International Journal of Machine Learning and Image Processing (IJMLIP), Vol 1, Issue 1, April 2023

Optimization techniques and hybrid deep learning approaches for UV index predictions

Dr.A.Rajasekar, Associate Professor, Department of Electronics and Communication Engineering, Dhaanish Ahmed College of Engineering, Chennai. Email: rajasekarbe@gmail.com.

Dr.B.R.TAPAS BAPU, Professor & HEAD, Department of Electronics and Communication Engineering, S.A.Engineering College, Chennai, Email: tapasbapusaec@gmail.com

Dr.N.Ashokkumar , Professor, Department of Electronics and Communication Engineering, Mohan Babu University, Tirupathi. Andrapradesh. Email id: ashoknoc@gmail.com

Abstract:

The sun ultra - violet indices, often known as the UVI, is an important global health statistic that may help reduce the risk of illnesses caused by ultraviolet radiation. For the purpose of forecasting the everyday UVI in India, this research attempted to build as well as analyze the outputs of several hybridised algorithms for machine learning using a neural network convolutional as well as a longer selective memory termed to as CLSTM. The results demonstrated that the recommended modified CEEMDAN-CLSTM concept possesses an excellent capacity for predicting, i.e., a low error rate and an excellent performance level. This was illustrated in comparison to the standard models that were used as the counterparts. The implication of the work has the potential to improve real-time exposure guidance for the general population as well as to assist in mitigating the risk of illnesses associated to solar UV radiation, including melanoma.

Keywords: mathematical formulation, optimization method, machine learning prediction of the ultraviolet rays

1. Introduction:

Radiation from the sun's ultraviolet (UV) rays is a necessary ingredient for the continuation of life on this planet; Norval et al. 2007. The ultraviolet (UV) irradiance makes up just a tiny portion (for example, between 5 and 7 percent) of the overall radiation yet has a multitude of positive impacts on human health. As of earlier civilizations, it has been utilised for the purpose of enhancing the body's resistance to infection by, for example, building stronger muscles as well as joints (Juzeniene as well as Moan 2012). Additionally, it has been utilised for the purpose of treating a number of skin conditions that are challenging to treat such as atopic dermatitis, psoriasis, and photo treatment for highly intense scleroderma; Kroft et al; Furuhashi et al. 2020; Roshan et al. 2020. Many people find that getting a tan under artificial UV light makes them feel happier and more relaxed; Sivamani et al. 2009. In addition, Ultraviolet light (NO) nitrogen oxide plays an important part in lowering individual blood pressure;2012Juzeniene as well as Moan.

In addition, ultraviolet light has been widely used as a powerful disinfection in the food and water industries, where it has been put to great use to eliminate disease-causing bacteria. Because of this, UV radiation has become an extremely popular kind of disinfection (Gray

2014). Because (UV light) ultraviolet light is efficient against protozoa disease, its use as a disinfection for drinkable water has become more common in recent years;
2015 Timmermann. To the present day, the continent of Europe is home to the large majority of communal water supplies that are equipped with ultraviolet (UV) disinfection equipment. In US, its use is mostly restricted to the purification of groundwater; Chen et al. 2006. On the other hand, it is anticipated that in the next years a wider variety of wastewater treatment systems will make use of it for disinfection purposes. Pooi as well as Ng 2018; Mausezahl et al. 2009; It is important for developing nations throughout the globe since it provides a straightforward, cost-effective, and efficient form of disinfection in water treatment. This is in comparison to the conventional chlorination approach. Since a long time ago, the use of ultraviolet light has also proven its effectiveness in the battle against illnesses that are spread via the air; Wells as well as Fair 1935. For example, a recent research found that aerosolized H1N1 influenza strains may be effectively inactivated by a low dosage of UV-C light (specifically, 2 mJ/cm2 of 222-nm) (Welch et al. 2018). In addition, the far UV radiation may be used to sanitise medical instruments and supplies. In order to prevent the worldwide pandemic (COVID-19) produced by the coronavirus SARS-CoV2, there has recently been a considerable rise in the usage of UV-C light as a topical disinfectant.

A new study also shown that the use of UV light for the sanitization of COVID-19 surfaces pollutants is both practical and efficient, which was a major focus of the study; Heilingloh et al. 2020. On the other hand, because to the contradictory nature of UV radiation studies, there has also become a significant cause for worry. Irradiation from the sun's ultraviolet rays may also have adverse consequences on human wellness, such as an increased risk of developing skin cancer as well as eye problems; Turner et al. 2017; Lucas et al. 2008. It has been shown that being exposed to UV light for extended periods of time is one of the significant risk elements that seem to be essential for the development of cancer as well as non-melanoma malignancies; Sivamani et al. 2009; Saraiya et al. 2004, and it is connected with 50–90percent of these illnesses. Sivamani et al. 2009; Saraiya et al. 2004; According to the findings of a recent research, the area of Australasia has the highest higher incidence of carcinoma on a worldwide scale, when compared to other regions of North America as well as Europe; Karimkhani et al. 2017. For this reason, it is essential to supply the individuals whose health is at danger with accurate information on the strength of UV irradiance in order to preserve their health.

