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## A Survey on Ionosphere TEC Prediction

Sumaiya Babu<sup>1</sup>, Chinju.K<sup>2</sup>

M. Tech Student, School of Computer Sciences, M G University, Kottayam, India<sup>1</sup>

Assistant Professor, School of Computer Sciences, M G University, Kottayam, India<sup>2</sup>

**ABSTRACT:** The electron content of the ionosphere is an important factor that helps in radio communication. The ions in the ionosphere reflect the signals in radio communications to a vast area. Total Electron Content or simply, TEC is the total electron content in a vertical column of 1 m<sup>2</sup> cross section along the signal path between GPS satellite and receiver. If we are able to forecast the TEC value of ionosphere, even for a short duration, it would be of great help in the field of communication. So, an attempt is made here to predict or forecast the ionosphere TEC data for a short period of time. To predict this TEC values, decision trees and forest can be used. Decision trees are flowchart-like structures that have nodes and paths. Multiple decision trees are constructed, each with different attributes. The mean of the outcomes of these trees is taken and is considered as our predicted outcome.

**KEYWORDS:** TEC, decision trees, forest.

### I. INTRODUCTION

Ionosphere is the upper part of the atmosphere where the cosmic rays of the sun falls on the gas molecules present there and ionizes them as ions or electrons. These free electrons are responsible for reflecting the radio signals that are used in radio communications. In other words, the free electrons in the ionosphere reflect the radio signals send from the earth and are an important factor in our radio communication system. Because of this significance, it would be useful if we could find a way to predict the number of electrons present in a particular region of the ionosphere on a particular time period. A unit called Total Electron Content (TEC) can be used to measure the same. TEC is the number of electrons that is present in a vertical cross section of 1m<sup>2</sup> in area between the GPS satellite and the receiver. TEC provides an indication of the ionospheric variations. It is a physical quantity and can be obtained from GPS data. Ionospheric delay, which is a main source of GPS positioning error is proportional to TEC and because of this reason, it is significant to hold a precise knowledge of the accurate TEC value at different location in different geophysical conditions. An attempt is made to predict the future TEC values with the available data set of present TEC values.

### II. LITERATURE SURVEY

Several attempts were made on calculating and interpreting the TEC values of the ionosphere. A few of those are as stated below.

1. A data preparation method was developed to perform neural network based on VTEC forecast over two stations in Malaysia. GPS Ionospheric Scintillation & TEC Monitor (GISTM) at UKM and LGKW became a part of the feasibility study for the development of data sets as inputs to the NN based TEC prediction model. The study period was selected based on the availability of data, which is from January 2011 to December 2012. The factors that influence VTEC performance were identified and processed accordingly, to be used as input parameter for the VTEC prediction NN model development. The selected parameters are seasonal variation, diurnal variation, and sunspot number which have similar conduct with VTEC for the selected 24 months.

2. Another attempt was to evaluate the performance of three ionospheric models as predictors of TEC at three stations placed near both peaks of the EA. The considered models are (1) the international reference ionosphere (IRI) (2) the semi empirical low latitude ionospheric model (SLIM) and (3) a Chapman layer. The TEC data of the southern peak of the EA were obtained using the ATS 3 geosynchronous satellite (0°N, 254.7°E) signal and the Polari meter located at

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Tucum in (26.9°S, 294.6°E, geomagnetic altitude: -15.4°) during 1982.F or this path the sub-ionospheric point was placed at 24.6°S, 290.2°E. Those corresponding to the northern peak are from the Polari meter located at Palehua (21.4°N, 203.2°E geomagnetic altitude: 21.3°) or 1978 when the ATS 6 geosynchronous satellite (0°N, 220.0°E) signal was received. In this case, the sub ionospheric point was placed at 20.0°N, 203.27°E. TEC data from the Faraday fading of low orbiting satellite signals received at Delhi (28.6°N, 77.2°E, geomagnetic latitude: 18.9°) for 56 satellite passes during 1968, for which the sub-ionospheric point was near Delhi, were also considered.

3. Another paper presents the prediction of hourly Total Electron Content (TEC) values of the ionosphere using neural network by utilizing the TEC data from a GPS Ionospheric Scintillation and TEC Monitor (GISTM) receiver. There are two network configurations; the first one by using data from January–November 2005 in training and December 2005 in testing, and the second one involved data from January–October and December 2005 in training and November 2005 in testing. Overall, the testing resulting RMSE of 3–7 TECU, absolute error of 2–5 TECU and relative error of 9–20%. The prediction of TEC on November 2005 which is during lower solar activity provides better results in comparison on December 2005 which is during a relatively higher solar activity.

4. A yet another work is one where a sine function is used to predict the diurnal ionosphere TEC. This model is estimated on the local scale, so the amplitude and the cycle of ionosphere TEC is not expanded in the geomagnetic latitude, and do not have a fixed initial phase of TEC and ionosphere TEC at night cannot be treated as constants, ionosphere TEC are predicted by this model which has only the four parameters simpler and more direct than the Klobuchar model. Ionosphere TEC used as a source of input data for this model are obtained from the two-way satellite time and frequency transfer (TWSTFT). TWSTFT is a technique of time transfer with high accuracy, most of the error on the propagation path can be eliminated from it. But adopted the frequency at C-band in the TWSTFT, the error due to Ionosphere delay still remains. In order to eliminate the Ionosphere delay, dual-frequency combination of observation in the TWSTFT is used to obtain the ionosphere TEC.

## III. PROPOSED METHODOLOGY & DISCUSSION

Decision tree forest is used for the prediction. Decision trees provide more accurate results. A decision tree is a [flowchart](#)-like structure in which each internal node represents a "test" on an each branch represents the outcome of the test, and each leaf node represents a class label i.e. decision taken after computing all attributes. The paths from root to leaf represent classification rules. In [decision analysis](#), a decision tree and the closely related [influence diagram](#) are used as a visual and analytical decision support tool, where the [expected values](#) of competing alternatives are calculated. A decision tree forest is created when more than one decision tree is linked.

The algorithm that is proposed in this work is Random Forest algorithm. It proceeds by constructing multiple decision trees for a particular problem being considered. Depending on the output that is expected, a number of attributes are considered and one tree for each attribute is constructed with a set of decision rules. Each of these trees will generate one output according to the decision rule. Problems can be classified under classification or regression. All prediction problems fall under regression group. In random forest algorithm, the output for a regression problem is the mean of the outputs from each decision tree.

## IV. CONCLUSION

TEC is the Total electron Content of the ionosphere. The electron content in the ionosphere is responsible for our radio communication since it helps in the propagation of the short radio waves. The short radio waves that are sent from the earth station are reflected by the ions present in the layers of ionosphere. Hence, TEC values play an important role in communication, being able to forecast TEC values is considered important for predicting the condition of atmosphere i.e. ionosphere and thus helps in error detection. To predict this TEC values, decision trees and forest can be used.

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