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Deep Learning Modeling Strategy and a Feasibility Study to Estimate Accident Source Term

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Introduction

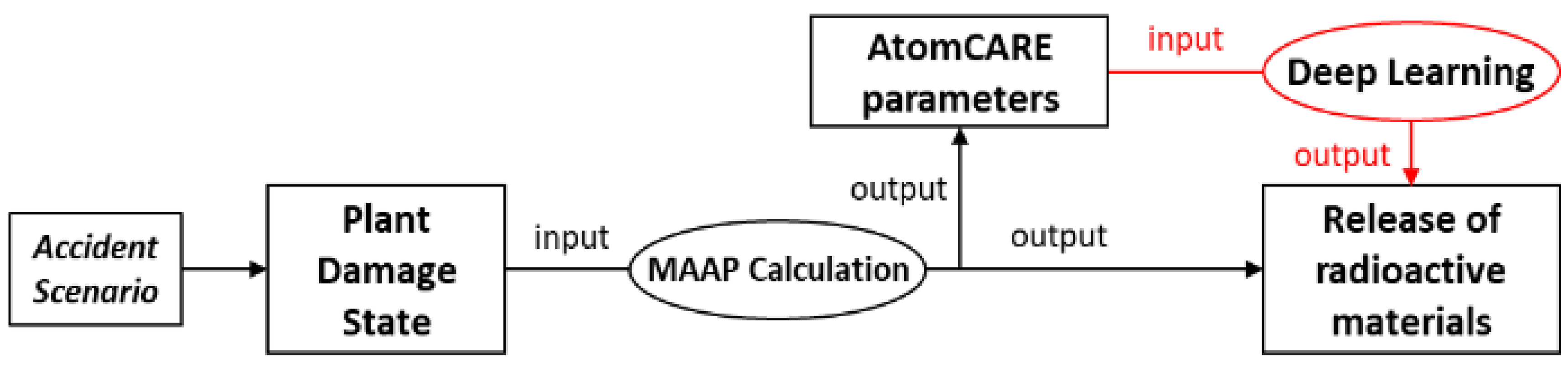
- After Fukushima accident, estimation of the amount of radioactivity release has become certainly decisive in the early stage of the public protection management.
- Radioactivity effect estimation system SPEEDI (System for Prediction of Environmental Emergency Dose Information) was not properly utilized for decision making of public protection management, and failed to provide accurate source term information.
- This paper suggests a strategy for fast and accurate prediction of accident scenario and source term from plant and environment information. (≥5 MW).

Strategy on Deep Learning Modeling

Overall Procedure: Five Steps

1. To select important parameters of state information
2. To select representative severe accident scenarios
3. To generate database about AtomCARE* parameters, MAAP input parameters (input) and release of radioactive materials (output)
4. To train the regression model (eQRNN in this study) using the input/output data
5. To review applicability of eQRNN model.

**AtomCARE (Atomic Computerized technical Advisory system for a Radiological Emergency) is an accident response system operated by KINS.*



<Deep learning strategy to estimate source term release>

Strategy on Deep Learning Modeling in this Study

- This study introduces the technique to supply the information regarding severe accident scenario and source term by using deep learning method.
- A database about radioactivity release was generated from MAAP (Modular Accident Analysis Program) code by using plant parameters.
- This paper tried to apply a pre-developed deep learning model, which is called as eQRNN (ensemble Quantile Recurrent Neural Network), to the source term estimation process.

