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# Consideration for applying machine learning in uncertainty analysis method of severe accident



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# 01 Introduction

## » Motivation

- KINS regulation about uncertainty in the severe accident analysis
  - The ability of simulation codes and methodologies used in the best-estimate analysis of severe accident should be appropriately presented, and the uncertainty of that should be estimated [1].
- “Ideal” way to assess the uncertainty
  - The analysis based on all parameters related with the target phenomenon.
- Due to the limitation of cost and time, “Real” analysis has been performed with the minimized parameters selected by sensitivity analysis.

[1] KINS, “Safety Review Guideline for Accident Management Program”, KINS/GE-N016 (Rev.1), December 2018.

# 01 Introduction

## » Objective

- Machine learning
  - Recently gets attention as the most proper method of understanding and arranging multi-dimensional data.
- Possibility to apply machine learning in the uncertainty analysis method
  - Input and output data including various parameters can be considered as data pairs.
- In this study, the current uncertainty analysis method, categories of the machine learning, and the possible way to apply the machine learning for improving the method were considered.

# 02 Current method for uncertainty analysis

## » CSAU methodology (1 / 3)

- CSAU (Code Scaling Applicability and Uncertainty)
  - A methodology for quantifying uncertainty based on the results of various studies proposed by USNRC.
- Element 1 : To determine code applicability based on the PIRT and the code model.
  - Basic parameters related to the phenomena are determined considering the scenario and the plant type through the PIRT.

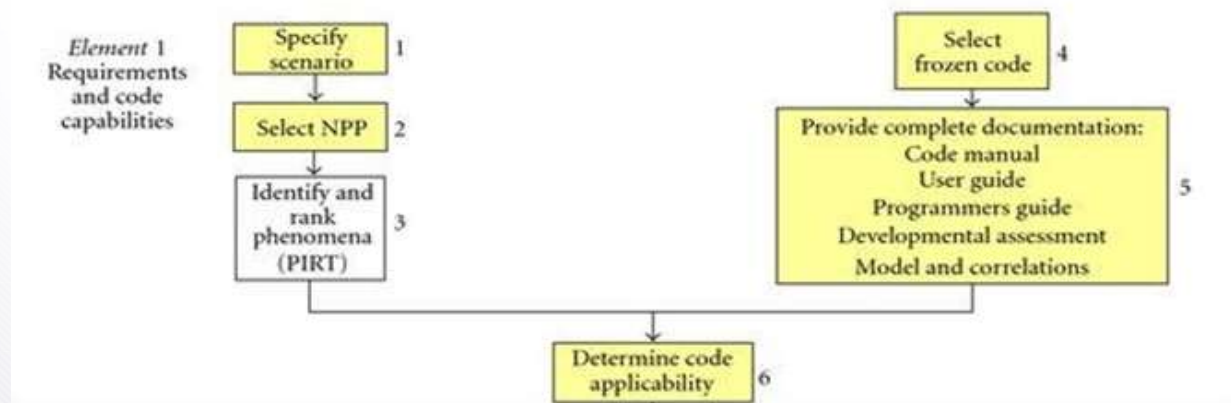


Figure 1. Element 1 of the CSAU methodology framework [2]

# 02 Current method for uncertainty analysis

## » CSAU methodology (2 / 3)

- Element 2 : To verify the accuracy of the selected code.
  - The accuracy can be quantified by the comparison between the experiment data and the benchmark result..

