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Forecasting Daily Maximum Temperature of Chennai using Nonlinear Prediction Approach

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Abstract

In recent years numerous research were made to are expecting the weather especially the most temperature of a location. The urban regions are the maximum vulnerable regions which can be tormented by the increase in the temperature. The prevailing paper is geared toward quantifying the trade inside the surface air temperature at the most populated metropolitan town Chennai. The town has experienced rapid urbanization in the latest beyond. The principle objective of the paper is to broaden a forecast model for max temperature of the metropolis. The nonlinear nature of the temperature time series is analysed the usage of the lyapunov exponent. The effects of lyapunov exponent shows that there is chaos present inside the time collection facts. This gives a terrific foundation for the choosing reasonable forecasting version along with the segment area reconstruction strategies proposed via farmer forecast the temperature all through the summer season months.

Keywords: Chaos, Lyapunov Exponent, Phase Space Reconstruction

1. Introduction

Humans are the maximum inclined sectors of the society who're affected in all dimension whenever there's trade inside the climate and weather structures. Heat exhaustion or warmness stroke takes thousands of lives during every summer time everywhere in the international. Water aid control, safety of vegetation, control of electricity resources like natural fuel and strength all rely on the climate circumstance of a particular region. The observed and the projected international warming in twentieth and twenty first century will keep affecting the hydrological cycle, ecological machine and environmental conditions[6]. In all of the above instances the prediction of temperature plays a completely important function. Well timed prediction of temperature will help to take precautionary measures. Atmosphere is incredibly dynamic in nature and calculation of the future country of the atmospheric gadget is tough. Likewise temperature is also motivated via various atmospheric factors on this planet.

The forecast of the most temperature has long been a place of hobby for various scientists. Extraordinary statistical methodologies have been attempted to forecast the temperature on a every day, monthly and seasonal time scale[4,5,10]. Maximum daily temperature is found when the quantity of incoming shortwave radiation equals to the quantity of outgoing lengthy wave during the mid to late afternoon at approximately 1400 hr neighborhood time. As maximum temperature is a parameter discovered each day, that is stimulated with the aid of the observations of previous days so it becomes a likely predictor.

The beyond every day maximum temperature for 44 years from 1971-2014 is selected to are expecting the destiny maximum temperature for the year 2015. The nonlinear man or woman of temperature is nicely documented in literature[3,7]. The nature of the most temperature

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time series is analysed the usage of lyapunov exponent. The outcomes of the lyapunov exponent reveal the presence of chaos in time series. To forecast such chaotic time collection a nonlinear forecast model needs to be evolved instead of the standard statistical models. This nonlinear chaotic behaviour of the time series can be properly analysed and modelled the usage of segment area reconstruction (psr) technique.

2. Study Area

Chennai is placed on the thermal equator at the southeast coast of India at a median altitude of 6 metres from the sea stage. Its miles called the "Gateway of South India". Latitude: 13° 00' n. Longitude: eighty° elevene. It's far the capital metropolis of Tamil Nadu. It's far a prime industrial, cultural, monetary and academic centre in south India. It is also called the «cultural capital of South India»

3. Data

The daily maximum temperature data of Chennai from 1971-2014 was procured from the web site http://en.tutiempo.net/climate/2013/ws-432790.html. The Lyapunov exponent method was applied to analyse the chaotic nature of the maximum temperature and a phase space prediction approach was used to forecast the maximum temperature for the Chennai city for the months of January, February and March of 2015.

4. Methodology

Nonlinear systems can also give upward thrust to the complex behaviour called chaos. To apprehend such system nonlinear time series techniques which include correlation measurement, surrogate information approach, lyapunov exponent technique, kolmogrov entropy approach can be used. For nonlinear device the same old strategies of forecast such as statistical techniques and predictors method do not deliver accurate forecast. In case of statistical method the correlation among the predictor and predictant maintain converting through the years and the forecast turns into misguided. In addition for the predictors' method the sufficient and important quantity of predictors concerned in the evolution of the gadget must be envisioned otherwise the forecast will no longer be accurate once more. Inside the gift paper lyapunov exponent method is employed to analyse the nonlinear chaotic nature of the day by day maximum temperature of Chennai. It's far one of the best tool to first analyse the records for its chaotic behaviour. The presence of 1 biggest superb lyapunov exponent will suggest that the statistics underneath evaluation is chaotic in nature. This would allow us to use the perfect nonlinear forecast for the statistics under observe. In the gift paper the forecast for 2015 is given using a nonlinear forecast version called segment space reconstruction approach the proportion mistakes within the forecast is likewise discussed.

