Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Application of an Area Overlap Similarity Measure to Estimate Code Prediction Accuracy

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1. Introduction

It is essential to validate the safety analysis code based on available experimental data. Extensive R&D programs have been progressed in order to support the development and validation activities of best estimate codes [1]. At the moment, the FFTBM (Fast Fourier Transform Based Method) is widely used to estimate the prediction accuracy of system-scale safety analysis codes, especially under the OECD/NEA and IAEA cooperation programs [2, 3]. In this paper, new method utilizing an area overlap similarity measure in the pattern recognition method was applied to the second ATLAS domestic standard problem (DSP-02) to find out how the pattern recognition method can be utilized in the code assessment area and overcome the known limitation of the FFTBM methodology.

2. Algorithms and Models

Pattern recognition is the scientific discipline whose goal is the classification of objects into a number of categories or classes [4]. Depending on the application, these objects can be images or signal waveforms or any type of measurements that need to be classified. The similarity between two signals *x* and *y* can be measured by the ratio of their overlap area to their total area, defined as

$$SA(x,y) = \frac{A(fx) \cap A(fy)}{A(fx) + A(fy) - A(fx) \cap A(fy)} \qquad (1)$$

where the summation is over all features *fx* of signal *x* and all features *fy* of signal *y*. Basically, this model treats each pattern as one feature and computes the truth value of the predicate existence of one pattern. It is obvious that similarity *SA(x,y)* between two signals takes value between 0 and 1. When the two signals coincide *SA(x,y)* is equal to 1 and when they don't have any overlap *SA(x,y)* is equal to 0 as shown in Figure 1.

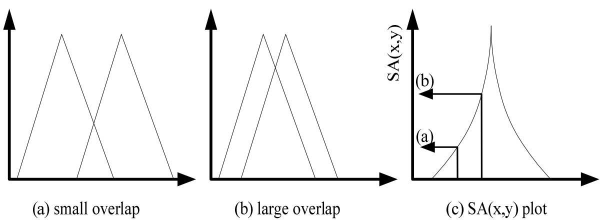

Figure 1 Concept of an area overlap similarity measure

3. Application to DSP-02

3.1 Domestic standard problem (DSP-02)

In the second ATLAS DSP program (DSP-02), twelve organizations finally participated and submitted their code calculations. Most participants used the best-estimate system code MARS-KS. Accuracy quantification of their transient calculations was performed by FFTBM. A total 22 key parameters were selected in the FFTBM calculation and three time frames were used; 0-24s, 0-300s, and 0-1000s. A typical result is shown in Table 1. It is known that the FFTBM method has some limitations; it cannot give information about when the disagreement is dominant in the entire time domain, and it can produce misleading results on the timing of the key sequence such as the PCT excursion.

Table 1 Typical FFTBM prediction of transient accuracy

N	Parameter	Time of interval		
		0 ~ 24 s	0~ 300 s	0 ~ 1000 s
		N=512	N=1024	N=4096
		AA	AA	AA
1	Core power	0.057	0.063	0.062
2	Pressurizer pressure	0.018	0.097	0.074
3	SG1 steam pressure	0.007	0.073	0.163
4	SIT-01 pressure	**Excl.**	**Excl.**	0.093
5	Core inlet temperature	0.003	0.020	0.020
6	Core exit temperature	0.009	0.024	0.024
7	Clad temp. at region 2	0.017	0.019	0.021
8	Clad temp. at region 10	0.006	0.014	0.016
9	Clad temp. at region 12	0.006	0.019	0.020
10	Hot leg 1 flow rate	1.170	1.632	3.124
11	Cold leg 1A flow rate	1.477	1.088	1.128
12	Active SIT-01 flow rate	**Excl.**	**Excl.**	1.937
13	Active SIP-01 flow rate	**Excl.**	0.118	0.084
14	Total break flow rate	0.689	0.765	0.861
15	Accum. break mass	0.138	0.044	0.049
16	Down-comer level	0.007	0.131	0.261
17	Active core region level	0.049	0.234	0.312
18	Pressurizer level	0.082	0.097	0.116
19	Water level IL1A	0.160	0.535	1.364
20	Water level IL1B	1.452	1.456	1.672
21	Water level IL2A	0.130	0.917	1.379
22	Water level IL1B	0.154	0.340	0.361
	Total (AA_{tot})	**0.137**	**0.207**	**0.313**