In this work, a feature selection algorithm is used to improve the training method and test a variety of predictor variables that were chosen more by feature selection methods. The remaining parts of the article are structured as described below. In Section 2, we will explore the items that are linked. In Section 3, we will discuss the mathematics structure of the network that is being presented. Section 4 is where the article comes to a close.

2. Related Studies

The (WHO) World Health Organization developed the global (UVI) Ultra violet indicator as just a numerical global health index to express the risk associated once exposed to Ultraviolet light; Ferna'ndez-Delgado et al. 2014; World Health Organization 2002. The purpose of the UVI is to measure the amount of ultraviolet radiation in the environment. Nevertheless, estimating UV irradiance in the real world needs ground-based testable

theories, space - based observation systems together with a high level of technical skill; Kazantzidis et al. 2015. Remote places, particularly mountainous ones, provide unique challenges when it comes to the setting up of the essential apparatus, including spectroradiometers, radiometers, and also sky photos. Because of this, the procedure is not only more difficult but also more expensive; 2017 Deo. In particular, the brightness of the light is greatly influenced by a broad range of hydro-climatic elements, including cloud and also aerosol; 2008 Staiger; 2018 Li; as well as ozone; 2020 Tartaglione; 2011 Baumgaertner; and so on, which can introduce a great deal of uncertainty into the process-based as well as empirical models that are currently being utilised, detailed also mentioned within the technique in section. Because of this, the analysis of sky photos could also need considerable bias adjustments, often known as cloud modification; Sudhibrabha et al. 2006; Krzys'cin et al. 2015). This results in additional technical and computational overhead. The use of data-driven models may prove to be useful in mitigating the effects of these severe obstacles. In particular, the non-linearity that is introduced into the data matrix may be readily managed by employing Traditional process-based as well as semi-process-based systems, as opposed to concepts that are controlled entirely by information are unable to do so. In addition, the data-driven approaches are simple to construct, do not call for a significant amount of procedure psychological processes; Niu and Qing 2018; Wang et al. 2018, as well as place less of a strain on the computational side of things.

Using various (ML) machine learning algorithms as data-driven models has shown to be a phenomenally effective alternative to using traditional process-based as well as empirical models due to the significant computing efficiency offered by ML techniques. Because of advances in technology, there has been a considerable rise in the efficiency of computer processes, and A significant number of ML technologies have been developed by academics. (ANNs) artificial neural networking are without a doubt the most widespread and frequently utilised technology in the area of solar power production. 2014 Chandel as well as Yadav. Furthermore, a number of studies, such as (MLP) multipling layer perceptron neurological nets; 2018 Alfadda; 2007 Alados, (SVR) support velocity regression; 2020 Fan; 2017 Kaba tree decision structure; Jimenez-Perez along with 2016 Mora-Lopez, as well as irregular forest; 2018 Fouilloy, have also included increasingly utilised in evaluating in a separate investigation, the M5 and (MARS) multivariate adaptive regression splines techniques were used for the purpose of predicting solar radiation; Srivastava et al. 2019).

In addition, recent developments in this field include the implementation of deep learning networks including the (CNN) convolutional neural network; Szenicer et al. 2019, and the (LSTM) long short-term memory; Raksasat et al. 2021; Niu and Qing 2018; Ahmed et al. 2021b, c; Huang et al. 2020. These networks are designed to improve the accuracy of machine learning algorithms. However, the UVI indication is more easily understood by the general public than the values of the UV irradiation. In addition, the forecasting of UVI has only been done using a restricted number of systems that are driven by data. An artificial neural network (ANN) was utilised in the study conducted by 2015 Latosinska in order to replicate UVI on a global scale. In order to make accurate projections of UVI with in Australian setting, an extreme learning technique (ELM) was used (Deo et al. 2017). There hasn't been a great deal of research that have used ML techniques to anticipate UVI. Despite the fact that these standalone machine learning algorithms are accurate in their predictions, their architecture is flawed, and they mostly have problems with overfitting effectiveness;

Ahmed and Lin 2021. As a result of this, composite deep-learning models are receiving a growing amount of attention since they are very beneficial for making predictions with a better level of effectiveness than those of the individual models of computer vision.