4.1 Lyapunov Exponent

The lyapunov exponents are basically a degree of the average costs of growth and contraction of point in trajectories in segment space[2]. They may be asymptotic portions, defined domestically in country area, describing the exponential price at which a perturbation to a trajectory of a machine grows or decays with time at a positive vicinity inside the nation area[8]. Lyapunov exponent is one of the tools which have been used to decide the sensitivity on a quantitative way. Author in[11] proposed a technique to estimate the most important lyapunov exponent from an discovered time collection data. Author in[9] expected lyapunov exponents for noisy time series. The most important lyapunov exponent is referred us the Largest Lyapunov Exponent (LLE) from which the notion of predictability for any dynamical device is always determined. LLE can be taken as strong signature of chaos. The mean exponential rate of divergence of two initially close orbits using the formula

$$\lambda = \underset{\substack{t\to\infty \\ |\Delta x_0|\to\infty}}{Lim} \frac{1}{t} \, log_z \frac{|\Delta x(X_0,t)|}{|\Delta x_0|}$$

The number l is called the Lyapunov exponent value and is useful for distinguishing among the various types of orbits. It works for discrete as well as continuous systems. The Lyapunov exponent for a set of N values can be found using the formula.

$$\lambda_k = \underset{\substack{N\to\infty \\ |\Delta x_0|\to\infty}}{Lim} \frac{1}{N} \sum_{k=1}^{N} log_z \frac{|\Delta x_{k+1}|}{|\Delta x_k|}$$

- l<0 the orbit attracts to a stable periodic orbit. Negative Lyapunov exponents are characteristic of dissipative or non-conservative systems. Such systems exhibit asymptotic stability.

- l = 0 the orbit is a neutral fixed point. A Lyapunov exponent of zero indicates that the system is in some sort of steady state mode. A physical system with this exponent is conservative such system exhibit Lyapunov stability.
- l>0 the orbit is unstable and chaotic. Nearby points, no matter how close will diverge to any arbitrary separation all neighbourhood in the phase space will be eventually visited. These points are said to be unstable.

The Rosenstein approach of estimation of the lyapunov exponent become calculated for finding chaos the usage of the Matlab algorithm. The delay time and the embedding size that's necessary to run the Rosenstein set of rules changed into calculated the usage of the common mutual records feature and false nearest neighbour approach respectively the usage of visual recurrence analysis software.

4.2 Non Linear Prediction-Phase Space Reconstruction Method

Phase space reconstruction approach is a class of model built directly from the available data. The data given as a time series is considered as single realization of continuous random process. This method was proposed by[1]. The linear methods of analysing a time series from weather and climate processes have had some success. But the major constrain in the such models is the lack of knowledge about the physical phenomena involved in the climate system. The concept of phase space is a useful tool for characterizing dynamical systems, such as the maximum temperature. A dynamical system can be described by a phase -space diagram, which is essentially a coordinate system, whose coordinates are all the variables that enter the mathematical formulation of the system. The path of the phase space diagram gives the evolution of the system from some initial state and hence represents the past behaviour of the system. Phase-space is a powerful concept because with a model and a set of appropriate variables, dynamics can represent a real-world system as the geometry of a single moving point. A common problem encountered while dealing with real systems, such as the river flow system, is the absence of information about all the variables involved in the underlying system. Under such circumstances, one way to represent the dynamics of the system is through the PSR, i.e., reconstruction (or embedding) of a single-dimensional (or variable) time series in a multi-dimensional phase-space. The physics behind such a reconstruction is that a nonlinear system is characterized by self-interaction, so that a time series of a single variable can carry the information about the dynamics of the entire multivariable system. Among a variety of methods available for reconstructing the phase-space, the method of delays [e.g. Takens, 1981] is the most popular one. The method is based on the concept that, using its past history and an appropriate delay time, a scalar (or single-variable) time series Xi, where i =1, 2;…; N; can be reconstructed in a multi-dimensional phase-space to represent the underlying dynamics, according to