Feasibility Study

Feasibility Study of eQRNN to Estimate Accident Source Term

- eQRNN: ensemble Quantile Recurrent Neural network
- To predict reactor behavior since accident when some actions are taken

Structure	Bi-directional LSTM
Activation function	LeakyReLU
Optimizer	Adam
Cost function	Mean Squared Error

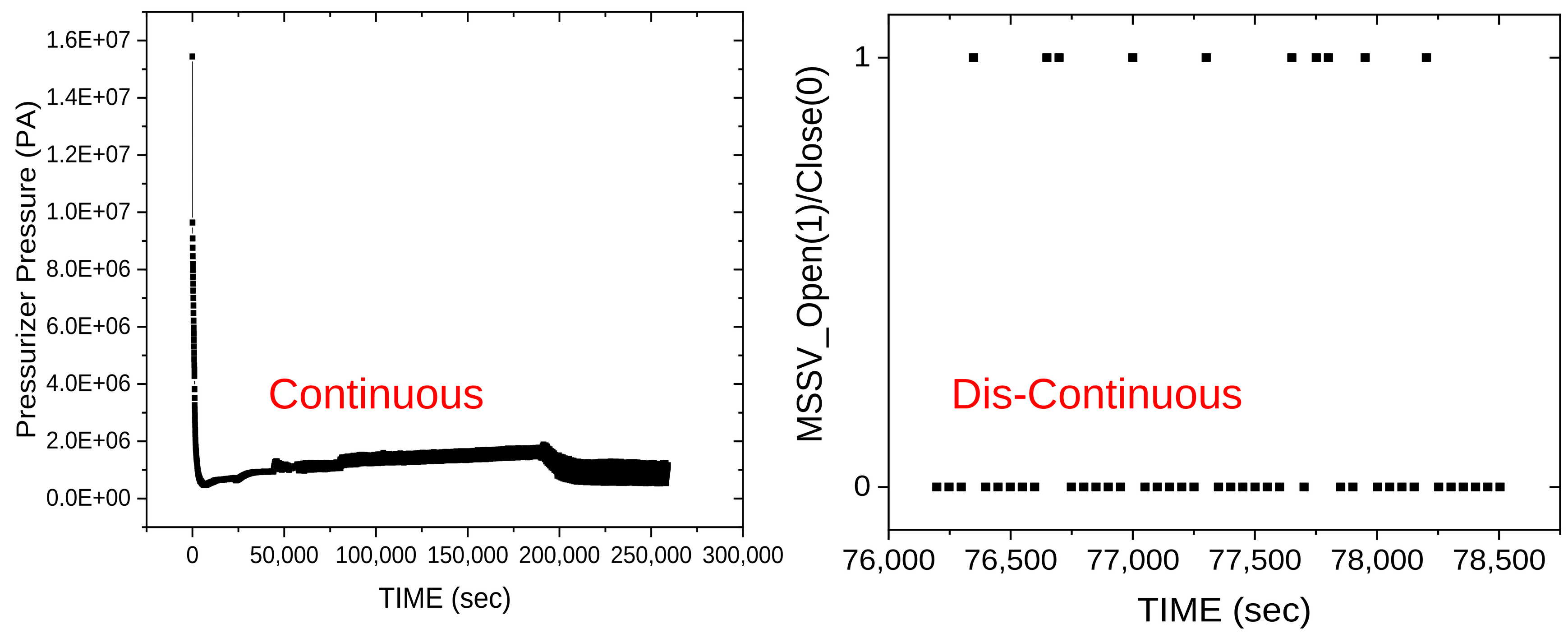
eQRNN Deep Learning Model Structure

eQRNN	INPUT	OUTPUT
Type	1. Break Size 2. Charging Valve Open 3. PZR heater on … 16. Class of initiating event	1. Reactor Power 2. SG 1&2 Level Diff. … 18. PZR Pressure 19.SG2 Pressure
Form	Set of [time, degree of action] [t1, x1, t2, x2, t3, x3, …, tn, xn]	Results obtained from TH Code at a specific interval
Example	2. Charging Valve Open; 3. PZR heater on; Time; Degree [1, 9.3, 50, 6.3, 50, 6.3, 1, … , 0] … [2, 5.4, 50, 6.3, 100, 2.1, 0, … , 1]	18. PZR Pressure 360 data (3600 sec) [158.6, 141.31, 135.73, … , 123.62] … [158.6, 157.27, 156.02, … , 89.441]

