Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

A Method for Improving Reliability of Radiation Detection using Deep Learning Framework

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1. Introduction

Radiation detection is essential technology for overall field of radiation and nuclear engineering. Previously, technology for radiation detection composes of preparation of the table of the input spectrum to output spectrum in advance, which requires simulation of numerous predicted output spectrum with simulation using parameters modeling the spectrum. However, this method has drawbacks that the parameters have low model capacity, and the simulation takes a while to fill the table. Moreover, the performance of the detector would be declined by several factors, and these lead to the necessity to update the table. In this research, we propose a method to model the relationship between the input source to the output spectrum using deep neural network and the method to model characteristics of each detector using generative adversarial network (GAN). With the huge capacity of deep learning, the model would capture the complex relationship than the previous model.

2. Methods

The methods for training the model to predict the type of the input source includes two phases: data collection, and training the model. Training deep networks need abundant amount of the data, so the first work should be data collection. After that, the model can be feeded in the form of data and label. Here, the data is the output spectrum obtained from the detector and the label is the type of the source.

2.1 Data collection

The representative source is NaI(I1) or CsI(T1). The spectrum of those sources is detected and obtained into the database. Also, CZT(Cadmium Zinc Telluride) and CdTe are widely used in low energy radiation detection fields. Optical sensors used in nuclear medical imaging fields such as MPPC or SiPM and LYSO are used to collect data, and these will be conducted in the precise experimental facilities such as Korea atomic energy research institute (KAERI) or inspection centers nearby nuclear power plants.

Moreover, each detector has slightly different characteristics so that the parameters should be calibrated before when it needs to be used. In order to improve the performance of the detector, the characteristic of each detector should be collected too.

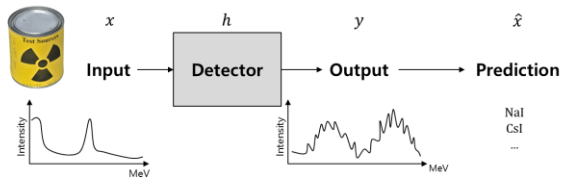

Figure 1 System flow of predicting input source

2.2 Input source prediction using deep learning

Machine learning is the field to research how to learn the relationship and correspondence between or inner data. Machine learning has shown dramatically rapid improvement in these days, especially using deep learning. Deep learning is a part of machine learning, and it employs set of perceptrons. Perceptron is the basic unit of deep learning, and it performs the non linear computation by intaking weighted input and output and applies nonlinear functions such as sigmoid, tanh, or rectified linear unit.

By stacking up those perceptrons into several layers, the model could represent highly complex data and it does not need preprocessed data anymore. This methodology has beat state-of-the-art which are composed of numerous heuristic and handcrafted features and classifiers. [1] Generally, the tasks beaten by deep learning are mostly distinguished as supervised learning, which means that the model is trained by pairs of data and label. Recently, the performance of deep learning has been more powerful using 'end-to-end' framework in speech recognition [2], object detection [3], and etc. Conventionally, even deep learning framework has feature extraction step, and deep learning model maps the features to label space. However, using end-to-end framework, the model only receives the raw input without any processing.

Same as the previous supervised setting, we also construct the model which could be trained by the data and label. Here, data is output spectrum detected by output, and the label is the prediction confirmed by human. In data collection phase, we already gathered data and label, so the model could be trained by using those dataset.

As shown in Fig. 1, the above description can be rewritten as formal way. The input source (x) is detected

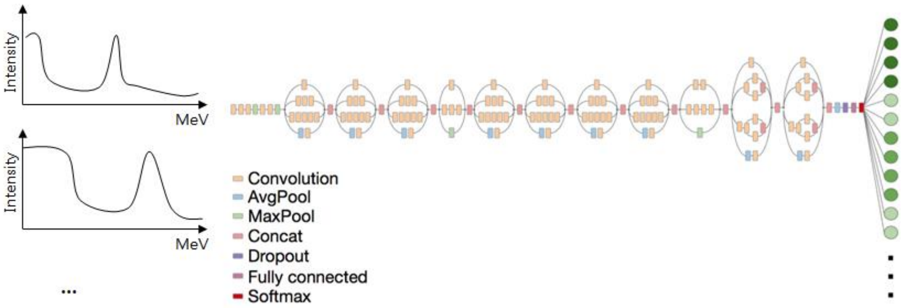

Figure 2 The example model for detecting input source from output spectrum

by the radiation detector (*h*), and output spectrum (*y*) is obtained. The type of input source (*l*) is determined by unfolding using predefined knowledge and simulation, which could have intrinsic error from low model capacity. We set the deep learning model (*g*) which is parameterized by numerous weights and biases (*w*), and the task is to predict the true input source among candidates. The candidates can be set by manually beforehand. For example, the input sources on interests could be limited in four sources, then the model only considers them as the output.

$$l^* = Softmax(g(y;w))$$

Note that *g* is represented as logit of the model, but generally the model also contains softmax itself as well. The model is trained to minimize the loss defined by the error between labels and prediction and its regularization, and it is normally considered as minimizing negative log likelihood of the training set. Cross entropy is well fit to the task, and the training samples for each class should be as uniform as possible.

2.3 Single radiation detector calibration using GAN

GAN [4] is the recently proposed method and highly attended in machine learning field. The general framework is as follows. GAN contains two major components: Discriminator (D) and Generator (G). We have input *x* and any priors *z*. G is trying to represent adverarial example $x' \sim G(z)$. Then the task of D is binary classification whether the input is sampled from the training data distribution or faked input from distribution of *x'*. Ideally, G makes perfect sample within training distribution and D never distinguishes between *x* and *x'*.

To apply GAN into radiation detector, first we collect numerous data from multiple radiation detectors. We set *x* as numerous data from multiple radiation detectors, and *z* is the data from single radiation detector. The task of G is to create *x'* which cannot be distinguished by D, and the task of D is to discriminate *x* and *x'*. After training the model, we can expect that G only leaves the information corresponding to the global information, and drops the rest. In other words, any detector information can be calibrated using GAN without any laborous tasks which has done.

3. Conclusions

In this paper, we propose new technique to improve the performance of radiation detector. The software in the radiation detector has been stagnant for a while with possible intrinsic error of simulation. In the proposed method, to predict the input source using output spectrum measured by radiation detector is performed using deep neural network. With highly complex model, we expect that the complex pattern between data and the label can be captured well. Furthermore, the radiation detector should be calibrated regularly and beforehand. We propose a method to calibrate radiation detector using GAN. We hope that the power of deep learning may also reach to radiation detectors and make huge improvement on the field. Using improved radiation detector, the reliability of detection would be confident, and there are many tasks remaining to solve using deep learning in nuclear engineering society.

ACKNOWLEDGMENT

This research was funded by the MSIP(Ministry of Science, ICT & Future Planning), Korea in the ICT R&D Program 2016 (2016M2A2A4A04913449) and was supported by KI institution-specific project (N10170002) of 2017 KAIST's own research projects.

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