$$Y_j = (X_j, X_{j+\tau}, X_{j+2\tau} \ldots\ldots X_{j+(m-1)\tau})$$

Where j = 1,2,…. N-(m-1)τ, m is the dimension of the vector Y_j, called as embedding dimension; and τ is a delay time [Packard et al., 1980; Takens, 1981]. A Phase space reconstruction in a dimension m allows one to interpret the underlying dynamics in the form of an m- dimensional map f_T, that is $Y_{j+T} = f_T(Y_j)$

where Y_j and Y_{j+T} are vectors of dimension m, describing the state of the system at times j (current state) and j + T (future state), respectively. Now we have to find an appropriate expression for f_T. There are several approaches for determining f_T, the most widely used one being the local approximation method proposed by[1]. According to this method, the f_T domain is subdivided into many subsets each of which identifies some approximations FT, valid only in that subset and, hence, in this way, the system dynamics is represented step by step locally in the phase space. The identification of the sets in which to subdivide the domain is done by fixing a metric $\| \quad \|$ and, given the starting point Yj from which the forecast is initiated, identifying neighbors Y_j^p ; p = 1; 2, … k; with $j^p < j$, nearest to Y_j, which constitute the set corresponding to Y_j. The local functions can then be built, which take each point in the neighborhood to the next neighborhood: Y_j^p to Y_{j+1}^p. The local map F_T, which does this, is determined by a least squares fit minimizing

$$\sum_{p=1}^{k} \left\| Y_{j+1}^p - F_T Y_j^p \right\|^2$$

In this study, the local maps are learned in the form of K-nearest neighbours. The forecasts are made forward from a new point Z_0 using these local maps. For the new point Z_0, the nearest neighbor in the learning or training set is found which is denoted as Yq. Then the evolution of Z_0 is found, which is denoted as Z_1 and is given by

$$Z_1 = F_q(Z_0)$$

The nearest neighbour to Z1 is then found, and the procedure is repeated to forecast the subsequent values. The forecasting algorithm is implemented herein using the Matlab software version 7.2.

5. Results and Discussion

The primary objective of the prevailing paper is to forecast the day by day most temperature of Chennai Menambakkam Station for the months of January, February and March 2015. Using a Section area forecasting method, data for 44 years from 1971-2014 was taken for calculation. The non linear chaotic nature of the most each day temperature of Chennai was studied with the lyapunov exponent. The maximum positive fee of the lyapunov exponent cost turned into determined to be 5.967. The predictability of the maximum temperature turned into calculated to be 0.167 days. Parent 1 indicates lyapunov spectrum for the daily maximum temperature for the Chennai vicinity.

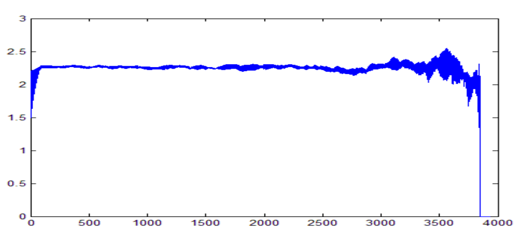


Figure 1. Lyapunov spectrum for daily maximum temperature.

The lyapunov exponent changed into calculated using Matlab model 7.1 using Rosenstein algorithm. The Rosenstein set of rules calls for the usage of calculation of time delay and embedding measurement. The time postpone become calculated the usage of average mutual information characteristic. The embedding size was calculated the use of the false nearest neighbours method. Visual recurrence evaluation version 4.9 became used to calculate the time delay and embedding measurement. Parent 2 shows the time postpone for the every day maximum temperature. The time delay turned into envisioned to be 9. Figure 3 shows the embedding dimension for daily maximum temperature. It was estimated to be 10.

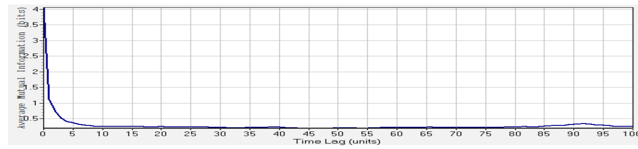


Figure 2. Time lag for maximum temperature.