Candidates for Input Data of Deep Learning

1. Atom CARE data
2. MAAP Input data

Type of Input	AtomCARE data	MAAP Input data
Type	1. PPZ (Pressurizer Wide Pressure Channel A) 2. ZWRCS (Reactor Vessel Head Water Level) … 37. NFH2RB (Containment Hydrogen Concentration)	1. Reactor Trip (0/1) 2. RCP_OFF (0/1) 3. HPSI_ON (0/1) …
Form	• N Set Data • Continuous time-variant (All Data)	• N Set Data • Discontinuous time-variant (Some Data)



<Example of AtomCARE data (Left) and MAAP Input data (Right)>

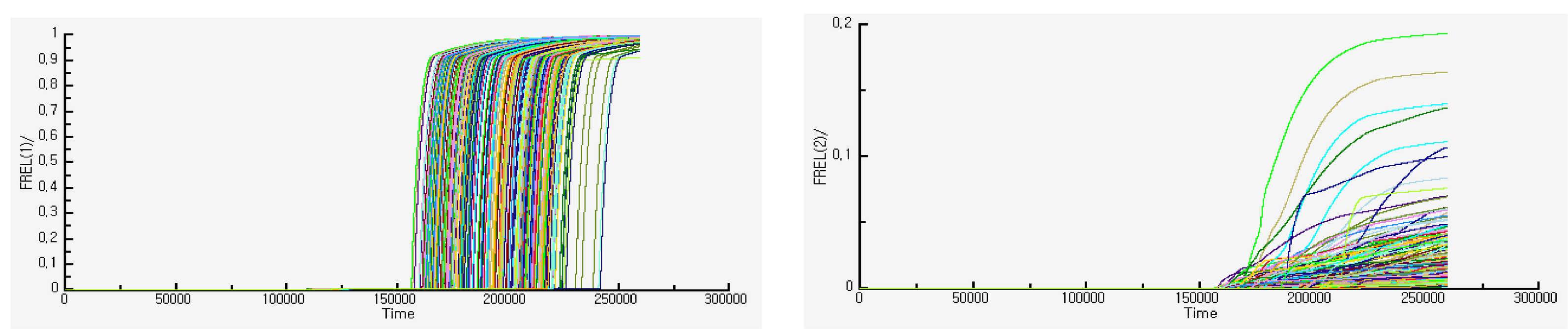
	eQRNN	Atom CARE	MAAP Input
Number of Input variables	16	36	58
Type of Input	Constant regardless of time	Continuous time- variant	Discontinuous time-variant

→ Inconsistent with input form of eQRNN

Output Data of Deep Learning

: Source-Term Release obtained from MAAP analysis

→ Consistent with output form of eQRNN



<Example of Source-Term Release from MAAP Output data Noble gas (Left) and CsI (Right)>

Not Applicable of eQRNN to Prediction of Source Term Release due to Inconsistency with Input Form

Conclusions and Future Work

- The strategy to estimate accident source term is developed through deep learning and it consists of five steps. This study focuses on step 4 and 5. It was evaluated whether the source term obtained from MAAP results could be estimated through the eQRNN deep learning model with the AtomCARE data or MAAP input data considered as training data of eQRNN. As a results, the eQRNN model is not applicable to estimate source term, because the AtomCARE data is continuous time-variant and the MAAP input data is discontinuous time-variant, whereas the input of eQRNN is constant regardless of time.
- From the feasibility study, the deep learning model, eQRNN is not applicable to estimate source release. In order to use the AtomCARE data or MAAP input data, the other deep learning model is needed to be employed or developed. The input of a new model will be continuous or discontinuous time-variant and the output of a new model also will be continuous time-variant. It is planned to search and develop an appropriate deep learning model for fast and accurate estimation of source term information from the plant state data.