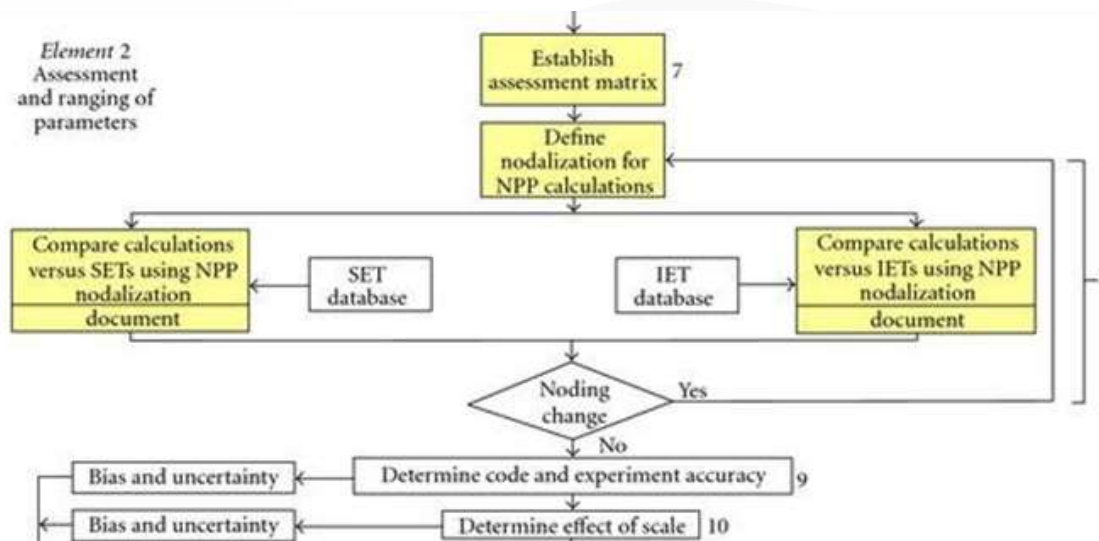


Figure 2. Element 2 of the CSAU methodology framework

[2] R. Martin et. al., "Development considerations of AREVA NP Inc.'s realistic LBLOCA analysis methodology", Science and Technology of Nuclear Installations, January 2008.

# 02 Current method for uncertainty analysis

## » CSAU methodology (3 / 3)

- Element 3 : To perform uncertainty analysis with the parameters and their range obtained from the sensitivity analysis.
  - Using a sampling method such as Latin-Hyper-Cube, the sequences are determined based on the values of the uncertainty parameters, then all sequences are calculated.
  - The difference between the experimental and the calculation result is indicated as a bias, and the final value is determined by reflecting the bias in the specific confidence level of the calculation result.

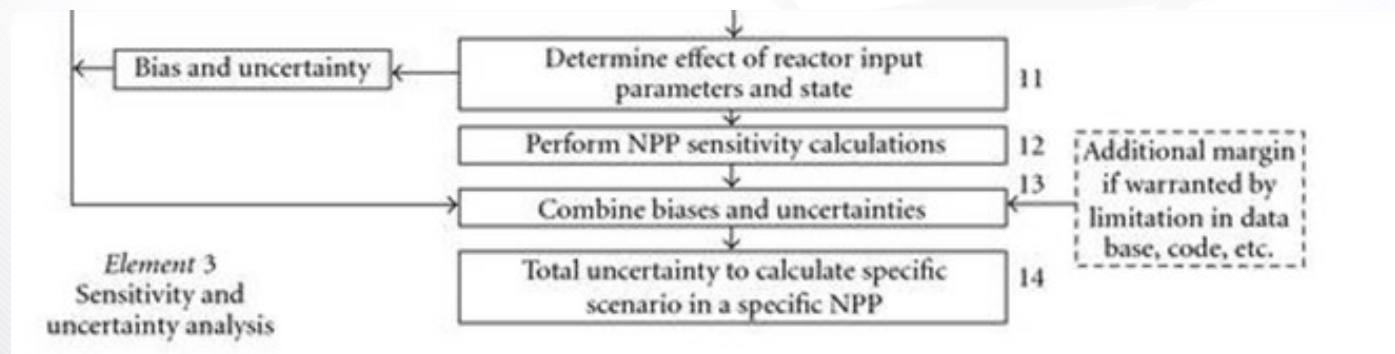


Figure 3. Element 3 of the CSAU methodology framework

# 03 Application of machine learning

## » Representative categories of machine learning (1 / 2)

- Supervised learning
  - It is used to solve a problem that involves both input and output pairs, which is called training sets, the model performs mapping using these sets.