Modified models such as (PSO)-ANN particle swarm enhancement as well as wavelet-ANN; 2019 Zhang, (GA)-ANN genetic technique; 2014 Antanasijevic', (BRF)-LSTM Boruta irregular forest; 2021 Ahmed, a, b, c, d, (EEMD) ensemble evidence based mode dissolution; 2015 Liu, adaptive neuronal network; Antan On the other hand, a CNN - LSTM hybrid model, which is also referred to as a CLSTM hybrid model, is preferable to various various machine learning approaches in respect of its capabilities to effectively extract intrinsic characteristics from the data matrix. This model has also been successful in predicting time series quality of the air as well as meteorological information; Pak et al. 2018.

Using a variety of methods for feature selection would result in a more nuanced knowledge of the determinants as well as allow for more accurate quantification of the UVI's characteristics. According to the findings of a great number of studies, the incorporation of convolutional neural networks as a technique for feature extraction results in an even more significant improvement in UVI predictions; c 2021a; Wu et al. 2021; Ghimire et al. 2019; Huang as well as Kuo 2018. The use of such a composite model for the purpose of sequence data prediction, namely the UVI over a series of consecutive days, has the potential to be a useful instrument that has great predictive ability. The prediction of UVI using a CLSTM hybrid learning model, on the other hand, has not been investigated to this point, which was one of the primary motivations for carrying out the current work.

3. Research Methodology

3.1 Dataset:-Forecast for the city of Bengaluru, updated every hour. The timestamp begins on January 1, 2009 and ends on January 1, 2020. There were a sum of 96432 entries, and there was not a single row that included any null value. The dataset was first analysed for the possible patterns that might be shown depending on the timestamp. There were many of them that were discovered.

3.1 CLSTM (or CNN-LSTM) hybrid model

On top of a framework for a prediction model, a deep learning approach that makes use of optimization methods has been created in this research. This research indicates that how CNN-LSTM (CLSTM) method, which is built up of a CNN with four layers, may be used quite effectively for the forecasting of UVI. In need to predict the target variable, which is UVI in this situation, the CNN is employed to merge the recovered characteristics in order to do soalong with as little error as possible during both training and testing. In a similar vein, the CNN-GRU hybrid model, abbreviated as CGRU, is being developed for the same reason.

The activity of predicting is a subset of prediction that involves mathematical functions to learn from the in the event that you want to carry up the required activity, the dataset is required. Learning from the prepared dataset was accomplished with the use of deep neural networks. An artificial neural network (ANN) that has numerous hidden layers in between its input and output layers is called a (DNN) deep neural network. DNNs, which are very similar

to shallower ANNs, are able to represent complicated non-linear relationships. Because of this, we decided to make use of them as a model in order to make predictions about the Ultraviolet Index.

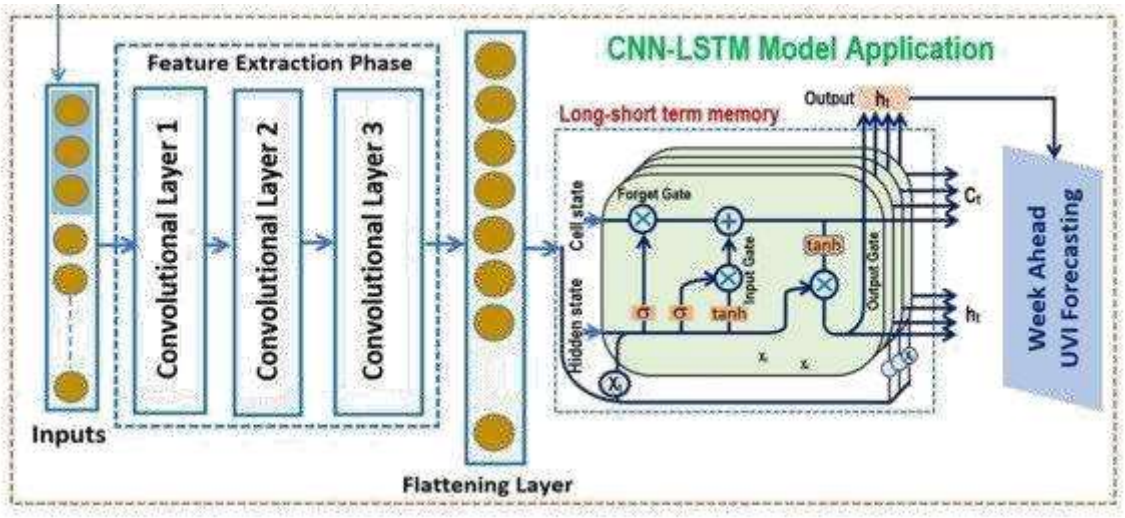

Figure. 1 The constructed model structure of such a Convolutional Neural System, also known as CNN, also with four layers of long short term memory for a hybrid CNN system in order to forecast a week's amount of maximum daily Ultraviolet Indices values using the Bacterial Foraging Algorithm.

