Consideration on the use of Explainable AI in Operator Support System

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1. Introduction

In the last few years, Artificial Intelligence(AI) technology achieved a notable research result on many industries including nuclear power plant. One of promising application is AI based operator support system which provides useful advice to operator such as abnormal status diagnosis[1, 2, 3]. There is an emerging need for understanding how such advice are derived by AI system when it gives the advice to operator. For the AI based operator support system, deep neural network has been applied for the plant status diagnosis. Because of the complex calculation and the large number of layers in the model, deep neural network is considered as black box which is opposite to transparency. As the demand for transparency is increasing, there are various researches on the eXplainable AI(XAI)[4]. XAI enables human to understand the network model and the results from the model. It is important that the operator understand the decision of AI system when AI based system applied to the mission critical system such as nuclear power plant.

In this paper, the application of XAI on operator support system has been reviewed and the framework of XAI application on abnormal procedure validation has been considered.

2. Classification of abnormal status with neural network.

There are about 200 abnormal status are categorized in the abnormal operating procedures. Convolutional neural network modeling has been developed for abnormal status diagnosis. To develop neural network model to classify status, various abnormal status operating data is required. However, there are limit of abnormal events in real plant operation history. So, the simulator is used to generate the data for abnormal status. Fig. 1 shows the main process of generating and training for abnormal status.
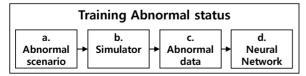

Fig. 1 Training configuration for abnormal status diagnosis

3. Operator support system for abnormal status diagnosis with XAI

Operator support system can be developed to classify the abnormal status according to pre-trained data. Normally, the neural network model provides only the classification result. Fig. 2 shows the operation data for normal operation and one of abnormal operation. Some of operation parameters are changed according to the effect of the event when there is abnormal status in nuclear power plant. In Fig. 2, yellow circle indicates that the operation parameters have changed. The neural network model has trained with the data difference and it classify the plant status according to trained network.

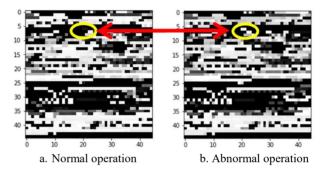a. Normal operation   b. Abnormal operation

Fig. 2 Characteristics for abnormal status diagnosis on operation data

Every classification may have the list of the parameters which has high weighting factor for the classification when the XAI is applied. The list of parameters is the basis of diagnosis. In the case of Fig. 2 'b. abnormal operation', data in yellow circle may be the list of the parameters. Some of data in yellow circle of Fig 2 has changed from 'a' to 'b' when there is abnormal event in the plant. It means that the selected parameters are main symptoms of abnormal status and these parameters are the main decision basis when operator confirm the diagnosis result. Because XAI provides these list of parameters to the operator with the classification result, the operator may understand the classification result and make the final decision of the plant status. Fig 3 shows the main process of application of XAI in diagnosis system.
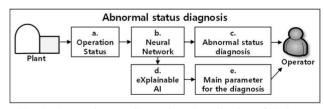

Fig. 3 Abnormal status diagnosis and application of XAI

4. Abnormal procedure validation system with explainable AI

The contents of abnormal procedures are 1) purpose, 2) alarms and symptom, 3) automatic actions, 4) urgent manual actions, 5) follow up actions. Abnormal procedures are prepared by operation expert and system design expert. These experts analyze the abnormal event and select alarms and symptoms of the events. Operating experience of the events may be used as the reference when abnormal procedures are prepared. However there is not enough operating history for every expected abnormal event. Even for the new type of plant such as APR1400, operation history is not available. The simulator can be used to verify abnormal events, however the number of abnormal events are so many to simulate every events by manually. Furthermore, each abnormal event should be verified with various abnormal simulation scenario according to the degree of abnormal event. For example, abnormal event for leakage, many simulation scenarios are needed from small leakage to large leakage.
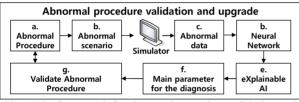

Fig. 4 The framework for abnormal procedure validation and upgrade

Abnormal status diagnosis system with XAI can be used to validation of abnormal procedure. For the abnormal diagnosis, various abnormal scenarios have been developed for the neural network training. For each abnormal event, XAI can provide main parameters for the diagnosis. These list of main parameters can be used as abnormal procedure validation. Fig. 4 shows the framework for abnormal procedure validation and upgrade with XAI.
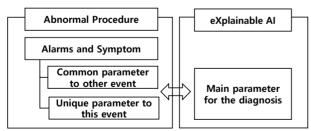

Fig. 5 The validation point for abnormal procedure with XAI

With the information provided by XAI, operator can validate the alarms and symptoms on abnormal procedure. Alarms and symptoms in abnormal procedure can be different with main parameters that XAI provided. For example, abnormal procedure lists up the expected alarms and symptoms related to the component when there is abnormal event on certain component. However, XAI may provide the parameters which are unique to the

event, so neural network can distinguish that one event from another event. Those information is important to operator because other information about the component may also be changed other related abnormal event. Fig 5 shows the validation point between abnormal procedure and XAI.

5. Discussion

Artificial intelligence and neural network have been applied to nuclear power plant Operator Support System. Automatic abnormal status diagnosis is one of the important function of the Operator Support System. In this paper, the application of XAI has been reviewed. XAI can provide abnormal diagnosis basis with main parameters. Operator can check the plant status with main parameters and may have clear understanding for the diagnosis result from neural network. Operator may select those diagnosis error from the information provided by XAI when there is diagnosis error on neural network. XAI also can be used for the validation and upgrade the abnormal procedure. Operator Support System have various abnormal simulation scenario and abnormal data already according to the scenario. XAI with those data can generate main parameters for that abnormal event with various abnormal cases. Even more, XAI can provide the unique parameter to diagnosis the abnormal event. The abnormal procedure can be upgrade to include the unique parameters or explain the abnormal status for accurate diagnosis.

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