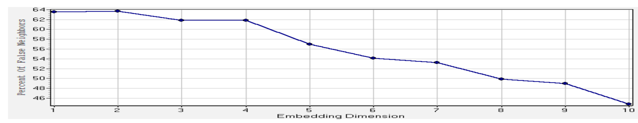


Figure 3. Embedding dimension for maximum temperature.

The segment area diagram of the most daily temperature of Chennai city suggests a clear chaotic nature of the collection. The time postpones and the embedding dimension expected above may be used to reconstruct the time series. This may help to perceive the presence of attractor within the device. Presence of attractor is also the indication of chaotic nature of the time series. Figure 4 shows the phase space diagram of the time series data.

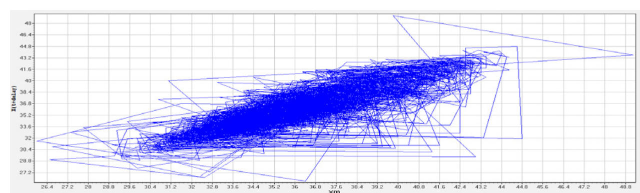


Figure 4. Phase space diagram of daily maximum temperature.

The Lyapunov exponent value indicates that the time series is chaotic in nature and is complex to forecast many days ahead. The phase space diagram insists on the chaotic nature of the daily maximum temperature. The Figure 4 correspond to the reconstruction in two dimensions (m = 10) with delay time τ = 1, i.e., the projection of the attractor on the plane $\{X_i, X_{i+1}\}$. For the time series the projection yields a clear attractor in a well defined region as it is scattered all over the phase space.

With the presence of chaotic nature in day by day maximum temperature it isn't possible to forecast the day by day most temperature for an extended duration. The most predictable time turned into envisioned to be 0.167 days. For that reason to forecast the most daily temperature of a place, one step in advance forecast can be used. The arima and ann strategies may be used for forecast-

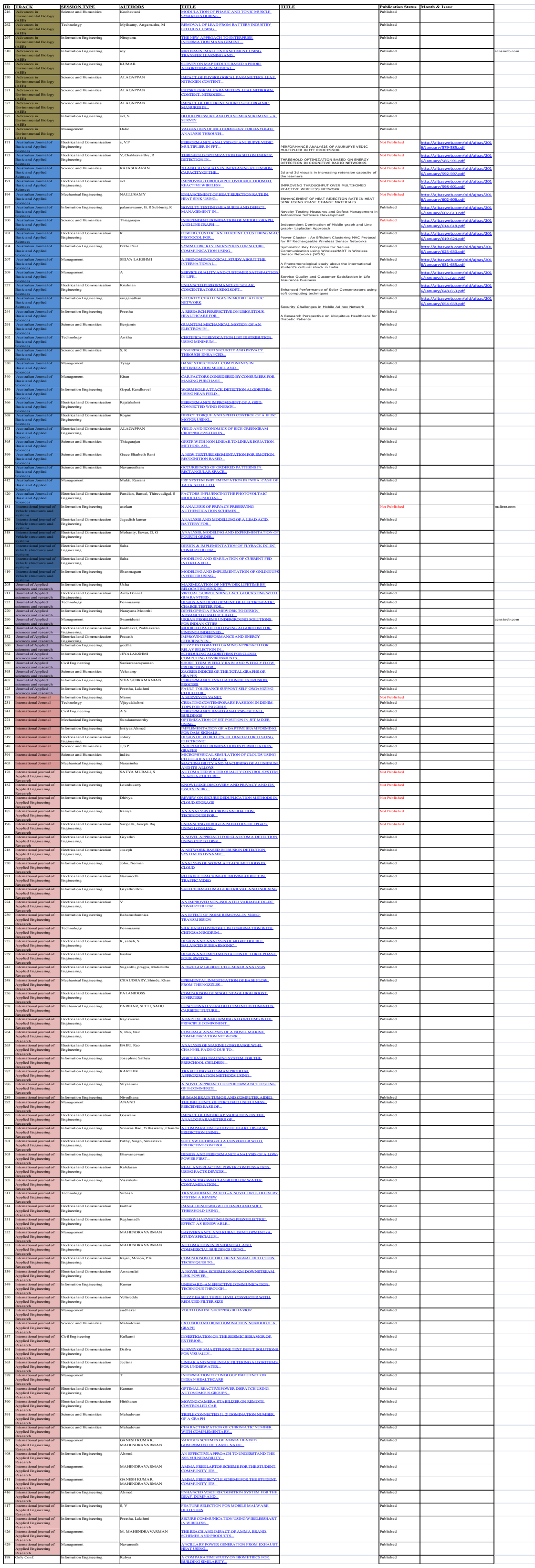
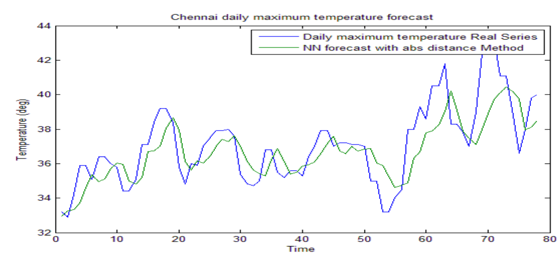
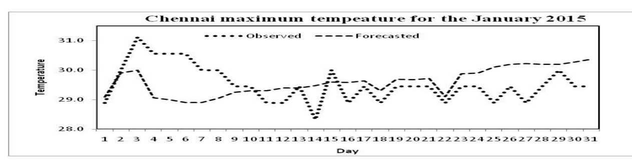
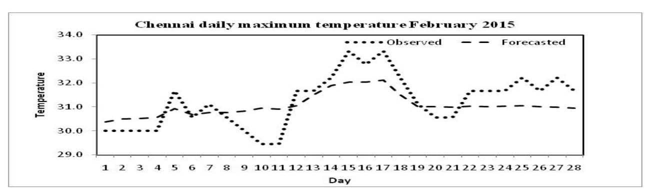