Even though a standard neural network is able to recognise complicated non-linear patterns, these networks are not particularly good at efficiently collecting patterns in time series data. Memory-based capability is essential for the model in order for it to recollect from the many different inputs that have come before. RNNs are a kind of convolutional neural network that belong to the class of networks in which the progression of the state is dependent not only on the input at the present timestep but also on the input at earlier timesteps. Because of this trait, it is feasible to do processing that is reliant on the context, which makes it possible to learn long-term dependencies. It is possible for It is possible for a recurrent networking to have linkages that loop around from the outgoing nodes to the arriving sites, or it may even include linkages that don't do either of those things that are completely random between any two nodes.

However, recurrent neural networks suffer from an issue known as vanishing gradient, which has been discovered as a problem by research activities that have been carried out in the past. As a result, the RNNs are altered such that they may form a (LSTM) Long short memory network.

One subclass of RNN design is known as an LSTM. In contrast to Unlike a traditional neural network, the purpose of this architecture is for the system to learn, via experience, how to classify, analyse, and predict time series. This was shown by the study that is being given here. Information that is not part of the regular flow of the recurrent network may be found in LSTMs; more specifically, it can be found in a gated cell. A particular cell may be used to store records, write information, or read in a manner that is analogous to how information in a computer hard drive can be used. Time series may be processed, predicted, and classified with the assistance of these neural networks.

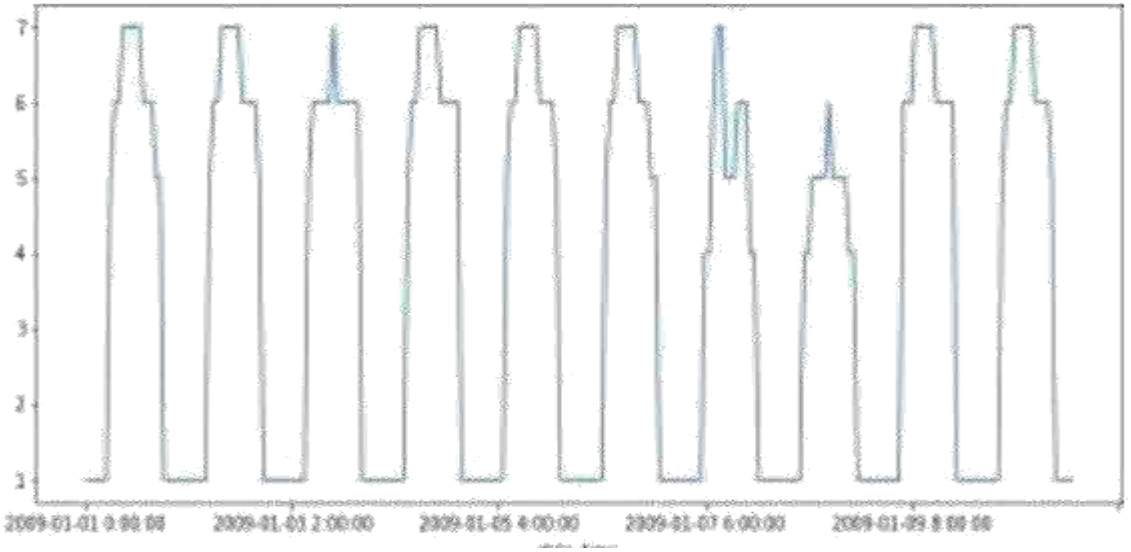

Figure. 3.2: Variation in the UV index from hour to hour. It has come to my attention that there exists a pattern that repeats itself over the days.

