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Literature Survey on Solar Flares Prediction

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A B S T R A C T

Space weather research faces a significant obstacle in predicting when and where space weather events like solar flares and X-ray bursts will occur in a particular area of interest. As a result, researchers studying space weather are gradually looking into data mining and machine learning-based multivariate data analysis methods that can be used to approximate future space weather event occurrences based on patterns of distribution. Most recent research on using machine learning (ML) to predict solar flares has focused on X-ray time series predictions due to the ionization effect caused by the extreme ultraviolet and X-ray radiation that flares produce in various layers of the ionosphere. In order to evaluate the possibility of predicting solar flares of the B, C, M, and X classes, we suggest classifying sub daily and diurnal total electron content (TEC) spatial changes prior to flares. In contrast to using ML techniques to predict TEC time series, this is done. The predictions and various skill scores, including precision, recall, the Heidke skill score (HSS), accuracy, and true skill statistics, are estimated up to three days prior to each tested class event. With 91% and 76% HSS skill scores, respectively, the suggested method is able to predict solar flare events of the X and M-class 24 hours before they occur, which is an improvement over the most recent related works. However, the suggested method does not achieve the same promising results for the small-sized C and B-class flares.

Keywords: SVM, solar, flares, radiation**.**

1. Introduction to Solar Flares

1.1 Introduction

The intense localized eruption of electromagnetic radiation in the atmosphere of the sun is what they are Electromagnetic Radiation is a type of energy that includes microwaves, visible light, X-rays, and gamma rays. Flares are the source of our solar system's most powerful explosion. It harms things made by humans, like spacecraft, as well as living things like humans and animals. They can last anywhere from a few minutes to an hour and look like bright spots on the sun. We typically recognize a solar flare by the photons (or light) it typically emits at nearly every wavelength of the spectrum. Flares are mostly monitored with optical light and x-rays. Flares also accelerate heavier and lighter particles, like protons and electrons. They are analogous to the sudden release of magnetic energy that accumulates in a specific area. Flares come in many different varieties; The M-class flares are ten times smaller than the X-class flares, followed by the C-class, B-class, and A-class flares, which are too weak to have a significant impact on Earth. Coronal mass ejections, which are large releases of plasma and the magnetic field from the sun, can be sparked by powerful M-class and X-class flares. Geomagnetic storms can occur as a result of this behavior, which has the potential to disrupt the magnetosphere of Earth. Damage to satellites, radiation hazards for astronauts and airline passengers, disruptions in telecommunications, outages in the electric power grid, and other effects of solar activity also affect Earth and space. The total number of electrons traveling between a radio transmitter and receiver is referred to as the total electron content (TEC). The presence of electrons affects radio waves. The radio signal will be affected more when there are more electrons in its path. TEC is a useful parameter to monitor for potential effects of space weather for satellite navigation and ground-to-satellite communication.

TEC Unit:1 TEC Unit TECU = 10^{16} electrons per m^2.

1.2 Motivation

i. Due to our increasing use of the space environment for satellites, GPS navigation, television, and cell phone communication, space weather research studies the interactions of the solar terrestrial environment.

ii. Extreme weather in space has the potential to harm vital infrastructure, particularly the electric grid, or the functionality of technology that we use on Earth.

iii. Current remote detecting innovations, working at an extensive variety of electromagnetic ranges, have become significant instruments to identify and quantify marks related to space climate occasions.

iv. Even though the most up-to-date forecasting systems use numerical models to describe the physical processes that lead to space weather events, there aren't enough real-time measurements to accurately predict these events.

v. In severe space weather forecasting and mitigation, predicting where and when severe weather events are likely to occur in a particular region of interest remains a significant challenge.

vi. Data-driven solutions are now possible for a growing number of scientific computing applications thanks to recent advancements in cloud-based big-data technologies.ML is one such data-driven solution strategy.

vii. I have a personal interest in astronomy and also machine learning is having a lot of scope in the future.

1.3 Aim and Objective of the work

Predicting where and when space weather events like solar flares and X-rays bursts are likely to occurs in a particular area of interest is a significant challenge in space weather research. The purpose of this project is to predict solar flares emitted by extreme ultraviolet and X-ray radiation, which causes an ionization effect in various layers of the ionosphere.

