Image-based Defect Detection and Classification in Manufacturing

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Introduction

Quality inspection is an essential stage in several industries. Over the last decade, machine learning models have shown achievements on various computer vision problems . The aim of this project is to build deep learning-based models to detect and classify defective products. It builds a solution based on publicly available image dataset regarding metal plates.

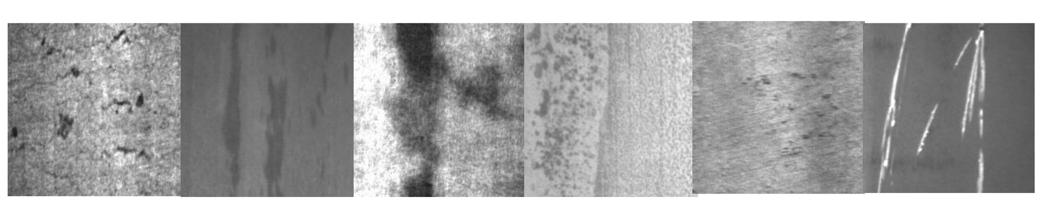

Fig. 1 Sample images of six classification of defects

Concept Generation

Machine learning mostly requires "Keras" and "TensorFlow", contributing to different layers of neural networks and help input datasets to the program. I built up the model over loading, defining, compiling, fitting, and evaluation. Over this algorithm, computer can learn patterns from myriad historical datasets and thereby determine new samples or make predictions.

Design Description

Convolution Neural Networks (CNNs) is good at extracting information from graphs, and then use a compact way to keep only the critical part of images. My program is composed of four 2-D CNN layers, coupled with four pooling layers respectively, one flattening layer, and three fully connected connected layers to manipulate image-based dataset.

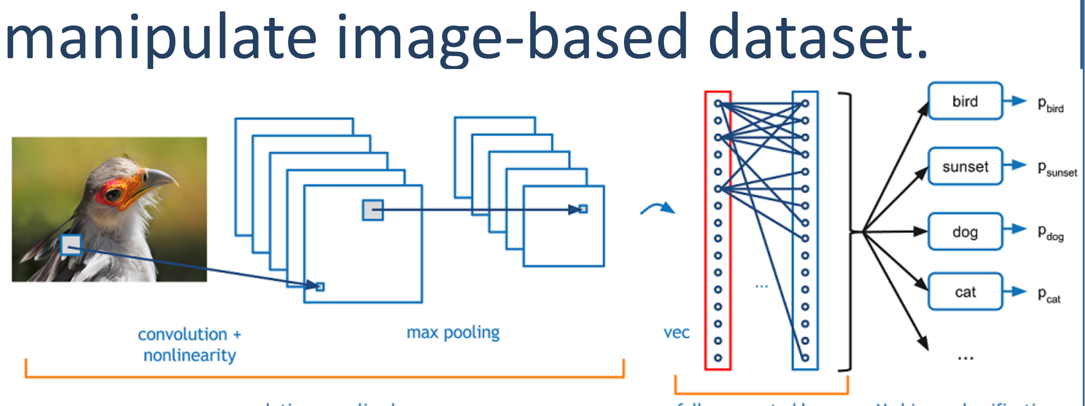

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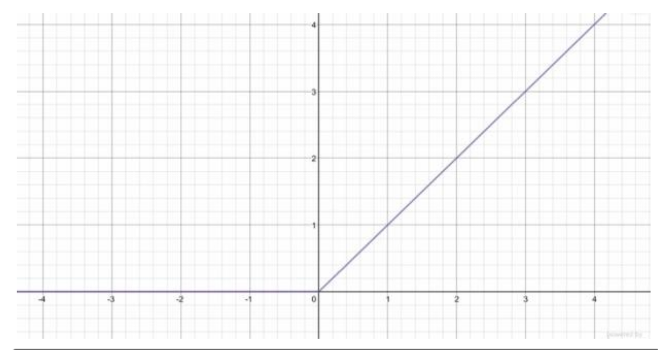
Fig. 2 CNN mechanism

Fig. 3 ReLU



Rectified Linear Unit Function

$$y(x) = \begin{cases} 0, & x \leq 0 \\ x, & x > 0 \end{cases}$$

Modeling and Analysis

The first CNN is responsible for accepting images after they are transformed to datasets. Essentially, rest of the CNN layers provide substantial and invariant feature space. Afterwards, I insert a flattening layer between CNN layers and FC layers to provide a dimension transformation from 2-D to 1-D array of data. The following FC layers are indispensable components since they coordinate with CNN layers to form a powerful core structure of deep learning models. They accept flattened outputs from the last CNN layer, and developers add FC layers which are helpful to learn non-linear features by selecting a proper activation function. In my program, I use Rectified Linear Unit (ReLU) function, shown in Fig. 3, not only because the significant decrease of calculation it facilitates but also ensure the convergence of data in a moderate speed.