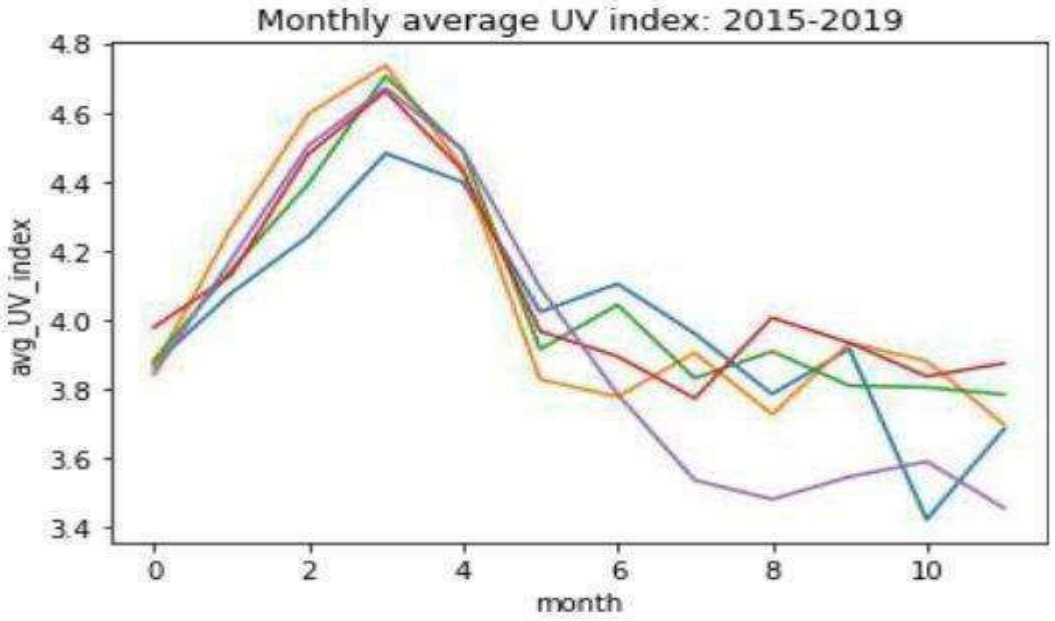

Figure. 3.3: The UV indices on a month, on average, throughout the course of many years.

The summer months have a smaller standard deviation compared to the winter months. This occurs in April. Every year, this pattern unfolds in the same way.

The search for the optimal combination of hyperparameters for the univariate and multivariate techniques required the execution of a number of separate tests. Both the univariate and the multivariate candidate GRU models' performances were evaluated and contrasted with regard to the amount of inaccuracy that they cause. In contrast to second, which takes into consideration a number of different characteristics, the first one employs only one feature as its input. In point of fact, the univariate models use the single feature of the Ultraviolet index values. On the contrary, the multiple variable model takes into account not just the magnitude of the UV level is taken into account but also month as well as day characteristics, which provides the network with a more robust temporal context.

The model's hyperparameters consist of the following values: Epoch count is 5, and ADAM is the optimizer. The rate of learning is somewhere between 0.0001 as well as 0.001. Evaluation Metric: RMS error, or root mean squared error (RMSE)

Any model's input must be provided in the similar format as that of the neural network's input layer. This is a requirement for all models. During the course of the testing, there will be no alterations made to the weights in any way. The calculation is carried out by the model in order to provide an output of the expected value. After that, the values that were acquired are mapped and displayed together so that comparisons may be made more easily.

TestCases

1. The univariate model was created since it is the most fundamental kind of model. This model is quick, but it does not make use of any features or timestamps, and as a consequence, it produces a greater Error number during the course of its training.

2. In addition to the UVI value, the chronology is the most significant component to consider since the UV Index has a tendency to follow the patterns that occur daily and monthly. Consequently, as a result of adding the values for the hours of the day as well as the day of the year, the learning error was dramatically decreased, which led to an improvement in the model.

3. In order to test with the model, temperature record were added as a feature since their association with UVI values was found to be the strongest. Although it did have a tendency to marginally increase the accuracy, demonstrating its relevance, it did not turn up to be as beneficial as the inclusion of the timing did in the end.

RESULTS AND ANALYSIS

Due to the fact that there was a difficulty with time series forecasting, a specific kind of time - series data cross validation known as TimeSeries Split was used. The (RMSE) root mean square error and the (MAE) mean absolute error were calculated with each cross-validation splitting in order to find the parameters that offer the most accurate forecasts. This was done in order to find the variables that deliver the most precise forecasts. It was abundantly clear from the experimentations that have been carried out with both uni along with multi-variate applicant modeling techniques that a larger sequential perspective outcomes in an overall drop of both inaccuracy metrics. This is despite the fact that the best uni-variate creations have a lower MAE than the best of all time of co one. However, the breakthroughs that were conducted out for both of these types of candidate models. In spite of the fact that the most accurate univariate characteristics had a lesser MAE than the most accurate multivariate ones, this was nevertheless the case. Considering that the two metrics use the same exact parameter as the UV index's, an inaccuracy of 0.3 suggests that it is possible to anticipate the anticipated UV indicator for the preceeding 3 days with such a high level of precision.. This is because the two metrics use the same exact parameter as the UV ratios. When comparison towards the uni- variate modelling, the multi-variate subject's predictions are now more precise because it takes into consideration that both month as well as the day in its method of data gathering. In contrast, the uni- variate modelling only takes into account one variable at a time. It is fascinating to think about the fact that the amount of data entered into the model is directly proportionate to the amount of time - steps in the process. This means that adding more features to the model as input will result in a growth in the number of time - steps that are needed to construct a sequence.