Project objectives:

i. Predicting where and when space weather events like solar flares and X-ray bursts are likely to occur in a particular area of interest is a significant challenge in space weather research.

ii. The purpose of this project is to predict solar flares emitted by extreme ultraviolet and X-ray radiation, which causes an ionization effect in various layers of the ionosphere.

2. Scope of ML in Solar Flares Predictions

Applications of machine learning and statistical techniques have increased across a variety of fields in recent years as a result of the explosion in computing power and available data. The scientific process, from data analysis to modeling, has benefited from the application of these techniques in astronomy and space sciences. For the purpose of forecasting solar flares, a variety of machine learning and statistical techniques are currently being utilized, allowing for early warning of severe flares.

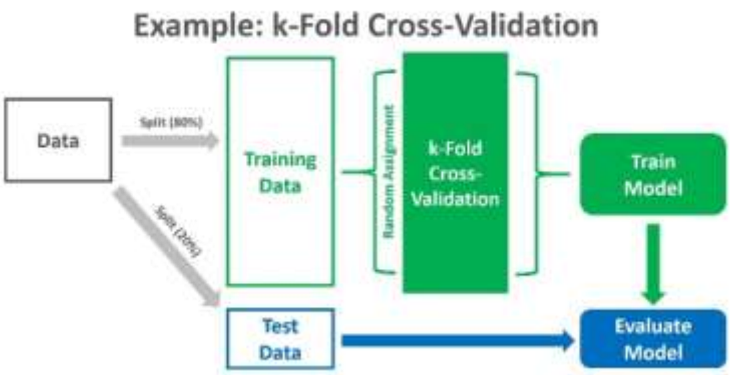
2.1 Specifications

i. Support Vector Machine

It is a collection of supervised learning techniques used for outlier detection, regression, and classification. When data are not otherwise linearly separable, SVM works by mapping them to a high-dimensional feature space so that data points can be categorized. Ionospheric Total Electron Content.

ii. K-fold

A K-Fold CV is a method in which a given data set is divided into K sections or folds, with each fold serving as a testing set at some point. Let's look at the 5-Fold cross validation scenario (K=5).The data set is divided into five folds here. The model is tested using the first fold in the first iteration, and the remaining folds are used to train the model. The second fold is used as the testing set in the second iteration, while the other folds are used as the training set. This procedure is repeated until all five folds of the testing set have been used.



iii. GPS

Global Positioning System

iv. Heidke Score Skill (HSS)

A forecasting skill measure is the Heidke Skill Score (HSS). The definition is as follows:

(NC - E) / (T - E)

where NC is the number of accurate forecasts (the number of times the forecast and the observations match), T is the total number of forecasts, and E is the number of forecasts that are expected to be confirmed by chance.

2.2 Equations

i. $Precision = \frac{TP}{TP+FP}$

ii. $Recall = \frac{TP}{TP+FN}$

iii. $HSS = \frac{2\cdot[(TP \times TN) - (FN \times FP)]}{(TP+FN)\cdot(FN+TN)+(TP+FN)\cdot(FP+TN)}$

iv. $Accuracy = \frac{TP+TN}{TP+FN+FP+TN}$

v. $TSS = \frac{TP}{TP+FN} - \frac{FP}{FP+TN}$

2.3 Features

i. With the TEC maps and the SVM method, the flares can be predicted three days in advance.

ii. Two-layered SVM with the help of the kernel function produces predictions of the X class with an accuracy of 80-90% and the M class with an accuracy of 80-87%. However, this method is not useful for predicting solar flares of the B and C classes.

iii. ML methods based on image processing take more time and power to implement.

iv. To determine whether there will be an eruption of a solar flare within three days, the SVM Algorithm is used to classify geographical changes on global TEC (Total Electron Content) maps