Figure 5. PSR method of Chennai daily maximum temperature forecast.

ing. Those strategies suffer from their feature desk bound and international forecast version respectively. A nonlinear and a nearby technique of forecast of temperature are chosen for the prediction of day by day most temperature. The phase area reconstruction techniques as discussed above serve the purpose. The phase space reconstruction forecast of the daily maximum temperature was done using the farmer's algorithm. Matlab 7.1 was used for the calculation of the forecast. The k value of the nearest neighbours was chosen following $k = \sqrt{n}$ method, where n is total number of data points considered. Figure 5 shows the phase space reconstruction forecast for Chennai daily maximum temperature. In the figure the observed and the forecasted value shows good harmony.







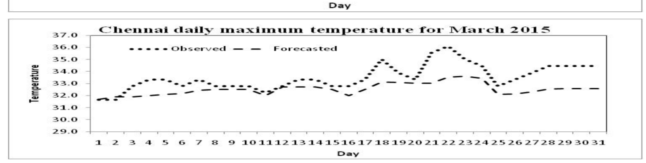


Figure 6. Chennai daily maximum temperature forecasted for the January, February and March 2015 using PSR method.

The above discern gives a clean idea about the technique chosen to forecast of most temperature of Chennai city. The x-axis represents the time (every day facts) and the y-axis represents the everyday maximum temperature for the corresponding time step. Now the algorithm is in addition applied for make a one step beforehand forecast. The information up to December 2014 changed into used to test and teach the time collection. The only step in advance forecast will deliver the most temperature for the 1st January 2015. Like smart each time with a unmarried step ahead forecast changed into made for the month of January, February and March 2015. Figure 6 shows the graphical representation of the forecasted and observed maximum temperature for the city of Chennai.

6. Conclusion

The every day most temperature of Chennai town turned into studied for the usage of past ten years of records from 2005 to 2014. The characteristics of the maximum every day temperature were studied the usage of lyapunov exponent. The most superb cost of the lyapunov exponent characterizes the time series to be chaotic in nature. The segment area diagram of the time collection additionally displays the presence of attractor in it. The plot is nicely scattered in to the section area that is the same person for a chaotic gadget with the chaotic individual of the day by day maximum temperature in thoughts, a farmers and sidorowich technique of segment area reconstruction forecasting technique turned into adopted using k-nearest neighbours for the local approximation procedure. The section area reconstruction approach has established to be the best forecast model for a non-stop time collection facts.

7. References

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