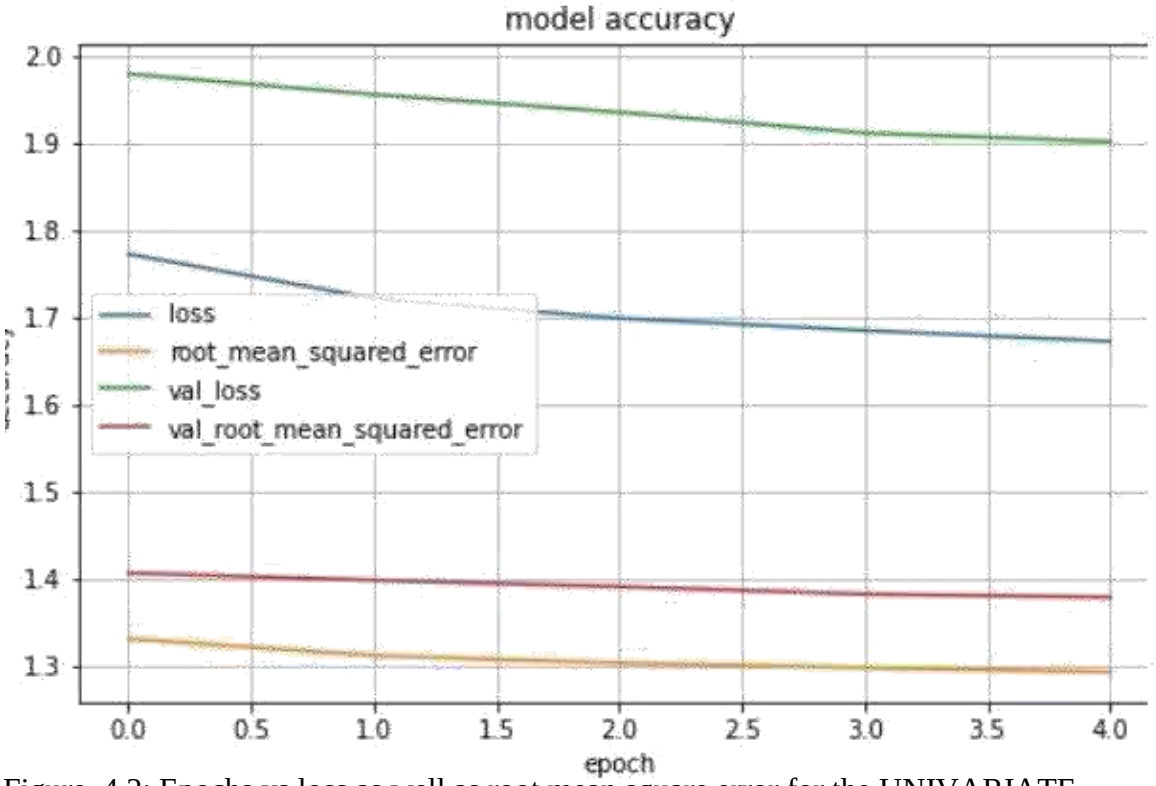

Figure. 4.2: Epochs vs loss as well as root mean square error for the UNIVARIATE MODEL. RMSE: 1.3098

