) Fuzzy K-Nearest Neighbor	The developed model determined the coefficient differentiated distinct symptoms occurred from mosquito. The developed KNN approach classified the infected or uninfected class.	However, the developed model was not applicable for facilitates services needed to provide notifications in the real time applications	Accuracy = 95.9% Recall = 94.5% Precision = 92.4% F-measure = 93.4%
Rajput and Manjhvar [25]	Novel model forecast Genetic Algorithm	The developed model showed that the altered methodology had the option to distinguish the virtual importance of characteristics in imperatives of their loads. The model thought the boundaries were set to get optimal prediction performance.	However, the developed model did not conduct preliminary experiment for representing the real time dataset since the synthetic dataset was used.	Accuracy = 96.56%
Withanage et al. [26]	Multiple time series regression approaches	The developed climate based forecasting model permitted alerts of approaching dengue flare-ups and epidemics ahead of time of one month with high accuracy.	The modifications was needed to be made with re-adjustment of the model as per the progressions of risk factors and related fields, for long term prediction.	RMSE = 146.83 p-value = 2.13E-11 Standard error = 0.01558 AIC = -65.31 Coefficient = 0.14715 Sensitivity = 92%.
Guo et al. [4]	Ensemble Penalized Regression Algorithm (EPRA)	The EPRA provided skillful forecasts that was utilized as ideal and reciprocal ways that evaluated dengue elements assisted with design interference to avoid dengue transmission.	The performance of the developed model was vulnerable to the effect of media reports and public concern, which came about with over-gauge of genuine occurrence of the studied infectious disease	Accuracy = 98.11% Sensitivity = 92.86% Specificity = 98.62%

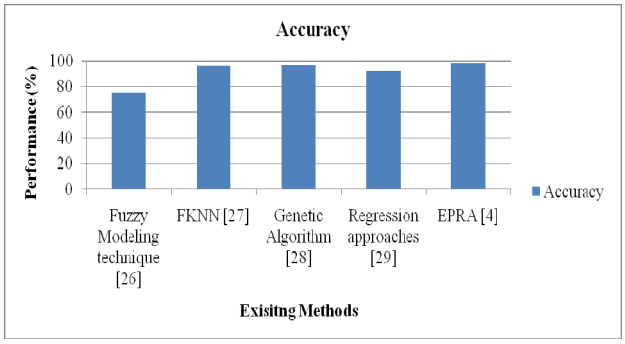

Fig. 2. Comparison Graph for The Existing Methods

IV. Conclusion

This research work identified the important components used for the dengue forecasting model. The various factors were analyzed for the dengue disease outbreak which was directly related to the occurrence of dengue epidemic disease, such as rainfall, rate of mosquito bites, climate factors. The processing of dengue information faced many challenges by the models such as Dynamic forecasting models, Big data, supervised unsupervised machine learning models, time series analysis, data processing were addressed. Unsupervised learning is utilized to get observations from datasets which have no predefined bunch reactions. Clustering is one of the most widely recognized strategies in the class. Neighborhoods are an approach to cluster data by finding the difference between one information point and another. From the exploration, the unsupervised learning strategies have not been utilized broadly for dengue outbreaks determining purposes till now. Among the clustering techniques, K-means clustering method could be introduced to improve the effectiveness of dengue disease prediction. K-Means techniques acts as a decision maker so as to recognize what everything states are there require to concentrate so as to distinguish the reason for diseases. The k-means clustering calculation seperates the dengue data observations to k-clustrers. The grouping is accomplished by limiting the total of squares of distances among information and the related cluster centroids. In this manner, K-Means clustering is expanding the capability of the outcomes. This is the effective method to forecast the dengue patients when the dengue dataset were completely grouped. Thus, the unsupervised learning methods need to be used in forecasting models to determine the outbreak of the dengue disease. In addition to this, usually for prediction model regression model provides a powerful statistical method that examines relationship among the variables. The Regression model describes number of dengue fever patients for the weather factors also. The model generates better relationship between the variables and predictors as well as variables [27]. Thus methods used in forecasting models to determine the outbreak of the dengue disease. Similarly, Fuzzy based systems can be used diagnosis of dengue disease at an early stage in patient based on the physical indications and clinical test reports. The information factors and changing over these informational factors into fuzzy membership functions will make a better decision making in predicting dengue forecasting model [28]. The challenges faced in the existing models make a major contribution to this research in future directions and upcoming researchers needed to concentrate on these types of difficulties.

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