Deep Learning for the detection and energy estimation of flares

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Nanoflares are one of the most possible candidates for the solution of coronal heating problem. We can evaluate how nanoflares contribute to heat the coronae by the power-law index of frequency distribution of flares. However, the detection and energy estimation of nanoflares are still difficult. The purpose of our research is to define the function which detects flares (from small to large) and estimates input energy by them from available data deriving from observation, by using deep learning. We obtain the time evolution of differential emission measures (DEM) of whole coronal loops occurring in various strength and frequency flares by magneto-hydrodynamics (MHD) simulations. We solve one-dimensional fluid motions and energy transportations along coronal loops which are assumed to be solid, inviscid and compressible fluid, and have uniform cross-sectional area. The thermal conduction, radiative cooling and gravitation are also considered. We run hundreds of simulations by injecting arbitrary flares into the simulation, and obtain datasets which contain the time evolution of DEM and flare input. Then we use the deep neural network based on convolutional neural network (CNN) to learn the relation between the time evolutions of DEM and the energy input of flares obtained from the simulations. The CNN has many convolutional layers which have 3x3 filters, and activation functions called Rectified Linear Unit (ReLU). We assume that the time differential of DEMs to be two-dimensional images (as a function of the temperature and time), and choose them as inputs of CNN. On the other hand, we choose evolutions of energy input of flares initially injected into the simulations as outputs. We let CNN learn multiple pairs of input and output to obtain a nonlinear function which has smaller (not the smallest, considering the versatility) squared error asymptotically. Therefore, we obtain a CNN which derives the time evolution of energy input of flares from the time evolution of DEM of coronal loop. We cross-validate the precision of the CNN from the point of view both energy scale and time evolution, i.e., we get the average and standard deviation of the ratio of total energy of flares and average correlation between output of CNNs and input of simulations. We will further discuss power-law index.

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