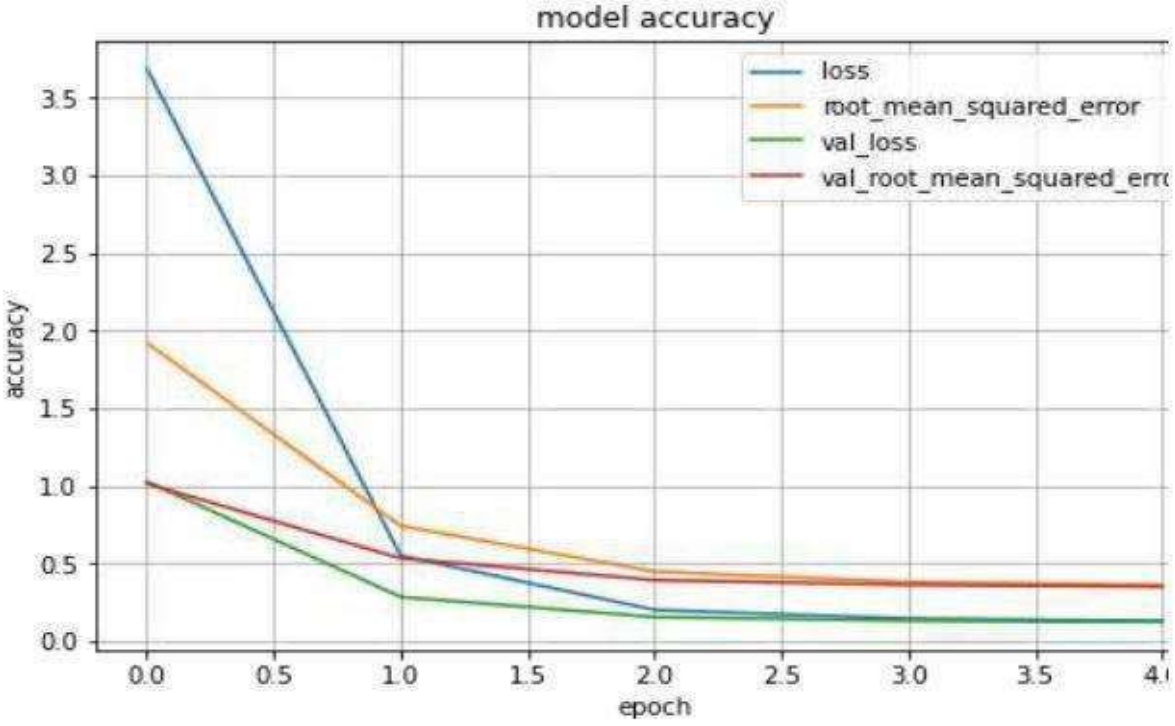

Figure. 4.3: Epochs vs loss as well as root mean square error for the TIMESTAMP MODEL RMSE: 0.3606

Bacterial Foraging Optimization Algorithm:

The BFOA is an optimization method that does not include gradients and is instead a bio-inspired, naturally self-organizing, and recently discovered tool. This method imitates the foraging, evolutionary reproduction, as well as natural birth-death dependent elimination as well as dispersion methods of common E. coli bacteria, which are all necessary for the bacteria to thrive in the complicated human digestive system. BFOA searches for optimum living energy sources in a problem domain that is both complex as well as impossible. This energy intake per unit time is believed to be the fitness, and it is collected by the type of bacteria using foraging behaviours called chemotaxis. Because bacteria have a short life span, they survive through evolution-based reproduction by the bacteria that are the fittest. Must provide variability in the bacteria culture as well as hence to globalise the search space to avoid being trapped into local analogues. Additionally, for the purpose of expediting the search for an answer, inter-communication-based communal swarming is being examined.

