Machine Learning and Deep Learning analysis on CMEs associated with flares and filaments

Hemapriya Raju[1], Saurabh Das[1]

1. Department of Astronomy, Astrophysics and Space Engineering, IIT Indore

Abstract

Solar eruptions such as CMEs, flares, and filaments disrupt geomagnetic and communication systems on Earth. While flares are abrupt, bright events that occur in the solar atmosphere and emit massive amounts of energy in the 1028 to 1032 erg range, CMEs are intense eruptions that hurl plasma into interplanetary space. CMEs can be found in conjunction with flares, filaments, or independent. Although both flares and CMEs are understood as triggered by a common physical process magnetic reconnection, yet the degree of association is unknown. We attempted to use this association of CMEs with flares and filaments through extensive Machine Learning and Deep Learning techniques to study the occurrence of CMEs. Further, since there is significant imbalance between the classes, we had explored approaches such as undersampling majority class, SMOTE. We achieved accuracy of around 95% for prediction of CMEs associated with flares and around 90% for those associated with filaments.

Motivation

- Out of a total of 85 quiescent filament eruptions, 46 or 54% are accompanied by CMEs [1]
- CMEs assosciated with eruptive prominences and flares 88% were associated with filaments and 94% were assosciated with flares [2]

Class Imbalance

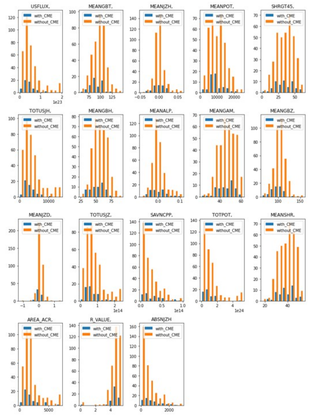

Figure 1:Class imbalance in flare with CME occurence

Data Source

Flare assosciated CMEs

- 18 physical parameters derived from Space-weather HMI Active Region Patches (SHARPs).

Filament associated CMEs

- Duration of the filament,Type of eruption,Type of filament,Presence of Twist motions,coronal cavity.

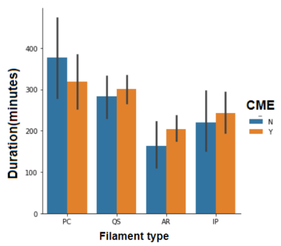

Figure 2:Relationship between different type of filaments, it's duration and CME occurrence

Results

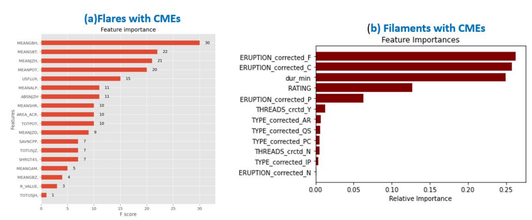

Figure 3:Feature importance analysis for CMEs with flare/filament occurrence

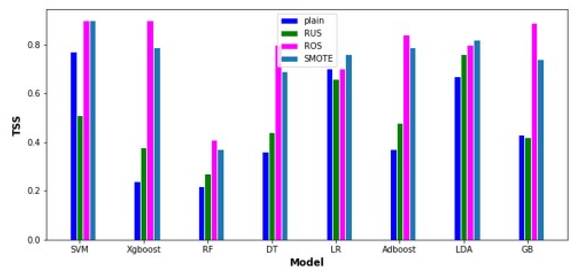

Figure 4:True Skill Score of flares associated with CMEs

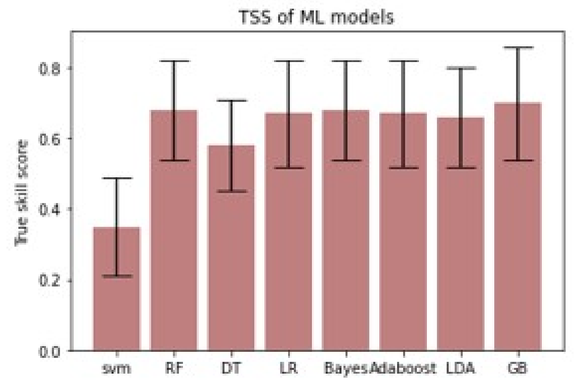

Figure 5:True skill score of filaments associated with CMEs

- We find that the LDA,XGBoost,SVM shows improved performance under various scenarios of sampling.

Results

- Incase of filament assosciated CMEs, We observe that Adaboost,GRBOOST and Logistic regression model gives better accuracy of 90% and with True skill score(TSS)=0.68±0.14

Summary

- Exhaustive analysis of prediction of CMEs associated with flares and filaments using ML techniques
- Adaboost shows better performance with reduced rate of false alarms in both cases.
- Address the class imbalance issue, through various undersampling majority class,SMOTE techniques to avoid biases in the model.

REFERENCES

[1] Ju Jing, Vasyl B. Yurchyshyn, Guo Yang, Yan Xu, and Haimin Wang. On the relation between filament eruptions, flares, and coronal mass ejections. *The Astrophysical Journal*, 614(2):1054–1062, oct 2004.

[2] M. G. Bobra and S. Couvidat. SOLAR FLARE PREDICTION USINGSDO/HMI VECTOR MAGNETIC FIELD DATA WITH a MACHINE-LEARNING ALGORITHM. *The Astrophysical Journal*, 798(2):135, jan 2015.

Contact Information

- Email id:phd1901121008@iiti.ac.in