2.4 Illustrations

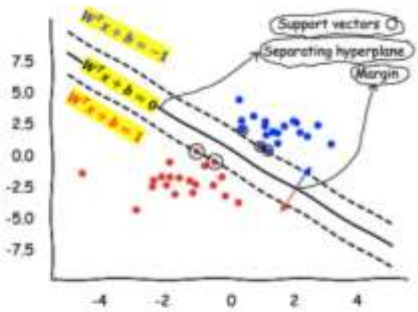
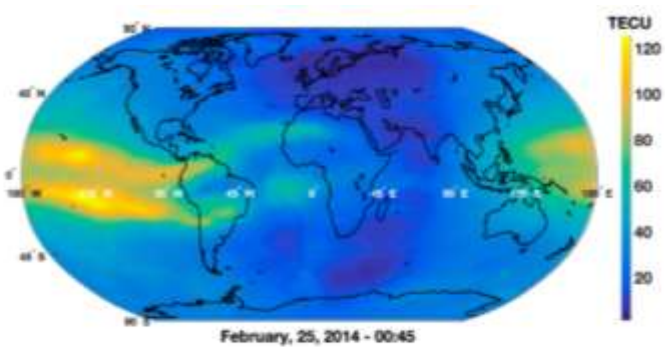


Illustration for the SVM



Global TEC map around the Time of an X-class solar flare event

2.5 Methodology

Low-level space weather events are frequent, even though severe space weather events are uncommon. Extreme and severe space weather disturbances have impacted every aspect of our space-based technology since the beginning of the 20th century. The ability to anticipate the impacts on our national infrastructures when they do occur is of the utmost importance in natural hazard prediction. As a result, extensive efforts have been put into continuously monitoring various solar indices and expanding the currently available datasets. The dataset collection and preprocessing (averaging, differentiating) phases of the suggested methodology's workflow are followed by the SVM implementation under a variety of conditions.

i. Solar Flares Dataset

ii. TEC Dataset

iii. TEC Dataset Selection

iv. TEC Data Rejection Process

2.6 Enhancement

i. There are a few drawbacks to the paper as this technique is very costly and is not possible for every country to use it. So, we can work on the project to reduce the cost.

ii. As we know this paper's research don't support or is applicable to B and C-class solar flares. So, there is a scope to enhance in this field, so we can predict B and C-class solar flares.

iii. Modified combination of TEC measurements and additional remote sensing data.

iv. As we know now the accuracy is X class with 80%-90% accuracy and M class with 80%-87% accuracy, we need to increase the accuracy of X and M class solar flares

3. Conclusion

In order to evaluate the possibility of predicting B, C, M, and X-class solar flare events, the paper demonstrates the application of SVM to ionospheric TEC data derived from the worldwide GPS geodetic receiver network. In it is concluded that the model can predict solar flare events of the X and M-class with 91% and 76% HSS skill scores, respectively, when using the DMF variation applied with the SVM technique. They have tested a wide range of possible products estimated from the initial GPS maps with a limited data budget. However, with solar flares of the minute size of B and C, where the HSS skill score drops to -0.3% -0.1%, the proposed method fails. This is due to the difficulty of obtaining sufficient TEC samples to train the SVM classifier on solar flares of a small size and the fact that these small bursts have no effect on the ionosphere. A modified combination of TEC measurements and additional remote sensing data may be used in future research to better preserve small flare event-related features that could not be identified by TEC modifications. Predictions of solar flares of a smaller size may also be more accurate as a result of this.

References

[1] D. N. Baker, "Satellite anomalies due to space storms," in Space Storms and Space Weather Hazards. New York, NY, USA: Springer, 2001, pp. 285–311

[2] R. Turner, "Solar particle events from a risk management perspective," IEEE Trans. Plasma Sci., vol. 28, no. 6, pp. 2103–2113, Dec. 2000.

[3] J.D. Rodriguez, A. Perez, and J. A. Lozano, "Sensitivity analysis of k-fold cross validation in prediction error estimation," IEEE Trans. Pattern Anal. Mach. Intell., vol. 32, no. 3, pp. 569–575, Mar. 2010.

[4] C. Cortes, L. D. Jackel, and W.-P. Chiang, "Limits on learning machine accuracy imposed by data quality," in Proc. Adv. Neural Inf. Process. Syst., 1995, pp. 239–246.

[5] G. C. Cawley and N. L. Talbot, "Preventing over-fitting during model selection via Bayesian regularisation of the hyper-parameters," J. Mach. Learn. Res., vol. 8, pp. 841–861, 2007.

[6] Y. Zheng, X. Li, and X. Wang, "Solar flare prediction with the hybrid deep convolutional neural network," Astrophysical J., vol. 885, no. 1, pp. 73–86, 2019.