*Excl.: excluded

3.2 Preliminary application results

In this paper, only the calculation results for the second time of interval of 300 s are used as a reference. For each parameter, an area overlap similarity measure was calculated. A union signal enveloping two data sets – calculation (x) and experimental data (y) – was first obtained to represent a union area $A \cup B$. Then a intersection of two signals was obtained to represent $A \cap B$. Finally, an area fraction, SA was calculated to estimate similarity between two signals.

One typical result by FFTBM of Table 1 was used in this paper and plotted in Figure 2 for comparison. A scale factor based on the core power was applied to the calculated area overlap similarity measures of the other parameters for easy comparison. It can be seen that the area overlap similarity measures SAs show the similar trend as the FFTBM results.

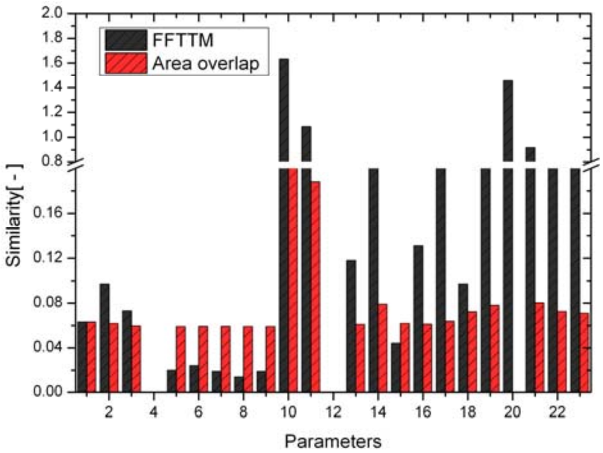

Figure 2 Comparison of calculaed accuracy index with the FFTBM results

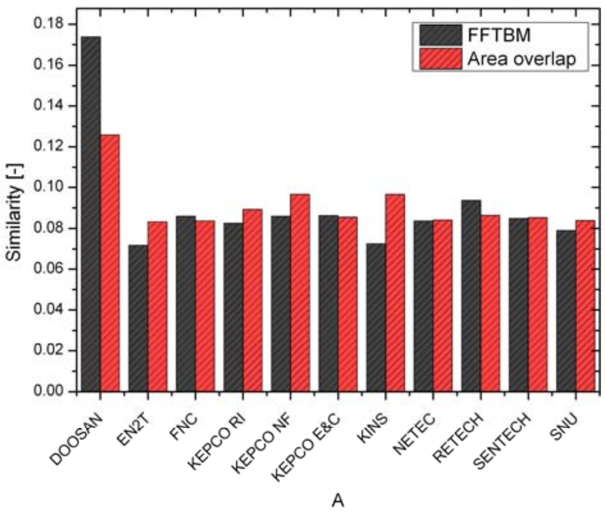

Figure 3 Comparison of calculated area overlap similarity measures with the FFTBM results

Each similarity measure was combined to result in a total similarity measures by weighting factors as follows:

$$SA_{tot} = \sum_i SA_i \cdot W_i \ , \tag{2}$$

where the same weighting factors W_i, used in the FFTBM were used to obtain consistent results in this calculation. Figure 3 shows comparisons of calculated area overlap similarity measures with the FFTBM results. The current method shows almost the similar results as those of FFTBM.

4. Conclusions and Further Study

In the present study, a similarity measure utilizing area overlap was investigated for estimating the code prediction accuracy. It was found that the area overlap similarity measure gives meaningful results when compared with the FFTBM method. However, it is known that this area overlap similarity method is prune to noise level.

This is the first step to develop the advanced quantification method for code prediction accuracy and this pattern recognition method is expected to overcome the limitation of the FFTBM methodology. As a further study, a feature to represent the typical transient thermal-hydraulic behavior will be defined and used to quantify how a given calculation is similar to the defined feature.

Acknowledgements

The authors are grateful to the Ministry of Education, Science and Technology (MEST) of Korea for their financial support for this project.

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