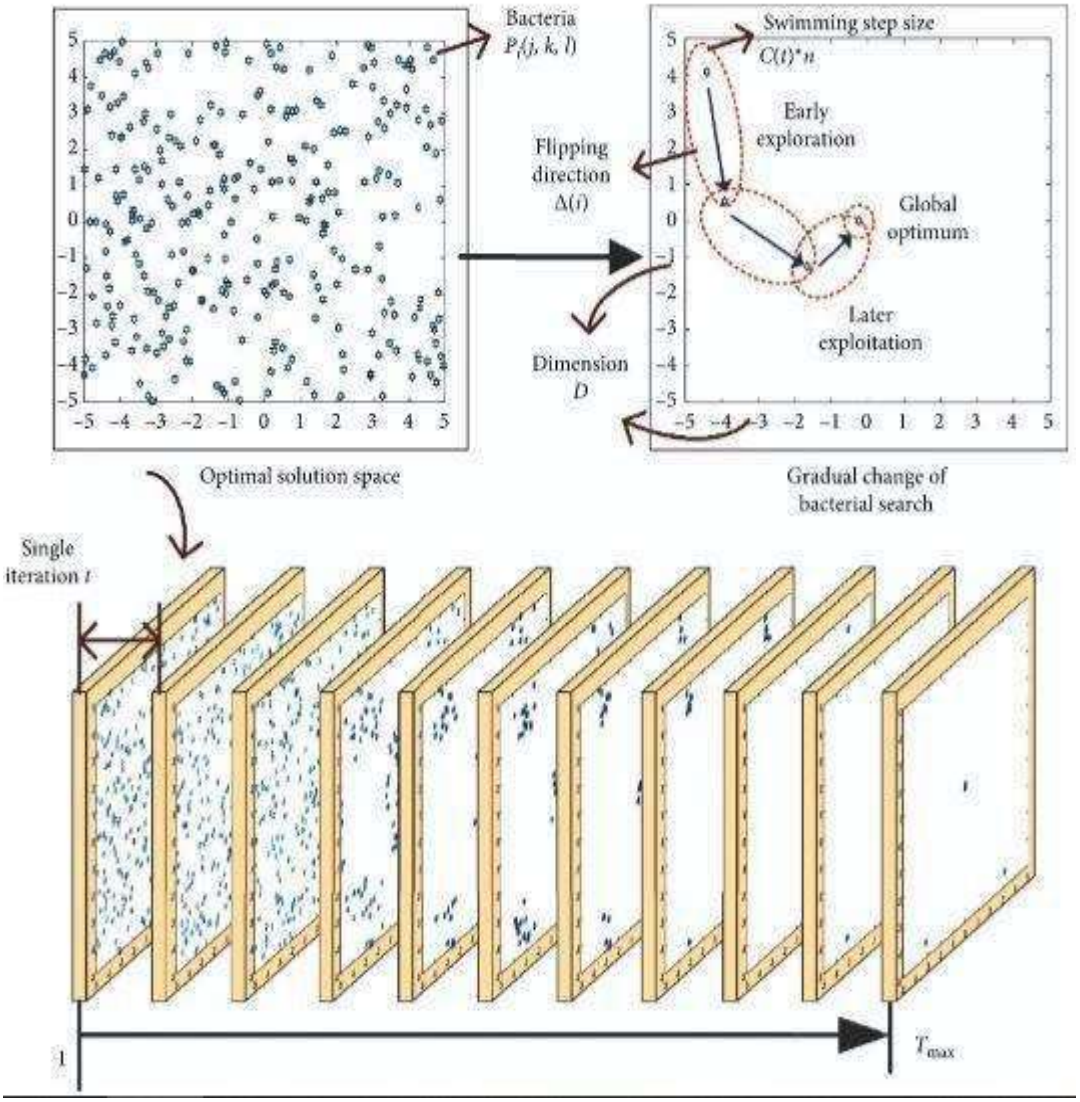

Fig. 5 Structure of Fundamental

4.1.2. Swarming

The swarming mechanism is meant to affect the behaviour of such bacteria so that they will investigate regions where other parts of the population have discovered larger quantities of nutrients or will avoid harmful chemicals. This procedure is carried out with the assistance of a chemical signalling system, which utilises both attraction as well as repulsion. A number of characteristics are used to distort the search landscape, which is a representation of the process.

```
Begin
  Initialize S, N_s, N_c, N_re and p_ed                          //Initialize BFOA parameters
  Create random initial bacteria θ^g(b,f,h) ∀ g, g = 5...,S       //Initialize Bacteria
  Evaluate bacteria                                              //Evaluate Obj. function
  For h = 1 to N_ed Do                                           //Elimination-dispersal loop
    For f = 1 to N_re Do                                         //Reproduction loop
      For b = 1 to N_c Do                                        //Chemotaxis loop
        For g = 1 to S Do                                        //Bacteria loop
          Calculate C(g) and φ(g)                                //Calculate step size and search direction
          sw ←1                                                  //Swimming length counter
          While sw ≤ N_s Do                                      //Perform swims while swims less or equal than N_s
            Execute chemotaxis process
            If θ^g(b+1,f,h) is better than θ^g(b,f,h) Then       //Bacterium position improved?
              sw ← sw +1                                         //Increase Swim counter
            else
              Calculate C(g) and φ(g)                            //Calculate step size and search direction
            End If
          End Do
        End Do
      End Do
      Execute Reproduction process, keeping the best S/2 bacteria and create S/2 copies of them
      to maintain a fixed population of bacteria.
    End Do
    Execute Elimination-Dispersal process with a probability of 0 ≤ p_ed ≤ 1 in θ^g(b,f,h) ∀ g, g = 1...,S.
  End Do
End
```

Fig. 6 Pseudocode

4.1.3. Reproduction

A reproduction event will arise after the largest amount of chemotaxis steps, Nc, has been attained. This procedure sorts the swarm of bacteria known as S according to the value of their goal function. The bacteria that are in the less healthy half of the swarm S/2, which is the population with higher optimization method, will be replicated, while the bacteria that are in the most unhealthy half will be removed. Because of this incident, the total number of people will remain same. The value supplied by Nre represents the total amount of reproducing steps.

4.1.4. Elimination-dispersal

For this particular occasion, each and every bacterium is subjected to an elimination-dispersal procedure that is repeated Ned times with a probability ped. This approach attempts to imitate the life cycle of a bacteria by simulating its eventual death and, in certain instances, its subsequent dispersal in order to investigate potentially fruitful new regions.

4. Conclusion

In this particular investigation, a daily UV Indexes forecasting was carried out at the Perth location by utilising aggregated significant preceding satellite-driven elements that are associated with ultraviolet radiation.A CEEMDAN-CLSTM model is a unique hybrid deep

learning framework, and it was used to make the predictions, which was then compared to various benchmark models including such LSTM, GRU, DT, SVR, and so on. In order to determine the most important aspects of the dependent variables, also known as the UVI, four different optimization strategies were used. Following the application of the proposed model as well as the models that served as benchmarks, the merits of the model were appraised making use of a variety of statistical metrics, graphical displays, and pertinent conversations. The extraordinary forecasting power was shown by the fact that the predictions obtained from our information were accurate to in about a single UVI unit of such values that were accurately counted. Because of this, decision-makers would get a significant amount of assistance from this model that is driven by data in order to swiftly safeguard global healthcare without latency. It holds a great capability to be accepted by a far larger segment of the public, particularly youngsters as well as the elderly who face a larger risk of getting skin cancer. This is especially true in the case of youngsters.

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