Bypassing the static input size of Neural Networks in flare forecasting by using Spatial Pyramid Pooling

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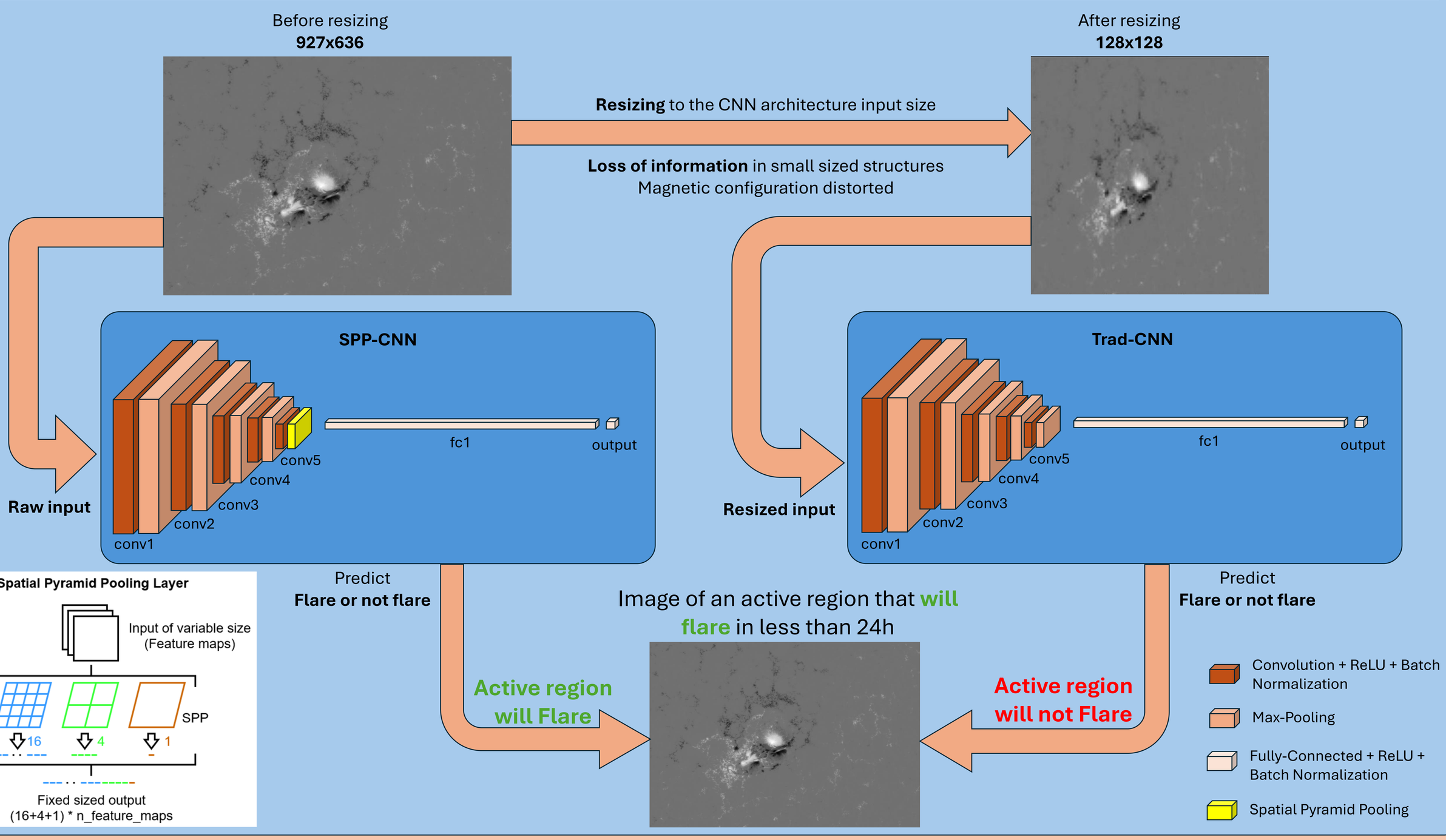
Flare forecasting with Spatial Pyramid Pooling vs Traditional CNN models



Context

Solar flares are releases of energy from active regions (AR) of the Sun. Such eruptions can be followed by Coronal Mass Ejections and may negatively impact our society. To minimize the damage caused by such events, forecasters **try to predict them** using various methods. Solar flare forecasting using traditional **Convolutional Neural Networks** (CNN) relies on **resizing** the images to fit the input size of their models. However, there are indications that triggering mechanisms leading to solar eruptions lie in the **small features** of the Sun. To bypass the use of such methods and to keep the full details of the original image, we can use of a **Spatial Pyramid Pooling**[1] (SPP) layer.

Methodology

In this poster, we present the prediction abilities of two architectures :

- **Trad-CNN** which represents a traditional CNN with layers of convolution, max-pooling, batch normalization and fully-connected layers
- **SPP-CNN** which follows the architecture of Trad-CNN but uses a **SPP layer** instead of a max-pooling before the flatten layer leading to fully-connected layers.

Both output a **binary classification** to predict solar flares **24h before their eruption** using the **SHARP**[2] dataset. Based on the GOES flare catalog, we first consider C, M and X (**CMX-classification**) as positive in our dataset, then only M and X (**MX-classification**)

Results

Table 1 : Average results of the evaluations of the cross-validations of SPP-CNN and Trad-CNN based on classification method. Trained with a binary-cross-entropy loss function and a 5-fold cross-validation.

Classification	Architecture	Accuracy	Precision	Recall	TSS	TSS Std Deviation	PR AUC
CMX	Trad-CNN	0.8	0.38	0.7	0.52	**0.02**	0.52
	SPP-CNN	**0.87**	**0.56**	**0.76**	**0.55**	0.16	**0.68**
MX	Trad-CNN	0.58	0.06	**0.77**	0.35	**0.17**	0.08
	SPP-CNN	**0.84**	**0.1**	0.62	**0.46**	0.24	**0.14**

We labeled our images to obtain a more detailed analysis of the prediction ability of our models in Figure 1 :

- The labels **X**, **M** and **C** represent images of AR producing flares of class X, M and C respectively **in 24h**.
- Labels **FUTURE-X**, **FUTURE-M** and **FUTURE-C** correspond to images of AR producing flares of class X, M and C respectively in **more than 24h**.
- The label **NO_FLARE** represents images of AR **not producing flares** in the future.

Figure 1 : Prediction accuracy per label for each model architecture on the CMX-classification. Values above each bar correspond to the maximum, average and minimum accuracy for the given label after a 5-fold cross-validation.

Conclusion

Using cutout of line-of-sight magnetograms as input, **Deep-Learning models** using a **Spatial Pyramid Pooling layer** present the ability **to predict flares of GOES class ≥C1.0**, **24 hours before the eruption**. Furthermore, there are indication of a more accurate and precise prediction than a traditional CNN, especially for images of active regions followed by a X-class flare. Figure 1 shows a **perfect prediction accuracy for X-class flares** with **SPP-CNN models** across 5-fold cross-validation.
However, we can notice the **prediction performance** of both our SPP-CNN and Trad-CNN models **drop** when used with the MX-classification, i.e, when only flares of GOES class **≥M1.0** are considered as positive flares.

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References

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