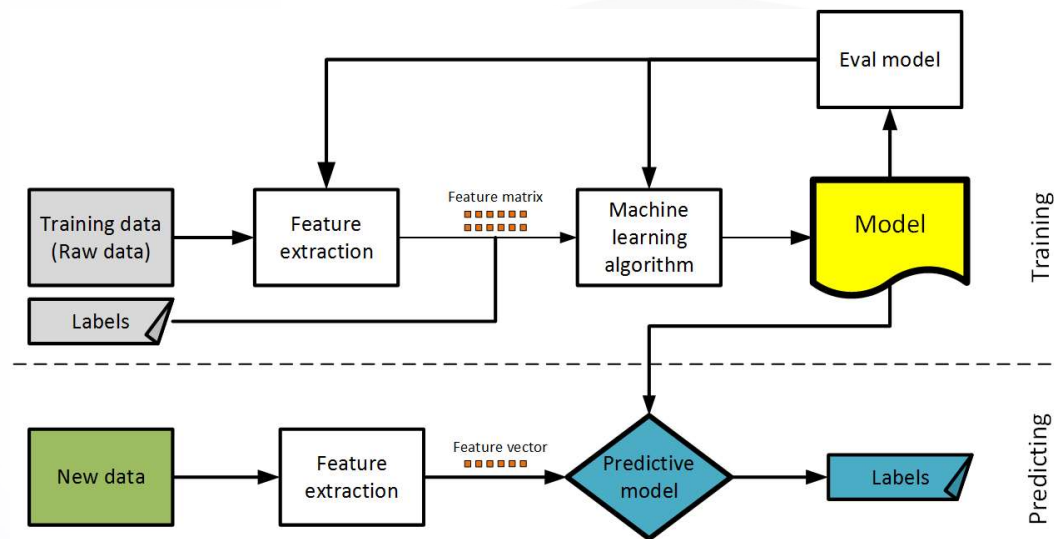


Figure 4. A flowchart of a supervised machine learning model [3]

[3] D. Nguyen et al., "Joint Network Coding and Machine Learning for Error-prone Wireless Broadcast", IEEE 7th annual computing and communication workshop and conference, January 2017.



# 03 Application of machine learning

## » Representative categories of machine learning (2 / 2)

- Unsupervised learning
  - It is used when the data does not involve the clear input and output pairs.
  - Instead constructing a fit model, the system extracts relationship in data compared to supervised learning.
- Reinforcement learning
  - The system learns the best approach using trial and error method.
  - If there is a set of goals which can be achieved in a specific environment, the system progresses to get the optimized way for the objective based on the feedbacks.

# 03 Application of machine learning

## » Conceptual approach to apply the machine learning (1 / 2)

- Limitation of current uncertainty analysis method
  - Minimized parameters based on the sensitivity analysis are used because of the limitation of cost and time.
- Possible category of machine learning for uncertainty analysis : Supervised learning
  - Code input and output can be defined as a training set.
  - If the model between code input and output can be constructed by the machine learning, the required number of simulations can be decreased.
    - In other words, code outputs for the uncertainty analysis can be obtained by the machine learning model without simulations.
  - The concept is indicated as a flow chart in the figure 5 (next page).

