Complexity Analysis of Convolutional Neural Network Applied to PV Fault Diagnosis via Image Processing

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Automatic and intelligent photovoltaic (PV) fault detection and diagnosis (FDD) via processing PV images has always been a tricky issue due to the difficulty for feature extraction and classification, especially for large-scale PV image dataset. Convolutional Neural Network (CNN), which has been successfully used in image processing and pattern recognition, has been exploited in the field of PV faults diagnosis in recent years by treating PV infrared (IR), electroluminescence (EL), visible (Vis) or other types of images. However, the complexity of CNN models could restrict the application from both tuning process of hyperparameters and highest performance requirements of computing. Therefore, assessment of model complexity is necessary for more efficient application of CNN in PV FDD. Commonly, two parameters are used to evaluate the complexity of CNN models, i.e., the time and space complexities, defined as following:

$$\text{Time complexity} \sim \boldsymbol{O}\left(\sum_{l=1}^{D} \boldsymbol{M}_l^2 \cdot \boldsymbol{K}_l^2 \cdot \boldsymbol{N}_{l-1} \cdot \boldsymbol{N}_l\right), \quad \text{Space complexity} \sim \boldsymbol{O}\left(\sum_{l=1}^{D} \boldsymbol{K}_l^2 \cdot \boldsymbol{N}_{l-1} \cdot \boldsymbol{N}_l\right) \tag{1}$$

where, $\boldsymbol{O}$ is the relative algorithmic complexity function, D is number of layers, M_l, K_l, N_l are respectively the size of feature map, the size of kernel and the number of kernels in l^{th} layer. The complexity levels of several recent application cases are compared in Table 1 with the structure of 2 typical CNN models illustrated in Fig. 1.

Table 1. Comparison of typical applied CNN in PV fault diagnosis

Ref	Input image	Applied Model	Structure	Time complexity	Space complexity	Target PV faults	Accuracy
[1]	IR images	VGG-16 (21 layers)	13C+5P+3FC	1.62E+10	4.44E+07	Cell defect	75.0%
[2]	EL images	GoogleNet (19 layers)	2C+9IC+5P+3FC	9.87E+09	1.22E+08	Cell defect	98.0%
[3]	Vis. images	CNN (9 layers)	4C+2P+3FC	1.73E+08	3.30E+06	Various Defects	98.9%
[4]	EL images	LeNet (5 layers)	2C+2P+1FC	1.89E+07	2.62E+04	Cell crack	98.4%

(where, C: convolutional layer, P: pooling layer, IC: inception layer, FC: fully-connected layer)

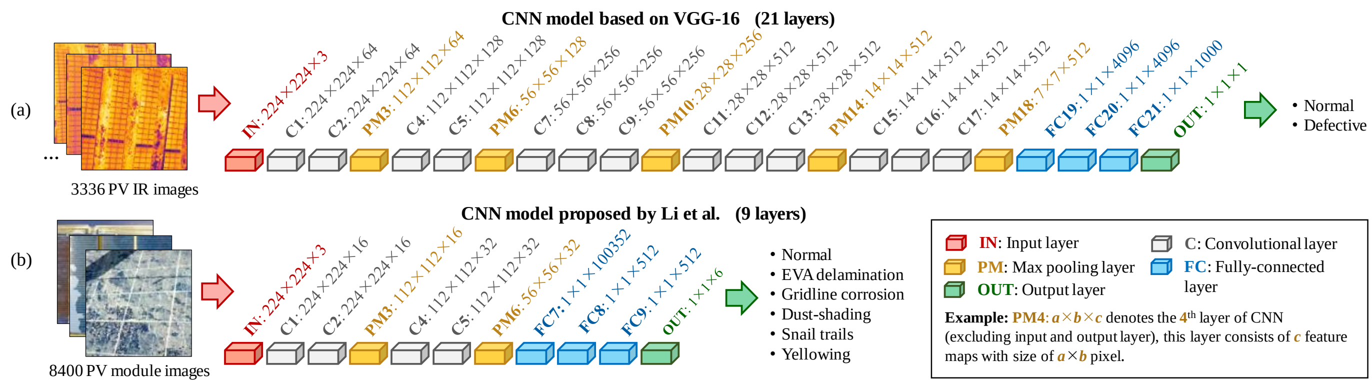

Fig. 1 Structure of 2 typical applied CNN models (model (a) from [1], model (b) from [3])

It is observed that [1, 2] use complex CNN models, i.e., VGG and GoogLeNet, which are designed for identification with large number of features (like ImageNet [5]: 14 million images of 20,000 categories). However simpler CNN models (like [3, 4]), with much less time and space complexities, could also realize good PV FDD performance. Therefore, considering PV images generally do not contain that level of features as ImageNet, the design of future models for PV FDD should fully re-examine the model structure, avoid using directly mature models so as to reduce unnecessary redundancy.

In this paper, a bibliography review and an analysis of complexity and performance for existing CNN models in PV FDD will be presented.

References:

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