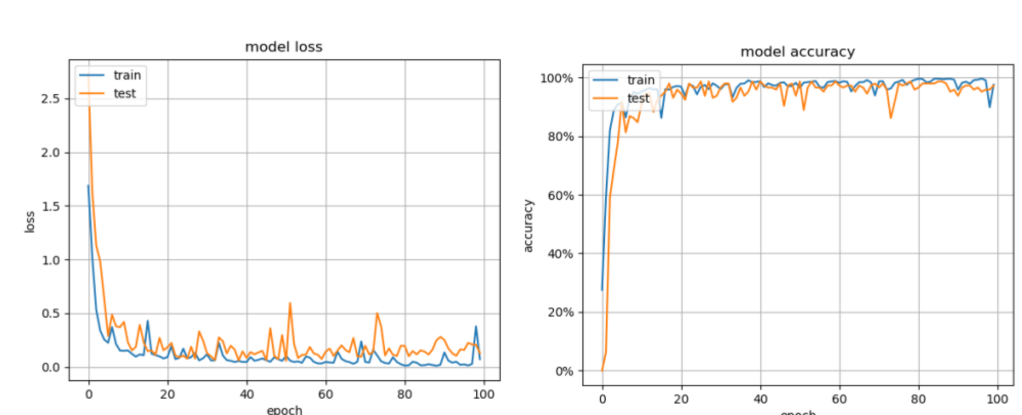


Fig. 4 *Model activity monitor*

The graph presented above showed activities tracked by the program during run time. Although there is underlying jump of loss and accuracy in some epochs during training, the overall performance is impressive.

Validation

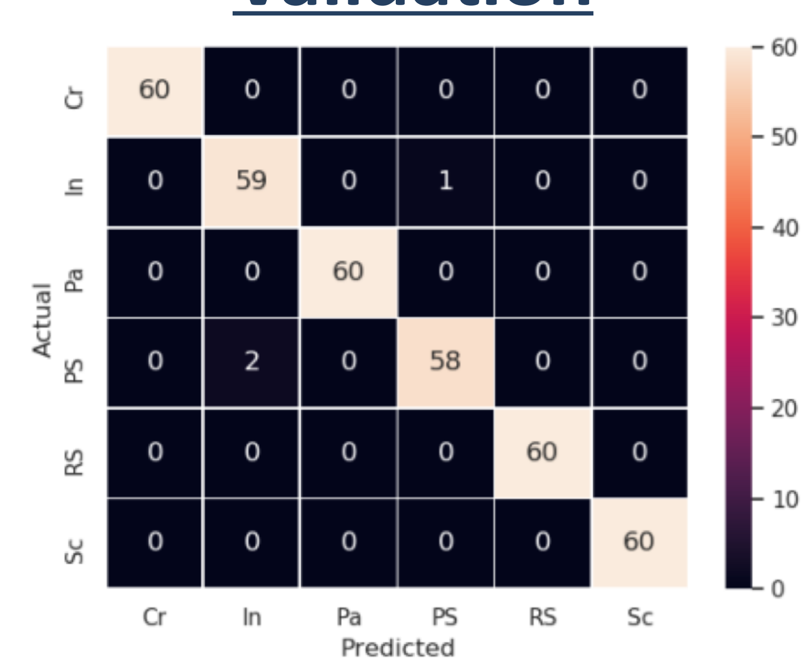


Fig. 4 Confusion matrix

The above square matrix demonstrate overall circumstances across each type of defect. Because there are six different types of defects, so it is in a 2-D dimension of 6×6.

Conv_size	Batch_size	Runtime	Accuracy
32	32	112.3s	98.30%
64	32	180.8s	97.50%
128	32	349.9s	93.80%
32	64	136.4s	96.90%
32	128	94.4s	97.50%
32	256	104.0s	86.38%

Epochs	Runtime	Accuracy
2	6.5s	45.20%
10	14.9s	92.70%
50	55.0s	96.90%
100	87.7s	99.20%
1000	1082.8s	97.50%

The two tables compare the performance of the model under different variables. Improper combination leads to a lower accuracy because the model either starts to overfit or lose the ability of representational learning on different type of features.

Conclusion

Defect detection is just a prologue of applications in machine learning. More accessible datasets can be used as a beneficial practice with various networks such as GAN and ResNet, contributing the improvement of our life quality in the near future.

Acknowledgement

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