# 03 Application of machine learning

## » Conceptual approach to apply the machine learning (2 / 2)

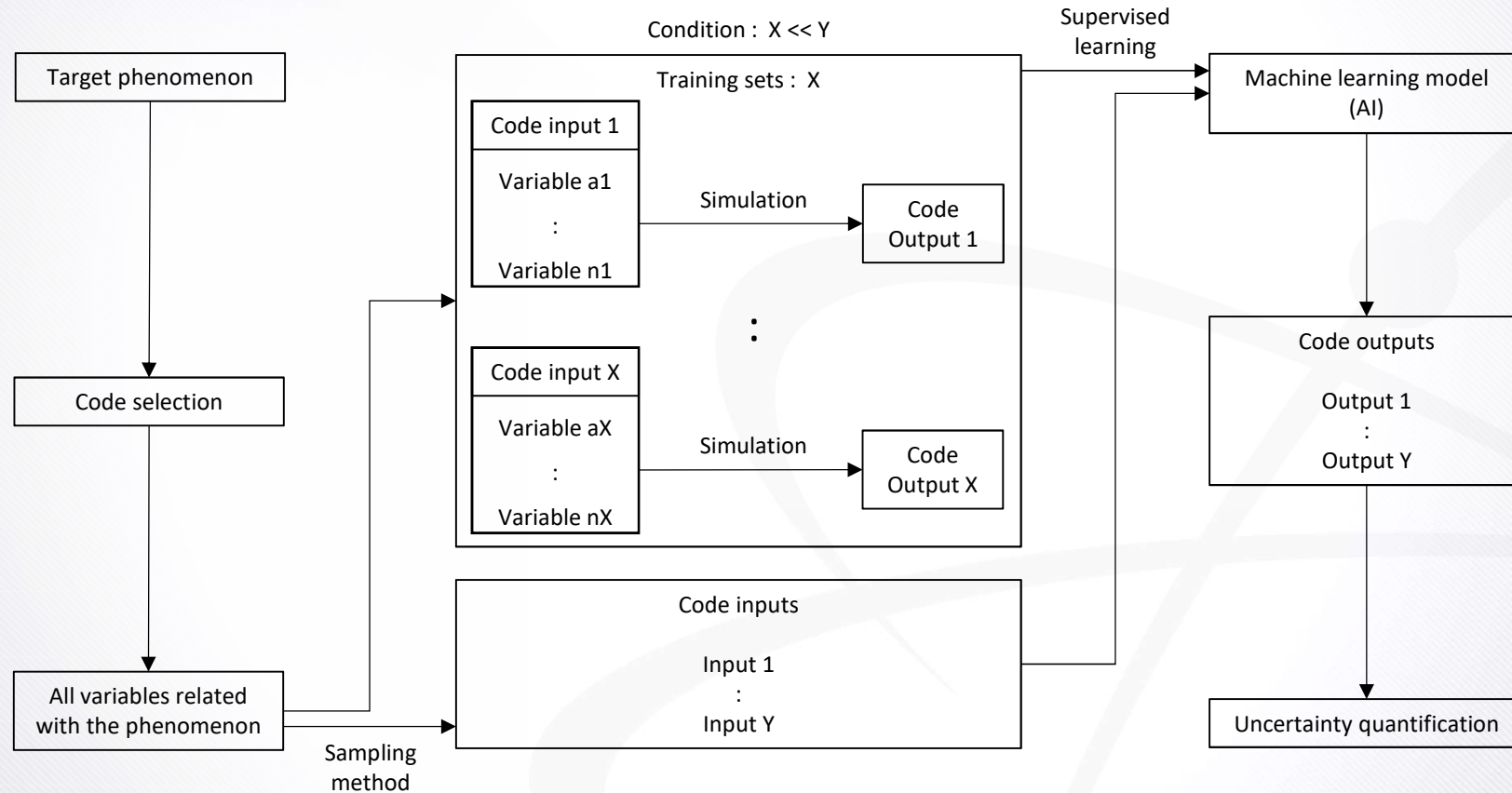


Figure 5. A flow chart of conceptual approach to apply the machine learning in the uncertainty analysis

# 04 Conclusion

## » Summary & Further study

- Supervised learning was considered to apply in the uncertainty analysis based on the assumption that input and result from the code can be considered as a training data set.
  - Required number of simulations may be reduced by the machine learning when required number of sampling inputs are larger than the number of training sets.
  - Uncertainty may be estimated more accurately based on the analysis with all parameters related to the target phenomenon.
    - However, uncertainty from the machine learning also should be quantified.
- Detailed application process, and the uncertainty analysis for a sample severe accident phenomenon will be provided in further study.
- Other possible ways to apply the machine learning also can be discussed later.



# THANK YOU

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